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TECHNICAL SPECIFICATION

Shunt capacitors for AC power systems having a rated voltage above 1 000 V –
Part 3: Protection of shunt capacitors and shunt capacitor banks

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SHUNT CAPACITORS FOR AC POWER SYSTEMS HAVING A RATED VOLTAGE ABOVE 1 000 V –

Part 3: Protection of shunt capacitors and shunt capacitor banks

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

International Standard IEC 60871-3, which is a technical specification, has been prepared by IEC technical committee 33: Power capacitors and their applications.

This second edition cancels and replaces the first edition published in 1996. This edition constitutes a technical revision.

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

a) Clearer writing of formulas on energy limitation for expulsion fuses;
b) Updated normative references and bibliography;
c) A new clause for synchronized switching has been added.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
33/545/DTS	33/563/RVC

Full information on the voting for the approval of this technical specification 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.

A list of all parts in the IEC 60871, published under the general title *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V*, can be found on the IEC website.

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

SHUNT CAPACITORS FOR AC POWER SYSTEMS HAVING A RATED VOLTAGE ABOVE 1 000 V –

Part 3: Protection of shunt capacitors and shunt capacitor banks

1 Scope

This part of IEC 60871, which is a technical specification, gives guidance on the protection of shunt capacitors and shunt capacitor banks. it applies to capacitors according to IEC 60871-1.

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 60549, *High-voltage fuses for the external protection of shunt capacitors*

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

IEC 60871-4, *Shunt capacitors for AC power systems having a rated voltage above 1 000 V – Part 4: Internal fuses*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60549, IEC 60871-1 and IEC 60871-4 apply.

4 Internal fuses

4.1 General

Internal fuses for shunt capacitors are selective current-limiting fuses arranged inside a capacitor. As defined in IEC 60871-4, they are designed to isolate faulted capacitor elements or capacitor unit, to allow operation of the remaining parts of that capacitor unit and the bank in which the capacitor unit is connected.

The operation of an internal fuse is initiated by the breakdown of a capacitor element. The affected element is instantaneously disconnected by the operation of the element fuse without interruption in the operation of the capacitor.

The number of externally parallel connected capacitors and the available short-circuit current of the supply system should not affect the current-limiting of internal fuses.

It should be noted that internal fuses do not provide protection against a short circuit between internal connections or a short circuit between active parts and casing, both of which may lead to case rupture.

4.2 Fuse characteristics

4.2.1 Rated current

There is no definition or test method existing for element fuses.

Element fuses are, in general, designed for much higher currents than the maximum permissible element current. They are meant to disconnect only faulty elements. The faulty elements and their fuses are not intended to be replaced.

4.2.2 Rated discharge capability

IEC 60871-4 and IEC 60871-1 specify that the capacitor be subject to five undamped discharges from a d.c. charge level of 2,5 U_N. For special applications, where inrush currents and/or peak voltages are limited, lower discharge requirements are applicable.

4.2.3 Disconnecting capability

Requirements and test procedures are given in IEC 60871-4. These tests verify that the fuse has a current-limiting action.

4.2.4 Voltage withstand capability after operation

Requirements and test procedures are given in IEC 60871-4.

4.3 Influence of capacitor element configuration on capacitor life

4.3.1 Capacitor with all elements connected in parallel

After the breakdown of an element, the respective fuse will melt in less than a millisecond owing to the discharge current from the parallel connected elements and capacitors and the power frequency current from the supply. The capacitor may, however, continue operating with a correspondingly reduced output.

If the capacitor is operated at a fixed bus voltage, no variation in operating voltage on the remaining healthy elements will occur.

4.3.2 Capacitor with elements connected in series and parallel

After the breakdown of an element, all parallel connected elements discharge their stored energy or part of it into the faulty element. The power frequency current is limited by the remaining healthy elements connected in series.

After the disconnection of the faulty element, the capacitor continues operating with a correspondingly reduced output. The remaining healthy elements of the group are then stressed with a voltage approximately $m \times n / [m (n - 1) + 1]$ times the initial voltage, where n is the number of parallel connected elements per group and m the number of series-connected sections per unit. In certain cases the voltage may be higher, for example due to neutral shift with an ungrounded star configuration.

5 External fuses

5.1 General

External fuses for shunt capacitors are defined in IEC 60549 as intended to clear faults inside a capacitor unit and to permit continued operation of the remaining parts of the bank in which the unit is connected. They will also clear an external capacitor bushing flashover.

The operation of an external fuse is generally determined by the power frequency fault current and by the discharge energy from capacitors connected in parallel with the faulty capacitor.

The initial breakdown is usually of an individual element within a capacitor. This invariably becomes a short circuit which removes all elements in parallel with it and eliminates one series section from the capacitor. Should the cause of the initial failure continue, failure of successive series sections (which see an increasing voltage with each series section removed) will occur. This causes an increase in the current through the capacitor to the point where the fuse operates removing the failed capacitor from the circuit.

It should be noted, particularly in the case of paper or paper/film dielectric capacitors, that the capacitor case may occasionally rupture in the event of failure. This occurs when the initial element failure has high resistance between the shorted electrodes due to the presence of paper and sustained arcing generates gas which swells the case to the point where it may rupture before the protecting fuse can disconnect the capacitor.

Capacitors with all-film dielectric have a lower incidence of case rupture because the film melts and generally allows a low resistance short between the electrodes. However, case rupture may still occur due to arcing when there is a broken internal connection and when there is excessive stored energy available in parallel capacitors and/or high power frequency fault current.

5.2 Fuse characteristics

5.2.1 Rated current

The rated current of the selected fuse should be consistent with the criteria used for the selection of a switch or circuit-breaker for the same bank. From the various national standards the minimum accepted rating is 1,35 times the rated capacitor current.

In a steady-state basis, there is no need for the fuse capability to exceed that for the switch or circuit-breaker. However, transient conditions such as currents associated with system or bank switching should be considered. It is common to use a fuse with a current rating of 1,65 times the rated capacitor current.

IEC 60549 specifies that the fuse rated current be at least 1,43 times the capacitor rating. This falls between the two values mentioned above of 1,35 and 1,65. For some banks, the fuse rating may be higher than 1,65 times the capacitor rated current to avoid spurious fuse operation due to switching transients and for mechanical reasons.

NOTE The continuous rating of the fuse is not necessarily its nameplate rating. For example, an expulsion fuse link with a rating much smaller than the rating of the fuse holder can carry 150 % of its nameplate rating on a continuous basis. It is extremely important that the actual current rating of the fuse link be known. Typically, fuse holders are available in two current ratings, one for up to 50 A and the other for up to 100 A, whereas fuse links used in these holders are rated from 5 A to 100 A. These holders also vary in voltage rating, e.g. up to 9 kV, 9 kV to 16 kV and 16 kV to 25 kV.

5.2.2 Rated voltage

The rated voltage of the fuse should be not less than 1,1 times the rated voltage of the capacitor with which it is associated in order to meet the requirements of IEC 60549.

5.2.3 Time-current characteristics

Time-current characteristics are available from most fuse manufacturers to assist in coordination.

This information is sometimes available in table form.

5.2.4 Discharge capability

The external fuse should be capable of withstanding inrush transients and currents due to external short circuits. IEC 60549 specifies tests to verify the I^2t to which the fuse may be subjected for 5 and 100 discharges.

5.3 Fuse types

5.3.1 General

The different types of fuse are indicated in Figure 1.

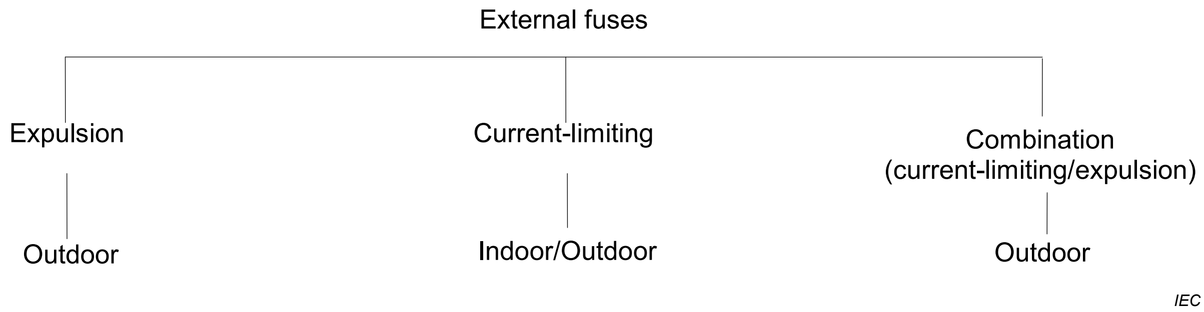

Figure 1 – Fuse types

5.3.2 Expulsion fuses

The following information on expulsion fuses should be noted:

a) Expulsion fuses are normally used in outdoor applications due to noise and gases released during fuse operation.

b) Expulsion fuses have limited power frequency fault current capability. Therefore consult with the fuse manufacturer when fault current at the fuse exceeds 1 800 A, or use current-limiting fuses.

   Floating star-connected banks and those with multiple series sections minimize the importance of the power frequency interrupting capability of the fuse.

c) Expulsion fuses have limited ability to clear against the discharge energy of capacitors connected in parallel with a shorted capacitor. Standard fuses are generally rated at 15 kJ or less; consult the fuse manufacturer.

   Both fuse tubes and capacitor cases may rupture due to energy available in the event of a capacitor failure. The probability of case rupture in the event of capacitor failure is generally considered acceptable with all-film capacitors when the parallel energy has generally been limited to 15 kJ. This limit is calculated on the basis that the capacitor voltage is at 1,1 times the peak value of rated voltage (when higher power frequency overvoltages are anticipated, the parallel energy should be reduced accordingly). At rated voltage, this limit is equivalent to 4 650 kvar of parallel connected capacitors at 60 Hz and 3 900 kvar at 50 Hz. For all-paper and film/paper capacitors, the energy is typically limited to 10 kJ.

   From energy in W.s. (J): Energy = $C \times (U_{rms})^2$

   Substituting capacitance: $C\ (\mu F) = \dfrac{\text{kvar} \times 1\,000}{2\pi \times f_N \times U_N^2}$

   It follows then that: energy = 159 × kvar/frequency

d) Expulsion fuse links are available in ANSI Type T and Type K (see bibliography).
   The difference in performance is in the time for melting of the link, as shown in Tables 1 and 2.