IEC 60549

Edition 2.0 2013-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

High-voltage fuses for the external protection of shunt capacitors

Coupe-circuit à fusibles haute tension destinés à la protection externe des condensateurs shunt

IEC 60549:2013

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FOREWORD

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International Standard IEC 60549 has been prepared by subcommittee 32A: High voltage fuses, of IEC technical committee 32: Fuses.

This second edition cancels and replaces the first edition published in 1976. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) alignment of the document with current IEC document structure requirements;

b) clarification of certain test requirements.

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

CDV	Report on voting
32A/294/CDV	32A/298/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability 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- withdrawn,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.

HIGH-VOLTAGE FUSES FOR THE EXTERNAL PROTECTION OF SHUNT CAPACITORS

1 Scope

This standard applies to external fuses used with high-voltage capacitors according to IEC 60871-1, Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 1: General. IEC 60871-1 is applicable to both capacitor units and capacitor banks intended to be used, particularly, for power-factor correction of a.c. power systems, and also to capacitors intended for use in power filter circuits.

Fuses according to this standard are intended to clear either faults inside a capacitor unit to permit continued operation of the remaining parts of the bank in which the unit is connected (unit fuses) or faults on the whole capacitor bank to isolate the bank from the system (line fuses).

In this standard the terms “capacitive current” and “inductive current” are used to indicate test currents that have a leading or lagging power factor, respectively, and in which the circuit contains predominantly capacitive or inductive components. The word "capacitor" is used when it is not necessary to lay particular stress upon the different meanings of the word "capacitor unit" or "capacitor bank".

In some cases, fuses tested only to IEC 60282-1 or IEC 60282-2 may be suitable for use with capacitors if they are not required to interrupt capacitive currents (e.g. if capacitive currents cannot flow, or if they are acting as a “back-up”, to provide high inductive current breaking, to other devices that will clear capacitive currents).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60282-1:2009, *High-voltage fuses – Part 1: Current-limiting fuses*

IEC 60282-2, *High-voltage Fuses – Part 2: Expulsion Fuses*

IEC 60871-1, *Shunt capacitors for ac power systems having a rated voltage above 1 000 V – Part 1: General*

3 Terms and definitions

For the purposes of this document, the following definitions apply.

3.1
(capacitor) element
a device consisting essentially of two electrodes separated by a dielectric

[SOURCE: IEC 60050-436:1990, 436-01-03]

3.2
(capacitor) unit
an assembly of one or more capacitor elements in the same container with terminals brought out

[SOURCE: IEC 60050-436:1990, 436-01-04]

3.3
(capacitor) bank
a number of capacitor units connected so as to act together

[SOURCE: IEC 60050-436:1990, 436-01-06]

3.4
unit fuse
fuse intended to be used for the protection of a capacitor unit which forms a part of a capacitor bank

3.5
line fuse
fuse intended to be used for the overall protection of a capacitor connected to a given point of a system

3.6
rated voltage of a capacitor
U_r
the r.m.s. value of the alternating voltage for which the capacitor has been designed

Note 1 to entry: In the case of capacitors consisting of one or more separate circuits (for example single phase units intended for use in polyphase connection, or polyphase units with separate circuits), U_r refers to the rated voltage of each circuit.

Note 2 to entry: For polyphase capacitors with internal electrical connections between phases, and for polyphase capacitor banks, U_r refers to the phase-to-phase voltage.

[SOURCE: IEC 60050-436:1990, 436-01-15, modified by addition of symbol and notes to entry]

3.7
refill unit
a set of replacement parts sufficient to restore a fuse-link to its original condition after an operation

[SOURCE: IEC 60050-441:2007, 441-18-15]

3.8
capacitive breaking current
current for which the specified conditions of use and behaviour include the opening of the circuit that includes capacitor elements and/or capacitor units in series with the fuse

3.9
rated maximum capacitive breaking current
maximum capacitive breaking current that the fuse shall be capable of breaking under the conditions of use and behaviour prescribed in this standard

3.10
rated capacitor discharge energy
Joule rating
stored energy in a capacitor that a fuse has been shown to be capable of withstanding during a capacitor discharge breaking test

4 Performance requirements

4.1 General

These fuses are not a substitute for a mechanical switching device, but when forming a part of a mechanical switching device such as a fused switch or a fused disconnector, they shall comply with this standard.

When fuses are used for the external protection of a capacitor unit or a capacitor bank (line fuses), their voltages and breaking ratings shall be adequate for the system.

Fuses according to this standard shall comply with the requirements of IEC 60282-1 or IEC 60282-2, except those which are specifically excluded in this standard.

The fuse is connected in series with the unit(s) that the fuse is intended to isolate if the unit(s) become(s) faulty. The range in currents and voltages for the fuse is therefore dependent on the characteristics of the capacitor and the bank in which the fuse is connected as well as the parameters of the supply circuit.

The operation of an external fuse is, in general, determined by the following two factors:

a) the power-frequency fault current resulting from either a partial or complete capacitor failure;
b) the discharge energy from any units in parallel with the fault.

However, this standard gives a method of separate checking of these factors.

These requirements are valid for capacitors switched by a switching device with a very low probability of restrike during interruption. If this is not the case, other requirements are to be agreed upon.

As used in this standard, U_r is the rated voltage of the capacitor unit and U_{rf} is the rated voltage of the capacitor fuse.

4.2 Breaking requirements

4.2.1 Rated maximum capacitive breaking current

The preferred rated maximum capacitive breaking currents for capacitor fuses are 1 kA r.m.s., 2,5 kA r.m.s., 3,15 kA r.m.s., 4 kA r.m.s., and 5 kA r.m.s.. Other values shall be the subject of an agreement between manufacturer and user.

4.2.2 Rated capacitor discharge energy

A rated capacitor discharge energy (joule rating) is assigned to a fuse based on the energy stored in a capacitor test bank prior to the time it is discharged through the fuse in the capacitor discharge breaking tests (5.5). Values should be selected from R10 series with a minimum of 10 kJ. The preferred value for current-limiting fuses is 40 kJ. To assign an “unlimited” rated capacitor discharge energy see 5.5.2.

The preferred frequency for the capacitor discharge breaking tests of 5.5 is:

– f = 0,8 U_{rf}

Where f is in hertz and U_{rf} is the rated voltage of the fuse, in volts.

5 Type tests

5.1 General

To comply with this standard, fuses shall be subjected to the tests specified in Table 1.

For fuses belonging to a homogeneous series as defined in IEC 60282-1 and IEC 60282-2, it is allowed that tests made on a reduced number of current ratings shall be valid for the other current ratings. Detailed information is given in 5.4.1 and 5.5.1.

Table 1 – Type tests required

Tests	Line fuses	Unit fuses	
		Where inductive currents are likely [a]	Where inductive currents are not likely [b]
Power-frequency Inductive currents (5.3)	X	X	–
Power-frequency Capacitive currents [c] (5.4)	X	X	X
Capacitive-discharge (5.5)	– [d]	X	X

[a] Examples of such applications are

– unit fuses in delta-connected banks without units in series;

– unit fuses in star-connected banks without units in series and with earthed neutral,

– unit fuses without capacitor units in series, used on single phase circuits

[b] Examples of such applications are:

– unit fuses in star-connected banks with unearthed neutral;

– banks where capacitor units are used in series.

[c] These tests are not required for fuses where capacitive limited currents are not likely to flow. Examples of such cases are capacitors having only a single internal group of elements, connected in delta or grounded star without capacitor units in series.

[d] Unusual applications, such as back-to-back banks on the same pole with each bank having its own line fuse could require the fuse to be capable of interrupting capacitive discharge currents. Since the size of these banks would generally be small, most line fuses could satisfactorily handle the discharge currents. Consult the fuse manufacturer for these types of applications.

5.2 Test practices

The fuse shall be new, clean and in good condition.

The fuse-link shall be tested in a fuse-base or directly mounted as specified by the manufacturer of the fuse-link.

In making tests of a test duty within a series of renewable fuse-links, only the fuse-elements, refill units and parts normally replaceable shall be replaced. A new fuse-carrier shall be used for tests of the other test duty.

5.3 Power frequency inductive current tests

These tests shall comprise the following: Test duties 1 and 2 according to IEC 60282-1 or Test duties 1, 2, 3 and 4 according to IEC 60282-2.

For the inductive current interrupting tests for capacitor unit fuses, a capacitor shall be placed in parallel with the fuse under test. This parallel capacitor shall be sized to draw a current at the test voltage of between 25 % and 75 % of the rated current of the fuse under test. The transient recovery voltage requirements of IEC 60282-1 do not apply to the tests on capacitor unit fuses when parallel capacitors are used in the test circuit.

Capacitor unit fuses that have met the interrupting requirements when tested without parallel capacitors need not be retested with parallel capacitors in the test circuit.

5.4 Capacitive breaking current tests

5.4.1 Description of tests to be made

For both current-limiting fuses and expulsion fuses belonging to a homogeneous series as defined in IEC 60282-1 and IEC 60282-2, tests shall be made on the fuse-links with the highest current rating. For expulsion fuses, test duty A shall also be made on the fuse-links with the lowest current rating of the series. A 6,3 A type K link (or the equivalent) may be used for the lowest current rating requirement.

These tests are intended to prove the ability of the fuse to break capacitive currents and shall include two test duties.

– *Test duty A*: verification of the rated maximum capacitive breaking current (see 4.2.2).

– *Test duty B*: verification of the operation with a current value resulting in a pre-arcing time of 10 s or more.

The test circuits specified in 5.4.2 and the parameters specified in 5.4.5 have been so chosen as to reproduce as closely as possible the duty which the fuses experience in actual applications.

When applied as capacitor fuses, the mode of failure of the capacitor units determines the magnitude and nature (capacitive or inductive) of the current that the fuse must break. Test duty A simulates the condition where the fuse breaks high capacitive current due to significant capacitor failure. For progressive element failure in the capacitor unit, the current increases until it reaches a magnitude that will just cause operation of the fuse. Test duty B simulates this condition.

5.4.2 Test circuits

5.4.2.1 General

The tests shall be made with single-phase alternating current and with single fuses.

The source impedance shall be such that the variation in the source voltage caused by switching the capacitive load current shall not exceed 10 % (i.e. in Figures 1 and 2, $U_{sc}/U_{so} \leq 1{,}1$). The power factor of the source circuit shall not exceed 0,15 lagging and its capacitance shall be as low as possible.

The waveform of the current to be broken should, as nearly as possible, be sinusoidal. This condition is considered to be complied with if the ratio of the r.m.s. value of the current to the r.m.s. value of the fundamental component does not exceed 1,2.

The current to be broken shall not pass through zero more than once per half-cycle.

5.4.2.2 Unit fuses

For test duty A, the load circuit shall be as shown in Figure 1.

Operation of the fuse is initiated by closing the switch S2 in series with the fuse, in order to simulate the total failure of a capacitor unit protected by the fuse.

C_T represents the capacitance in the bank that limits the fault current and C_P represents the capacitors which are in parallel with the failed unit. The value of C_P in microfarads shall be $C_p \geq 1\,000 / U_{rf}^2$, U_{rf} being expressed in kilovolts.

NOTE 1 In order to achieve the specified recovery voltage in Table 2, the open circuit source voltage U_{SO} has to be of a higher value. It may be determined by considering the ratio of the capacitances, approximately $U_{SO} = (C_T + C_p)/C_T \times U_{rf}$.

For test duty B the load circuit shall be as shown in Figure 2.

Operation of the fuse is initiated by opening the switch S in parallel with the fuse.

C_T represents the remaining healthy elements of the capacitor unit and C_P represents the other units in the bank which are in parallel with the failed unit. The value of C_P in microfarads shall be $C_p \geq 1\,000 / U_{rf}^2$, U_{rf} being expressed in kilovolts.

NOTE 2 In both circuits, the effect of capacitance on the recovery voltage appearing across the fuse when it operates is taken into account by C_P. The minimum value specified represents between 300 kVAr and 400 kVAr (depending on frequency), i.e. the size of the smallest capacitor bank on which individual fuses would normally be applied. Experience has shown that the value of C_P is not critical in its effect on the capacitive current-breaking performance of fuses, and therefore only a minimum value is specified.

5.4.2.3 Line fuses

For test duties A and B on line fuses, the load circuit shall be as shown in Figure 1, except that capacitance C_P shall be omitted.

5.4.3 Arrangement of the equipment

Expulsion and current-limiting fuses that automatically provide an isolating gap after operation shall be mounted as they will be in a capacitor bank. An energized fuse shall be placed on each side of the fuse under test to determine adequately that any expulsion of gas or reduction of clearance does not cause flashovers which might initiate operation of the adjacent fuses. The spacing between fuses shall be recorded.

Other current-limiting fuses may be mounted in any convenient manner.