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

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- ☐ Safety / Sécurité
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Titre :

Title : Amendment 1-f3 to IEC 60099-4 Ed 2.0 = Surge Arresters - Part 4, Metal-oxide surge arresters without gaps for a.c. systems

Note d'introduction

Introductory note (See attached Attachment A)

ATTENTION	ATTENTION
CDV soumis en parallèle au vote (CEI) et à l'enquête (CENELEC)	**Parallel IEC CDV/CENELEC Enquiry**

Attachment A

Introduction

As a result of a decision during the IEC TC37 Kristiansand meeting in June 2000, the short-circuit tests have become informative Annex O in 60099-4 Ed.1.2 and Annex N in 60099-4 Ed. 2, respectively. As this situation is extremely unsatisfying, MT4 considered working on these tests as their main task.

More than 50% of time in all meetings was spent with discussion on short-circuit testing in order to look at this from all possible views. A questionnaire to 51 high-power labs worldwide was sent out that was answered by 18 labs and brought very informative and helpful feedback.

Main reasons for missing international consensus so far

Many problems have risen in achieving a value of 2.5 for the "asymmetry factor" (i.e. the ratio of first short-circuit current peak value to the r.m.s. value) on certain new designs, which have become possible only by the use of polymeric housings. Designs of concern are extremely tall arresters (unit length 2 m and above, which is not possible with porcelain housings) and the various makes of polymer housed arresters with housings directly applied onto the MO resistors, without any gas volume included (designated as "Design B, Polymer Housed" arresters in the new short-circuit test draft).

The first design requires very high testing voltages of 50 kV and more, which limits the number of laboratories worldwide being able to run the short-circuit test close to only one.

The problem with the other design mentioned is that the short-circuit current has reasonably to be initiated by pre-failing (i.e. electrical overloading) and not by a fuse wire, which would lead to too severe or to too simple test conditions, depending on the location of the wire (within a drilled hole or along the outer surface of the MO resistors). Pre-failing, however, usually does not result in the full asymmetry factor and – in addition – poses problems with the test circuit, which must be able to provide in succession a high pre-failing voltage (at limited current) and a high short-circuit current. It also turned out to be a problem to re-ignite a short-circuit current arc if the test sample was allowed to cool down after pre-failing.

All this had lead, for instance, to the compromise to allow tests at full voltage on samples of only 20 kV rated voltage (see IEC 60099-4, Ed. 2, N.8.7.3), whereas it is doubtful if these can really be representative for the short-circuit performance of a high-voltage arrester of this design.

Thus four main concerns dominated the MT4 discussion over the past two years:

- classification of arrester designs (with/without enclosed gas volume, porcelain housed, polymer housed)
- requirements on test currents (full asymmetry, no asymmetry)
- test procedure ("failure mode") (pre-failing, re-pre-failing, fuse wire method, fuse wire position)
- test evaluation (diameter of test circle, weight of pieces outside the circle, self extinguishing open flames)

MT4 now considers that satisfactory solutions have been found for all these problems. Details are given below.

Classification of arrester designs

MT4 has defined two designs, designated as "Design A" and "Design B". They differ in the relative volume of an enclosed gas channel that runs along the entire length of the arrester.

In case of a breakdown/flashover in the gas channel, the arc will develop very quickly over the entire length of the arrester. This may generate an intensive shock wave in the gas channel, stressing the housing over its entire length and imposing high requirements on pressure relief devices to open quickly. In case of a breakdown in the solid material, the arc will develop more slowly.

"Design A" defines an arrester where the probability of a failure initiated in the gas volume is much higher than in the solid material.

"Design B" defines a design with a higher probability of failure initiated in the solid material.

There are also different considerations of porcelain and polymeric housings. All porcelain housed arresters shall be tested in full length without any exception because the brittleness of the material has to be taken into account, and in all cases the fuse wire method is applied.

"Asymmetry factor"

Based on laboratory investigations, report A3-105 [1] of the CIGRÉ 2004 session suggested skipping the asymmetry factor requirement for "Design B" arresters. This is justified by the fact that a symmetrical current transfers more energy during the first 2 to 3 ms, the typical time of the housing to open for this design. Besides further reasons that are mentioned in this report, one of the most important is that "Design B" arresters can thus be tested in full length. Independent of the discussion if the symmetrical current constitutes the most onerous stress or not (at least differences will be marginal) this benefit countervails all possible trade-offs. There is consensus within MT4 that a test at maybe only 95% of the most severe stress on the full arrester is by far more meaningful than any test on a reduced 20-kV sample! Thus MT4 adopted this proposal for "Design B" arresters in the new short-circuit test draft.

For "Design A" arresters the asymmetry requirement was kept as it usually takes more time than up to the first current peak until the arc has fully commutated to the outside of the housing.

Test procedure ("failure mode")

There has been a lot of discussion over the last years if the short-circuit current should be initiated by a fuse wire along the MO resistor surface, a fuse wire through a drilled hole in the center of the MO resistors or by pre-failing (electrical overloading). For porcelain housed arresters and polymer housed arresters with composite hollow insulator ("Design A" arresters according to the new definition) it is mostly generally agreed that the fuse wire in the gas volume along the surface of the resistor column represents the most relevant failure scenario and at the same time the most severe test condition as this design has mainly to prove its ability to handle the shock wave caused by the internal arc.

For polymer housed arresters with housing directly applied onto the MO resistors ("Design B" arresters according to the new definition) it has often been claimed that puncture of the MO resistors will not happen under overload conditions, but any proof of this assertion is missing so far. It seems reasonable to assume that the better the homogeneity of the MO material is the higher the probability of puncture anywhere in the resistor (and thus also in or close to the center) will be. But there is no general published knowledge about these dependencies. Improvement of the homogeneity is a declared goal of MO development. It can thus not be taken for granted that even if today many arresters do fail without puncture this will also be the case for future designs.

A short-circuit test has to consider worst case scenarios. Thus a fuse wire along the MO resistor surface can definitely not be accepted. On the other hand, a fuse wire through holes drilled through the blocks is vice versa an obviously too harsh scenario, as it can hardly be imagined that all MO resistors of a failing arrester will break by puncture. It is therefore justified to specify the pre-failing method, which among the alternatives mentioned above seems to be the most reasonable compromise with regard to test severeness and realism, and it will automatically cover possible influences of material homogeneity.

An exception had to be made only for porcelain housed arresters of "Design B", where the pre-failing method could cause less severe test conditions (in case the arc develops in the gas channel and not in the solid material as originally intended), a risk that can be accepted for polymer housings but not for housings of brittle material.

Test evaluation

a) Parts allowed to be found outside the enclosure

Practice over decades has shown that in many cases one particular pass criterion of the old "pressure relief test" was the reason for failing the short-circuit test, though the arrester basically performed well. The requirement "no single part shall be found outside the enclosure" is unrealistically hard, as very often parts of porcelain or MO resistors just "jump" over the enclosure of the circle, without any dangerous kinetic energy. This had just been taken into account in the short-circuit test of 60099-4, Ed. 2, Annex N, by allowing pieces of up to 10 g to be found outside the circle. This requirement was again discussed in MT4, and the following is now specified:

- The diameter of the circle has been increased by 20 % compared with the old requirement. Justification: it was observed in many cases that after non-violent thermal breaking of the porcelain housing the active part, completely intact, fell down such that its top end collided with the enclosure (which has a radius equal to the arrester height according to the former requirements) and some parts of its top end just jumped outside the enclosure. Though in these cases the short-circuit performance was good, the arrester did not pass the test. In order to avoid this conflict the radius of the enclosure was chosen to be 20% larger than the arrester height.
- Parts of up to 60 g are allowed to be found outside the circle. Justification: the IEC 62271-200:2003 for metal-enclosed substations and the future IEC 61330 for medium-voltage/low-

voltage prefabricated substations explicitly deal with internal arc testing with respect to the safety of personnel and public in case of failures within such stations. Two levels of accessibility have been adopted, where the accessibility B refers to stations that are directly accessible to the public. Although these standards deal with the safety of persons and are, therefore very restrictive concerning possibly arising danger, they permit projection of parts out of the station up to a weight of 60 g each as compared to the value of 10 g specified in IEC 60099-4, Ed. 2. Furthermore, it would be of advantage if all standards dealing with similar parts of a power system specify similar requirements. MT4, therefore, decided that the permitted value of 60 g per projected part is also adopted for the short-circuit testing of surge arresters.

b) Ability to self extinguish open flames

As one of the requirements, the arrester shall be able to self extinguish open flames within 2 minutes. The actual time interval between pre-failing and the short-circuit test may influence this test result. It must be pointed out that the specified time interval of ≤ 15 minutes is a compromise, in order to enable as many high-power labs as possible to run the short-circuit tests.

15 minutes are considered a well-balanced compromise, based on the feedback to the questionnaire sent out to the high-power labs, but even this is a hard requirement to many labs. The question if the 15 minutes may ensure that designs prone to catching fire will always be inflamed cannot be finally answered until more test experience has been gained. MT4 feels that further investigations on this issue should be performed in the near future. This will take longer time, however, and should not be a reason to further delay publication of a mandatory short-circuit test procedure.

Literature

[1] R.P.P. Smeets, H. Barts, W. A. van der Linden, L. Stenström
Modern ZnO Surges Arresters Under Short-Circuit Current Stresses: Test Experiences and Critical Review of the IEC Standard
CIGRÉ 2004 Session, Report A3-105

The following material is to replace that in Clause 8.7 of 60099-4 Ed 2.0

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 sub-clause. The test shall be performed in order to show that an arrester failure does not result in a violent shattering of the arrester housing, by testing each arrester type 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 2 designs of surge arresters as follows:

- “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 a 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 number of test samples, initiation of short-circuit current, and amplitude of the first short-circuit current peak. Table 1 shows a summary of these requirements which are further explained in the following subclauses.

NOTE After agreement between the manufacturer and the purchaser the test procedure could be modified to e.g. include 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 Figure 1 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 the initiation of the test current.

NOTE In order to have melting of the fuse wire within the specified time limit and create suitable condition for arc ignition, it is generally recommended to use a fuse wire of a low resistance material (for example copper, aluminum or silver) with a diameter of about 0,2 mm to 0,5 mm. Higher fuse wire cross-sections are applicable to surge arrester units prepared for higher short circuit test current. When there are problems in initiating the arc a fuse wire of larger size, but with diameter not exceeding 1,5 mm, may be used since it will help arc establishment. In such case a specially prepared fuse wire, having 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 by 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 outside porcelain or other hollow insulators, 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 outside porcelain or other mechanically supporting structures, 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. It is not allowed to open the arrester 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 in a time within 5 +/- 3 minutes. The resistors are considered to be 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 minutes.