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Amendment 1

Surge arresters –

Part 4:
Metal-oxide surge arresters without gaps for a.c. systems

*This **English-language** version is derived from the original **bilingual** publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.*

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FOREWORD

This amendment has been prepared by IEC technical committee 37: Surge arresters.

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

FDIS	Report on voting
37/324/FDIS	37/325/RVD

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

Page 3

CONTENTS

Replace, on page 7, the title of Annex N by the following new title:

Annex N (normative) Test procedure to determine the lightning impulse discharge capability

Page 9

Add:

Figure 13 – Examples of arrester units

Figure 14 – Short-circuit test setup

Figure 15 – Example of a test circuit for re-applying pre-failing current immediately before applying the short-circuit test current

Delete the titles of Figures N.1, N.2 and N.3.

Page 11

Add:

Table 14 – Test requirements

Table 15 – Required currents for short-circuit tests

Delete the titles of Tables N.1, N.2 and N.3.

Page 51

6.11 Short circuit

Replace the text of this subclause by the following:

An arrester for which a short-circuit rating is claimed by the manufacturer shall be subjected to a short-circuit test according to 8.7 to show that the arrester will not fail in a manner that causes violent shattering of the housing and that self-extinguishing of open flames (if any) occurs within a defined period of time.

6.12.1 Disconnector withstand

Add to this subclause the following third dashed item:

– for surge arresters to be installed in overhead lines with system voltages exceeding 52 kV, test of the lightning impulse discharge capability (see Annex N).

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Add, after 6.16, the following new subclause:

6.17 Lightning impulse discharge capability

For surge arresters to be installed in overhead lines with system voltages exceeding 52 kV, the lightning impulse discharge capability shall be demonstrated by the tests and procedures of Annex N.

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Table 3 – Arrester type tests

Delete all references to Annex N.

Page 75

Add, after 8.5.2.2, on page 77, the following new subclauses:

8.5.2.3 Test procedure for resistor elements stressed at or above the reference voltage

If U_{ct} is close to or above the reference voltage, it may not be possible to perform an accelerated ageing test at U_{ct}, due to the extreme voltage dependence for the power losses and stability of available voltage source. If $U_{ct} \geq 0{,}95*U_{ref}$ and if it is not possible to perform an accelerated ageing test according to 8.5.2.1, this alternative test procedure shall apply and replaces 8.5.2.1 and 8.5.2.2.

NOTE To provide an overview and to serve as an aid to understanding the procedure, the steps required are as follows.

1) Calculate power loss, P_{ct}, for the highest stressed resistor (at T_a = 40 °C and $U = U_c$).
2) Determine the steady-state temperature, T_{st}, for the highest stressed part of the arrester by using one of the three alternative procedures of 8.5.2.3.1.
3) At a voltage U_{ct}, determine the ratio, k_x, of power loss at 115 °C to power loss at T_{st} for the type of resistor elements used.
4) Perform an accelerated ageing test at constant power loss, $k_x * P_{ct}$.
5) Interrupt the test for a short time and take measurements of power loss at specified time intervals.
6) If T_{st} > 60 °C, increase test temperature or test time.
7) Evaluate the power losses of step 5) according to 8.5.2.3.3.

8.5.2.3.1 Determination of test parameters

Calculate the power losses, P_{ct}, per resistor element at the maximum ambient temperature of 40 °C with the arrester energized at U_c, for the highest voltage stressed resistor according to Annex L including the effect of the resistive current.

NOTE 1 For dead-front and liquid-immersed arresters, 65 °C and 95 °C, respectively, apply as maximum ambient temperatures.

Select one of the three following test procedures to determine the steady-state temperature, T_{st}, of the most stressed part of the arrester at maximum ambient temperature.

NOTE 2 The test procedures are considered to be conservative in increasing order from 1 to 3.

1. At an ambient temperature of 25 °C ± 10 K, energize the complete arrester at the claimed U_c until steady-state temperature conditions have been attained. The temperature shall be measured on resistor elements, at five points as evenly spaced as possible over the most highly stressed 20 % portion of the length of each column of the arrester. If this 20 % portion contains less than five resistor elements, the number of measuring points may be limited to one point on each resistor element. The average temperature rise above ambient of the resistor elements shall be added to the maximum ambient temperature to obtain the temperature T_{st}.
2. At the maximum ambient temperature, energize a thermally pro-rated section representative for the arrester type at a voltage level, which results in the same power losses per resistor element as determined above. Keep the power losses constant by adjusting the voltage if necessary. Measure the temperature of the resistors in steady-state condition and calculate the average steady-state temperature, which is set equal to T_{st}.
3. At an ambient temperature of 25 °C ± 10 K, energize a thermally pro-rated section representative for the arrester type at a voltage level which results in the same power losses per resistor element as determined above. Keep the power losses constant by adjusting the voltage if necessary. Measure the temperature of the resistors in steady-state condition and calculate the average steady-state temperature rise, ΔT_{st}, above ambient. Determine the temperature, T_{st}, by adding ΔT_{st} to the maximum ambient temperature.

The prorated section shall represent the steady-state thermal behaviour of the complete arrester.

NOTE 3 The section may not necessarily be the same as that used for the operating duty test.

At a voltage U_{ct}, determine the ratio, k_x, of power losses at 115 °C to power losses at T_{st} for the type of resistor elements used. For this test the voltage source shall fulfil the requirements according to 8.5.1.

8.5.2.3.2 Test procedure

Three resistor samples shall be subjected to constant power losses equal to k_x*P_{ct} (tolerance $^{+30}_{\ 0}$ %) for 1 000 h. During the test, the temperature shall be controlled to keep the surface temperature of the resistor at the required test temperature $T_t \pm 4$ K. The applied test voltage at the start of the test shall be not less than $0{,}95*U_{ct}$.

If the temperature, T_{st}, is equal to or below 60 °C, T_t shall be 115 °C. If T_{st} is above 60 °C, either the test temperature or the testing time shall be increased as follows.

a) Increase of the test temperature

$$T_t = 115 + (T_{st} - T_{a,max} - \Delta T_n)$$

where

T_t is the test temperature in °C;

T_{st} is the steady-state temperature of the resistors in °C;

$T_{a,max}$ is the maximum ambient temperature in °C;

ΔT_n = 20 K.

NOTE 1 For liquid-immersed arresters ΔT_n = 25 K, which results from the requirement that the operating duty test starting temperature for these arresters (120 °C) is 25 K above the maximum ambient temperature (95 °C), while for other arresters the difference between the operating duty test starting temperature and the maximum ambient temperature is 20 K.

b) Increase of the testing time

$$t = t_0 * 2{,}5^{\Delta T/10}$$

where

t is the testing time in h;

t_0 = 1 000 h;

ΔT is the temperature above 60 °C.

NOTE 2 For dead-front and liquid-immersed arresters, t_0 is 2 000 h and 7 000 h, respectively, and ΔT is the temperature above 85 °C and 120 °C, respectively.

8.5.2.3.3 Determination of elevated rated and continuous operating voltages

The three test samples shall be heated to $T_t \pm 4$ K and subjected to the constant power losses k_x*P_{ct}. One to two hours after the voltage application, the voltage is adjusted to a voltage in the range $0{,}95*$ U_{ct} to U_{ct} and the power losses, P_{1ct}, are measured. During the test, after 30 %, 50 % and 70 % of the testing time, the measurement of power losses is repeated under the same conditions with respect to temperature and voltage. The minimum power loss values at these times are designated as P_{3ct}. At the end of the ageing test, under the same conditions with regard to block temperature and at the same voltage, the power losses P_{2ct} are determined.

- If P_{2ct} is equal to or below 1,1 times P_{3ct}, then the test according to 8.5.4 and 8.5.5 shall be performed on new resistors:
  - if P_{2ct} is equal to or less than P_{1ct}, U_{sc} and U_{sr} are used without any modification;
  - if $P_{2ct} > P_{1ct}$, the ratio P_{2ct}/P_{1ct} is determined for each sample. The highest of these ratios is called K_{ct}. On three new resistors at ambient temperature, the power losses P_{1c} and P_{1r} are measured at U_{sc} and U_{sr}, respectively. Thereafter, the voltages are increased so that the corresponding power losses P_{2c} and P_{2r} fill the relation:

$$\frac{P_{2c}}{P_{1c}} = K_{ct}\ ; \qquad \frac{P_{2r}}{P_{1r}} = K_{ct}$$

  U_c^* and U_r^* are the highest of the three increased voltages obtained. As an alternative, aged resistors may also be used after agreement between the user and the manufacturer.
- If P_{2ct} is greater than 1,1 times P_{3ct}, and P_{2ct} is greater than or equal to P_{1ct}, then aged resistors shall be used for the following test of 8.5.4 and 8.5.5. New resistors with corrected values U_c^* and U_r^* can be used, but only after agreement between the user and the manufacturer.

Aged resistors are, by definition, resistors tested according to 8.5.2.3.2.

These cases are summarized in Table 7.

Where aged resistors are used in the operating duty test, it is recommended that the time delay between the ageing test and the operating duty test be not more than 24 h.

The measuring time should be short enough to avoid increased power loss due to heating.

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8.7 Short-circuit test procedure

Replace the title and contents of 8.7 by the following new title and text:

8.7 Short-circuit tests

8.7.1 General

Arresters, for which a short-circuit rating is claimed by the manufacturer, shall be tested in accordance with this subclause. The test shall be performed in order to show that an arrester failure does not result in a violent shattering of the arrester housing, and that self-extinguishing of open flames (if any) occurs within a defined period of time. Each arrester type is tested with four values of short-circuit currents. If the arrester is equipped with some other arrangement as a substitute for a conventional pressure relief device, this arrangement shall be included in the test.

The frequency of the short-circuit test current supply shall be between 48 Hz and 62 Hz.

With respect to the short-circuit current performance, it is important to distinguish between two designs of surge arresters.

– "Design A" arresters have a design in which a gas channel runs along the entire length of the arrester unit and fills ≥50 % of the internal volume not occupied by the internal active parts.
– "Design B" arresters are of a solid design with no enclosed volume of gas or having an internal gas volume filling <50 % of the internal volume not occupied by the internal active parts.

NOTE 1 Typically, "Design A" arresters are porcelain-housed arresters, or polymer-housed arresters with a composite hollow insulator which are equipped either with pressure-relief devices, or with prefabricated weak spots in the composite housing which burst or flip open at a specified pressure, thereby decreasing the internal pressure.

Typically, "Design B" arresters do not have any pressure relief device and are of a solid type with no enclosed volume of gas. If the resistors fail electrically, an arc is established within the arrester. This arc causes heavy evaporation and possibly burning of the housing and/or internal material. These arresters' short-circuit performance is determined by their ability to control the cracking or tearing-open of the housing due to the arc effects, thereby avoiding violent shattering.

NOTE 2 "Active parts" in this context are the non-linear, metal-oxide resistors and any metal spacers directly in series with them.

Depending on the type of arrester and test voltage, different requirements apply with regard to the number of test samples, initiation of short-circuit current and amplitude of the first short-circuit current peak. Table 14 shows a summary of these requirements which are further explained in the following subclauses.

NOTE 3 After agreement between the manufacturer and the purchaser, the test procedure can be modified to include, for example, a number of reclosing operations. For such special tests, the procedure and acceptance criteria should be agreed upon between the manufacturer and the purchaser.

8.7.2 Preparation of the test samples

For the high-current tests, the test samples shall be the longest arrester unit used for the design with the highest rated voltage of that unit used for each different arrester design.

For the low-current test, the test sample shall be an arrester unit of any length with the highest rated voltage of that unit used for each different arrester design.

NOTE 1 Figure 13 shows different examples of arrester units.

In case a fuse wire is required, the fuse wire material and size shall be selected so that the wire will melt within the first 30 electrical degrees after initiation of the test current.

NOTE 2 In order to have melting of the fuse wire within the specified time limit and create a suitable condition for arc ignition, it is generally recommended that a fuse wire of a low resistance material (for example copper, aluminium or silver) with a diameter of about 0,2 mm to 0,5 mm be used. Higher fuse-wire cross-sections are applicable to surge arrester units prepared for higher short-circuit test currents. When there are problems in initiating the arc, a fuse wire of larger size but with a diameter not exceeding 1,5 mm, may be used since it will help arc establishment. In such cases, a specially prepared fuse wire, having a larger cross-section along most of the arrester height with a short thinner section in the middle, may also help.

8.7.2.1 "Design A" arresters

The samples shall be prepared with means for conducting the required short-circuit current using a fuse wire. The fuse wire shall be in direct contact with the MO resistors and be positioned within, or as close as possible to, the gas channel and shall short-circuit the entire internal active part. The actual location of the fuse wire in the test shall be reported in the test report.

No differences with regard to polymer housings or porcelain housings are made in the preparation of the test samples. However, differences partly apply in the test procedure (see 8.7.4.2). In this case, “Design A” arresters with polymeric sheds which are not made of porcelain or other hollow insulators, and which are as brittle as ceramics, shall be considered and tested as porcelain-housed arresters.

8.7.2.2 “Design B” arresters

“Design B” arresters with polymeric sheds which are not made of porcelain or other mechanically supporting structures, and which are as brittle as ceramics, shall be considered and tested as porcelain-housed arresters.

8.7.2.2.1 Polymer-housed arresters

No special preparation is necessary. Standard arrester units shall be used. The arrester units shall be electrically pre-failed with a power frequency overvoltage. The overvoltage shall be run on completely assembled test units. No physical modification shall be made to the units between pre-failing and the actual short-circuit current test.

The overvoltage given by the manufacturer shall be a voltage exceeding 1,15 times U_c. The voltage shall cause the arrester to fail within (5 ± 3) min. The resistors are considered to have failed when the voltage across the resistors falls below 10 % of the originally applied voltage. The short-circuit current of the pre-failing test circuit shall not exceed 30 A.

The time between pre-failure and the rated short-circuit current test shall not exceed 15 min.

NOTE The pre-failure can be achieved by either applying a voltage source or a current source to the samples.

– Voltage source method: the initial current should typically be in the range 5-10 mA/cm². The short-circuit current should typically be between 1 A and 30 A. The voltage source need not be adjusted after the initial setting, although small adjustments might be necessary in order to fail the resistors in the given time range.

– Current source method: Typically a current density of around 15 mA/cm² with a variation of ±50 %, will result in failure of the resistors in the given time range. The short-circuit current should typically be between 10 A and 30 A. The current source need not be adjusted after the initial setting, although small adjustments might be necessary in order to fail the resistors in the given time range.

8.7.2.2.2 Porcelain-housed arresters

The samples shall be prepared with means for conducting the required short-circuit current using a fuse wire. The fuse wire shall be in direct contact with the MO resistors and be located as far away as possible from the gas channel and shall short-circuit the entire internal active part. The actual location of the fuse wire in the test shall be reported in the test report.

8.7.3 Mounting of the test sample

For a base-mounted arrester, the mounting arrangement is shown in Figures 14a and 14b. The distance to the ground from the insulating platform and the conductors shall be as indicated in Figures 14a and 14b.

For non-base-mounted arresters (for example, pole-mounted arresters), the test sample shall be mounted on a non-metallic pole using mounting brackets and hardware typically used for real service installation. For the purpose of the test, the mounting bracket shall be considered as a part of the arrester base. In cases where the foregoing is at variance with the manufacturer's instructions, the arrester shall be mounted in accordance with the installation recommendations of the manufacturer. The entire lead between the base and the current sensor shall be insulated for at least 1 000 V. The top end of the test sample shall be fitted with the base assembly of the same design of an arrester or with the top cap.

For base-mounted arresters, the bottom end fitting of the test sample shall be mounted on a test base that is at the same height as a surrounding circular or square enclosure. The test base shall be of insulating material or may be of conducting material if its surface dimensions are smaller than the surface dimensions of the arrester bottom end fitting. The test base and the enclosure shall be placed on top of an insulating platform, as shown in Figures 14a and 14b. For non-base-mounted arresters, the same requirements apply to the bottom of the arrester. The arcing distance between the top end cap and any other metallic object (floating or grounded), except for the base of the arrester, shall be at least 1,6 times the height of the sample arrester, but not less than 0,9 m. The enclosure shall be made of non-metallic material and be positioned symmetrically with respect to the axis of the test sample. The height of the enclosure shall be 40 cm ± 10 cm, and its diameter (or side, in case of a square enclosure) shall be equal to the greater of 1,8 m or D in Equation (1) below. The enclosure shall not be permitted to open or move during the test.

$$D = 1{,}2 \times (2 \times H + D_{arr}) \qquad (1)$$

where

H is the height of tested arrester unit;

D_{arr} is the diameter of tested arrester unit.

Porcelain-housed arresters shall be mounted according to Figure 14a. Polymer housed arresters shall be mounted according to Figure 14b.

Test samples shall be mounted vertically unless agreed upon otherwise between the manufacturer and the purchaser.

NOTE 1 The mounting of the arrester during the short-circuit test and, more specifically, the routing of the conductors should represent the most unfavourable condition in service.

The routing shown in Figure 14a is the most unfavourable to use during the initial phase of the test before venting occurs (especially in the case of a surge arrester fitted with a pressure relief device). Positioning the sample as shown in Figure 14a, with the venting ports facing in the direction of the test source, may cause the external arc to be swept in closer proximity to the arrester housing than otherwise. As a result, a thermal shock effect may cause excessive chipping and shattering of porcelain weather sheds, as compared to the other possible orientations of the venting ports. However, during the remaining arcing time, this routing forces the arc to move away from the arrester, and thus reduces the risk of the arrester catching fire. Both the initial phase of the test as well as the part with risk of catching fire are important, especially for arresters where the external part of the housing is made of polymeric material.

For all polymer-housed arresters, the ground conductor should be directed to the opposite direction as the incoming conductor, as described in Figure 14b. In this way, the arc will stay close to the arrester during the entire duration of the short-circuit current, thus creating the most unfavourable conditions with regards to the fire hazard.

NOTE 2 In the event that physical space limitations of the laboratory do not permit an enclosure of the specified size, the manufacturer may choose to use an enclosure of lesser diameter.

8.7.4 High-current short-circuit tests

Three samples shall be tested at currents based on selection of a rated short-circuit current selected from Table 15. All three samples shall be prepared according to 8.7.2 and mounted according to 8.7.3.

Tests shall be made in a single-phase test circuit, with an open-circuit test voltage of 77 % to 107 % of the rated voltage of the test sample, as outlined in 8.7.4.1. However, it is expected that tests on high-voltage arresters will have to be made at laboratories which might not have the sufficient short-circuit power capability to carry out these tests at 77 % or more of the test sample rated voltage. Accordingly, an alternative procedure for making the high-current, short-circuit tests at a reduced voltage is given in 8.7.4.2. The measured total duration of test current flowing through the circuit shall be ≥0,2 s.

NOTE Experience from porcelain-housed arresters has shown that tests at the rated current do not necessarily demonstrate acceptable behaviour at lower currents.

8.7.4.1 High-current tests at full voltage (77 % to 107 % of rating)

The prospective current shall first be measured by making a test with the arrester short-circuited or replaced by a solid link of negligible impedance.

The duration of such a test may be limited to the minimum time required to measure the peak and symmetrical component of the current waveform.

For “Design A” arresters tested at the rated short-circuit current, the peak value of the first half-cycle of the prospective current shall be at least 2,5 times the r.m.s. value of the symmetrical component of the prospective current. The following r.m.s. value of the symmetrical component shall be equal to the rated short-circuit current or higher. The peak value of the prospective current, divided by 2,5, shall be quoted as the test current, even though the r.m.s. value of the symmetrical component of the prospective current may be higher. Because of the higher prospective current, the sample arrester may be subjected to more severe duty, and, therefore, tests at X/R ratio lower than 15 shall only be carried out with the manufacturer’s consent.

For “Design B” arresters tested at rated short-circuit current, the peak value of the first half-cycle of the prospective current shall be at least √2 times the r.m.s. value.

For all the reduced short-circuit currents, the r.m.s. value shall be in accordance with Table 15 and the peak value of the first half-cycle of the prospective current shall be at least √2 times the r.m.s. value of this current.

The solid shorting link shall be removed after checking the prospective current and the arrester sample(s) shall be tested with the same circuit parameters.

NOTE 1 The resistance of the restricted arc inside the arrester may reduce the r.m.s. symmetrical component and the peak value of the measured current. This does not invalidate the test, since the test is being made with at least normal service voltage and the effect on the test current is the same as would be experienced during a fault in service.

NOTE 2 The X/R ratio of the test circuit impedance, without the arrester connected, should preferably be at least 15. In cases where the test circuit impedance X/R ratio is less than 15, the test voltage may be increased or the impedance may be reduced, in such a way that,

– for the rated short-circuit current, the peak value of the first half-cycle of the prospective current is equal to, or greater than, 2,5 times the required test current level;
– for the reduced current level tests, the tolerances in Table 15 are met.