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Surge arresters

Part 3:
Artificial pollution testing of surge arresters

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SURGE ARRESTERS

Part 3: Artificial pollution testing of surge arresters

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

This Technical Report has been prepared by IEC Technical Committee No. 37: Surge arresters.

It replaces and cancels Appendix D of Publication 99-1 (1970). A new edition of Publication 99-1 is being prepared..

The text of this report is based on the following documents:

Six Months' Rule	Report on Voting
37(CO)24	37(CO)27

Full information on the voting for the approval of this report can be found in the Voting Report indicated in the above table.

SURGE ARRESTERS

Part 3: Artificial pollution testing of surge arresters

1 Scope

This Technical Report gives the basic principles of artificial pollution testing of non-linear resistor type (valve type) surge arresters, together with details of pollutant compositions and methods of application and the test procedures associated with each mode of pollution.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 99-1: 1970, Lightning arresters – Part 1: Non-linear resistor type arresters for a.c. systems.

IEC 507: 1975, Artificial pollution tests on high-voltage insulators to be used on a.c. systems.

3 Basic principles

It is well known that a surge arrester can fail at normal service voltage under certain pollution conditions, owing to the setting up of a very uneven voltage distribution on its external surface and/or because of very rapid changes in this distribution. These two stages arise as a consequence of the formation under such conditions of an initially nearly continuous conducting surface layer consisting typically of an aqueous solution of electrolyte formed under high humidity by the moisture pick-up of hygroscopic solid particles or liquid droplets deposited on the surface. Dusts may also be present, affecting the washing and drying characteristics of the surface. It is well established also that the effect of leakage current heating the surface layer, when the conductivity is high enough, is to cause "dry bands" to form, across which most of the voltage drop occurs and that surges of leakage-current occur when these bands are temporarily bridged by an arc.

These phenomena can result in the voltage applied across some of the gaps exceeding their sparkover value, with consequential failure, in some cases, through disturbance of the gap potentials caused by capacitive coupling between electrodes and wet bands.

It is consequently the primary purpose of artificial pollution testing of surge arresters to simulate relevant pollution conditions, representative of those occurring in service and establishing that when subjected to these, the surge arrester, energized at appropriate power-frequency voltage does not suffer gap sparkover.

Pollution flashover of the surge arrester surface is a serious matter operationally, and the performance in this respect also must be determined. This is discussed in the following paragraphs.

There is now evidence both from service and testing that the pollution conditions which may result in surge arrester sparkover can be generally different from those leading to surface flashover. The latter is associated typically with severe conditions characterized by frequent high-amplitude leakage-current surges, whereas gap sparkover is typically associated with pollution onset or drying-out of the pollutant. Accordingly, separate tests for these two distinct modes of failure may be needed, at least with some test methods.

Some artificial pollution test methods for surface flashover of high-voltage insulators have been developed to a stage where they are generally accepted as giving a valid indication of pollution performance. These are fully described in IEC 507. The essential common feature of the tests, even though there are differences in the polluting techniques, are the repeatable production of various degrees or "severities" of pollution, measured, for example, in terms of specific conductance of the pollutant, application of a suitable test voltage and consequent determination of the performance in terms of a given severity.

The mode of operation of surge arresters, however, is such that the methods used for insulator testing are not directly applicable to surge arresters, especially in respect of arrester sparkover. The tests described in this report, though broadly based on those of IEC 507, are essentially aimed at meeting the special requirements for surge arrester operation and bear specifically on gap sparkover.

The methods of IEC 507 are directly applicable to surface flashover of insulation, and it is accordingly recommended that they should be used to determine performance in this respect.

It should be noted that the tests according to IEC 507 with respect to such surface flashover performance and those proposed here to check sparkover performance are recommended only for surge arresters exposed to natural pollution, possibly with live washing, and not for those subject to periodic cleaning or greasing.

From the foregoing account of the failure mechanism it follows that for pollution tests of both kinds, it is essential that they be performed on a complete service surge arrester assembly.

When sufficient experience has been gained from the tests described in the following clauses, this experience will form the basis of a type test.

NOTE – In service, surge arresters sometimes suffer long-term deterioration associated with internal corona discharges. The tests described in this report do not demonstrate the performance of the surge arrester in this respect.

4 Test objective

The objective of the test is to establish that the surge arrester can withstand a specified severity of pollution without sparkover when energized at a specified voltage or voltage-application mode, both severity and voltage mode being representative of service conditions.

5 General requirements

5.1 *Test arrester*

The test shall be made on a complete arrester, with all normal spark-gaps, grading resistors and any grading ring, etc., which may significantly affect the voltage distribution of the arrester. However, for pollution tests, it is not generally necessary to mount the arrester on a pedestal. This is because the conductive surface layer and the internal processes determine the voltage distribution and its variations in this case, as opposed to that of tests for impulse sparkover performance in the normal unpolluted state, for example, where the distribution, though partly controlled by grading resistors, series capacitance of the gaps, etc., can also be affected by the distributed capacitance to the earth plane and high-voltage lead, etc.

The dry arrester power-frequency sparkover value and grading current measured at the operating voltage should be measured prior to and after the test.

5.2 *Cleaning*

Before the arrester is tested for the first time, the surface shall be carefully cleaned (using a detergent solution such as trisodium phosphate) and thoroughly rinsed (using tap or mains water) so that all traces of surface contamination, particularly grease, are removed before testing. Care must be taken to avoid touching the cleaned arrester.

NOTE – It may be necessary in some cases, particularly when spraying salt pollutants, to paint the metal parts and cement to ensure that no corrosion products wash down onto the insulating surface during the test.

5.3 *Installation*

The cleaned arrester shall be erected so that the minimum distance between any part of it and any earthed object other than the jets, and a ceiling or a wall is not less than one-half of the length of the arrester. The arrester shall be in thermal equilibrium with the ambient air at the start of the test and the temperature shall be noted. The temperature shall not be below 5 °C or greater than 40 °C.

5.4 *Arrangements for arrester current monitoring*

For test result diagnostic purposes according to 7.5 the surface leakage and internal current paths shall be separately connected to the earth terminal of the test voltage source so that the surface leakage and internal currents can be separately monitored. If the arrester is not provided with an internal current lead isolated from the bottom flange, a surface leakage current collecting band is fitted above the flange and the insulation surface between the band and the flange should be greased. Band/flange spacing should be as small as possible, subject to provision of the necessary insulation, to minimize encroachment on the leakage path. For most designs of arrester housing these requirements are met by fitting the band immediately above the bottom shed.

In the case of a multi-unit arrester, the band is applied only to the bottom unit.

5.5 *Test circuit requirements*

The impedance of the whole circuit, including the transformer and regulator, should not be so great that sparkover is inhibited by a drop in the voltage, or distortion of the wave shape.

This condition is met when the regulation of the source is such as to maintain the specified voltage on the arrester except for infrequent, non-consecutive, half-cycle voltage dips of no more than 5% during leakage current pulses.

It is also met by compliance with IEC 507.

The values in IEC 507 for the circuit *R/X* values and minimum short-circuit current are given in Table 1.

Table 1

R/X at test voltage	Minimum short-circuit current at test voltage A
<0.05	5
0.05 to 0.15	7
0.15 to 0.5	10
0.5 to 1.5	15

NOTES

1 The values in the above table are based on investigations on a small number of insulators. They represent the best suggestion that can be given at present, but may be modified with further experience.

2 In the case of large diameter housings, it may be necessary to increase the source short-circuit current to values higher than those specified in the table, in order to avoid premature extinction of the arcs bridging dry bands in the pollution layer.

3 One method of determining the *R/X* value of the circuit is to measure:

a) The short-circuit current I_{sc} corresponding to an open circuit voltage U_o equal to the specified test voltage.

b) The voltage U_L existing when the current passes through a load whose resistance is such that the r.m.s. value I_L of the current is equal to 1 A.

R/X can be found from the following formula:

$$R/X = \frac{U_o^2[1 - (I_L/I_{sc})^2] - U_L^2}{\sqrt{4U_o^2\, U_L^2\, (I_L/I_{sc})^2 - \{U_o^2[1 - (I_L/I_{sc})^2] - U_L^2\}^2}}$$

6 Voltage application

The requirements here are specific to arresters, two different modes of application being recognized according to the operating conditions of the arrester.

6.1 *Arresters for use on isolated neutral and resonant earthed systems – test methods according to 8.2 and 8.3*

A steady voltage equal to the rated voltage of the arrester is applied throughout the test period.

NOTE – When the rated voltage exceeds the highest voltage (between phases) of the system, by agreement between the user and the manufacturer, the test voltage chosen should be the latter.

6.2 *Arresters for earthed neutral systems – Earth-fault factor between 1,2 and 1,4*

A voltage of 0,75 to 0,8 (see note 1) times the rated voltage of the arrester, or 0,87 (= 1/1,15) times the specified continuous operating voltage*, whichever is lower, is applied initially and at intervals is increased quickly to a higher value corresponding in principle to the earth-fault voltage (see note 2) for 1 to 2 s, and then lowered quickly to the initial value. The intervals and higher voltage values are specified in 8.2, 8.3 and 8.4.

NOTES

1 The factors of 0,75 and 0,8 correspond to system earth-fault factors of 1,33 and 1,25 respectively.

2 The differences in the higher voltage levels used in 8.2, 8.3 and 8.4 are a reflection of the sensitivity of the method to the long rise and fall times necessitated with present testing techniques, compared with the very much shorter times occurring in service.

3 In some resistance earthed systems the earth-fault factor can continually exceed 1,4. Where the voltage rise can persist for more than 10 s, the procedure of 6.1 is applied. Where it persists less than 10 s, that of 6.2 is applied, however, with voltage levels to be agreed upon between the user and manufacturer.

7 Test procedure

7.1 *Test initiation*

The prepared arrester is installed in its test position. Pollution and voltage are applied according to the selected method. The test is deemed to have begun when the full test voltage as specified in clause 6 is applied under the relevant polluting conditions.

7.2 *Test sequence*

Tests should be made at each of the three pollution severities of 7.3 for the methods given in 8.2 and 8.3 and using the prescribed pollutant given in 8.4 and clause 9 for the method given in 8.4, and the occurrence noted of arrester sparkover or flashover of the surface insulation.

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* Specified continuous operating voltage is a voltage which can be applied continuously between the arrester terminals. This value is equal to or less than the rated voltage.

7.3 *Pollution severities*

The severities are characterized by the solution salinity for the salt-fog method and by the slurry suspension conductivity for the solid pollutant methods. The following levels are recommended:

- salt-fog according to 8.2: 2,5, 5,0 and 10 kg of $NaCl/m^3$;
- solid pollutant – wetting according to 8.3: 2,5, 5,0 and 10 mS/cm;
- solid pollutant – drying according to 8.4: not greater than 2,5 mS/cm.

7.4 *Test evaluation*

The results of the tests establish the severity which the arrester withstands without sparkover in four tests at a given severity.

There shall be no significant change in the dry power-frequency sparkover value nor grading current value following the test.

7.5 *Test monitoring: indication of breakdown*

The applied test voltage, the current flowing internally and the surface leakage current should be recorded separately with an oscillograph in order to distinguish between surface flashover or gap sparkover.

A sudden increase in surface current to near short-circuit current, usually supplemented by visual and aural observations, indicates a flashover. A similar increase in internal current indicates gap sparkover.

If the oscillogram shows a collapse of voltage for approximately five half cycles to a value less than 10% of the test voltage, an external flashover is indicated. A voltage collapse to values higher than 10% indicates gap sparkover.

8 **Methods of applying pollution**

8.1 *General*

The methods given below, although related to the procedures now established for determining the flashover performance of insulators (see IEC 507) have been specifically developed for determining the gap sparkover performance of arresters under pollution conditions.

Two basic methods are proposed:

a) Application of a salt-fog, according to 8.2, while the arrester is energized at a specified voltage level(s).

b) Application of a conducting layer of solid pollutant which, in one case, is wetted before voltage application at the specified level(s) according to 8.3 and, in the other, during this application according to 8.4.

8.2 *Salt-fog method*

After preparation in accordance with 5.1, 5.2, 5.3 and 5.4, a fine mist or fog of salt solution of controlled salinity is produced from arrays of special spray jets of specified design set 0,6 m apart and arranged in two vertical columns on opposite sides of the arrester, to which are fed the solution and compressed air. The solution flow rates per nozzle during the test is 0,5 l/min ± 5%. The air supply pressure is between 650 and 700 kPa.

A full description of the apparatus and its normal application, including the preconditioning, is given in clause 8 of IEC 507.

For the present purpose of testing for arrester sparkover, it is recommended that fog production should be stopped after 15 min from the beginning of each test, drying processes taking place during the remainder of the test period of 30 min.

The test voltage as given in 6.1 or 6.2, as appropriate, is applied during the above period or until sparkover or flashover occurs. For 6.2 the higher voltage level is the arrester rated voltage or an agreed voltage calculated on the basis of the highest system phase/earth voltage times the earth-fault factor, the interval between voltage excursions is 5 min.

This process is repeated, the arrester being cleaned between each test.

Four tests are made at each of the three reference salinities given in 7.3.

8.3 *Solid pollutant-wetting method*

After preparation in accordance with 5.1, 5.2, 5.3 and 5.4, the dry arrester is completely coated, as uniformly as possible, by flow-coating with the suspension given in 9.1. The surface conductivity of each of the units (i.e. conductance of each unit times the form factor*) of the arrester, measured 2 min after coating, should not differ by more than 10% from the average.

The layer is allowed to dry completely before beginning the test. Four tests, each lasting 30 min or until sparkover occurs, are made at each reference conductance value given in 7.3. Each test consists of the application of the test voltages of 6.1 or 6.2, as appropriate. Before every test the arrester should be rinsed with tap or mains water and then coated anew.

For 6.2, the higher voltage level is the arrester rated voltage or an agreed voltage calculated on the basis of the highest system phase to earth voltage times the earth-fault factor, and the interval between voltage excursions is 5 min.

For wetting the pre-applied layer on the test arrester, steam fog should be used. To achieve a uniform wetting over the whole length and around the arrester enough steam fog shall be introduced inside the test chamber. A rate of flow of 0,5 kg steam per hour and per cubic meter chamber volume is sufficient. The steam fog may be introduced by several tubes placed at uniform distances at the bottom of the test chamber.

If the external flashover of the arrester occurs at or below rated voltage during the test cycle, attempts to perform the test cycle shall be made at about 5 min intervals until a cycle has been

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* For the definition of "form factor" see IEC 507.

successfully performed. The cycles during which the flashover occurred shall not be considered as part of the test.

NOTE - In the case of a multi-unit arrester, the parts may be polluted and measured separately with respect to surface conductivity. In the case of very large units it is advisable to flow-coat from bottom to top and finally from top to bottom.

8.4 *Solid pollutant-drying method*

After preparation in accordance with 5.1, 5.2, 5.3 and 5.4, the arrester is completely coated including the area under the sheds, by spraying, flow-coating or dipping with the pollutant given in 9.2. Within 3 min after the coating operation the initial test voltage of 0,8 times the arrester rated voltage is applied to the arrester. At intervals of 60 s the voltage is increased to rated voltage, held for 1 s, then lowered to the initial value.

This cycle is repeated eight times to produce a test period of approximately 8 min. After completion of the 8-cycle test period, the test is stopped and a fresh coating of pollutant is applied to the arrester. Four series of 8-cycle test periods shall constitute a complete test.

Because the greatest reduction in arrester internal sparkover occurs when there is profuse scintillation (i.e. numerous short low-current arcs) on the arrester housing, the volume conductivity of the pollutant must be high enough to cause scintillation and may vary with the design of the housing sheds. Some designs require a higher conductivity than others but the conductivity of the pollutant used should not be more than 2,5 mS/cm.

Successive pollutant coatings may be applied without washing and drying the arrester, although washing and drying between coatings is permissible. However, if the test sequence is interrupted or delayed to the point where a coating has dried, the arrester shall be washed and dried before it is again coated.

If the external flashover of the arrester occurs at or below rated voltage during a test cycle, attempts to perform the test cycle shall be made at about 1 min intervals until a cycle has been successfully performed. The cycles during which the flashover occurred shall not be considered as part of the test.

The arrester shall be considered to have passed this test if it has not sparked over at or below the specified test voltage at any time during the test.

9 Solid pollutants for the methods of 8.3 and 8.4

9.1 *Pollutant for the methods of 8.3*

A suspension of:

1000 g water
20 g Aerosil 380 (highly dispersed SiO_2)
2 g wetting agent (nonyl-phenol-polyethylene-glycol-ether)
Sodium chloride (NaCl).

The conductivity of the suspension is adjusted to the desired level by adding a suitable amount of sodium chloride.

NOTE - The suspension should not be used more than 48 h after preparation.

9.2 *Pollutant for the method of 8.4*

A slurry of 5 g of bentonite and 1 g of an undiluted non-ionic detergent, such as nonyl-phenol-polyethylene-glycol-ether, per litre of water. The resistivity of the pollutant can be adjusted to the desired level by adding a suitable amount of sodium chloride.

10. Pollutants for trial use with the methods of 8.3 or 8.4

10.1 *A suspension of:*

40 g kaolin powder in 1000 g water

To the above is added a quantity of sodium chloride, for example 20 g, 40 g, 80 g or 160 g, to give the required conductance.

10.2 *A suspension of Portland cement*

NOTE - The cement is composed of a large number of slightly soluble salts which form a film of saturated electrolyte on wetting.