

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**

IEC TS 60871-3:2015

<https://standards.iteh.ai/catalog/standards/sist/936181a9-adc5-4e4b-865f-5f96b90be834/iec-ts-60871-3-2015>



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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.240.99; 31.060.70

ISBN 978-2-8322-7449-1

Warning! Make sure that you obtained this publication from an authorized distributor.

REDLINE VERSION



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

[IEC TS 60871-3:2015](https://standards.iteh.ai/catalog/standards/sist/936181a9-adc5-4e4b-865f-5f96b90be834/iec-ts-60871-3-2015)

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CONTENTS

FOREWORD.....	5
1 Scope.....	7
2 Normative references	7
3 Terms and definitions	7
4 Internal fuses.....	7
4.1 General.....	7
4.2 Fuse characteristics.....	8
4.2.1 Rated current.....	8
4.2.2 Rated discharge capability.....	8
4.2.3 Disconnecting capability	8
4.2.4 Voltage withstand capability after operation.....	8
4.3 Influence of capacitor element configuration on capacitor life.....	8
4.3.1 Capacitor with all elements connected in parallel.....	8
4.3.2 Capacitor with elements connected in series and parallel	8
5 External fuses	8
5.1 General.....	8
5.2 Fuse characteristics.....	9
5.2.1 Rated current.....	9
5.2.2 Rated voltage	9
5.2.3 Time-current characteristics	9
5.2.4 Discharge capability	10
5.3 Fuse types	10
5.3.1 General	10
5.3.2 Expulsion fuses	10
5.3.3 Current-limiting fuses.....	11
5.3.4 Combination current-limiting/expulsion fuses	11
5.4 Influence of capacitor bank configuration on fuse selection.....	11
5.4.1 Single series section grounded star and delta banks.....	11
5.4.2 Single series section ungrounded star banks	11
5.4.3 Multiple series section banks	11
5.5 Coordination with case rupture curves	11
6 Unbalance detection	12
6.1 Operation.....	12
6.2 Types of unbalance protection	12
6.2.1 Neutral current (Figure 3)	12
6.2.2 Neutral voltage (Figure 4).....	12
6.2.3 Current unbalance between neutrals (Figure 5)	13
6.2.4 Phase voltage unbalance (Figure 6)	13
6.2.5 Voltage difference (Figure 7)	13
6.2.6 Current unbalance in bridge connection (Figure 8).....	13
6.3 Current and voltage transformers.....	13
6.3.1 Current transformers.....	13
6.3.2 Voltage transformers	14
6.4 Relays and protection settings	14
6.5 Sensitivity	14
6.6 Initial unbalance.....	15

6.7	Calculation of the unbalance relay's settings.....	15
7	Overload current.....	15
7.1	Operation.....	15
7.2	Protective arrangement.....	15
7.3	Current transformers.....	16
7.4	Relays.....	16
7.5	Protective settings.....	16
8	Over and undervoltage.....	16
8.1	Operation.....	16
8.2	Overvoltage protection.....	17
8.3	Undervoltage protection.....	17
8.4	Reclosing.....	17
9	Other protection.....	17
9.1	Surge arresters.....	17
9.1.1	General.....	17
9.1.2	Operation.....	17
9.1.3	Lightning transients.....	17
9.1.4	Switching transients.....	18
9.1.5	Temporary overvoltages.....	18
9.1.6	Rated voltage.....	18
9.1.7	Energy absorption.....	18
9.2	Damping devices.....	18
9.2.1	Capacitor switching.....	18
9.2.2	Inrush currents.....	18
9.2.3	Voltage transients.....	19
9.2.4	Ratings.....	19
9.3	Synchronized switching.....	19
9.3.1	Operation.....	19
9.3.2	Breaker contacts delay.....	20
10	Safety.....	20
10.1	Discharging devices.....	20
10.1.1	General.....	20
10.1.2	Internal resistors.....	20
10.1.3	External discharge devices.....	20
10.1.4	Discharging after disconnection.....	20
10.2	Dead metallic parts.....	21
	Bibliography.....	26
	Figure 1 – Fuse types.....	10
	Figure 2 – Typical case rupture curves for approximately 30 000 cm ³ case volume.....	22
	Figure 3 – Star connection with the neutral grounded through a current transformer.....	22
	Figure 4 – Star connection with voltage transformer between neutral and ground.....	22
	Figure 5 – Star connection with ungrounded neutral and voltage transformers connected in an open delta.....	23
	Figure 6 – Double-star connection with ungrounded neutral.....	23
	Figure 7 – Star connection with grounded neutral and voltage transformers connected in differential measurement.....	23

Figure 8 – Bridge connection	23
Figure 9 – Line overcurrent relays for capacitor bank, grounded	23
Figure 10 – Line overcurrent relays for capacitor bank, ungrounded	24
Table 1 – Melting currents for type-K (fast) fuse links, in amperes	24
Table 2 – Melting currents for type-T (slow) fuse links, in amperes	25

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**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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This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC TS 60871-3 edition 2.1 contains the second edition (2015-06) [documents 33/545/DTS and 33/563/RVC] and its amendment 1 (2023-08) [documents 33/688/DTS and 33/691/RVDTs].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- 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 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.

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 document and its amendment will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

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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

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*

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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.

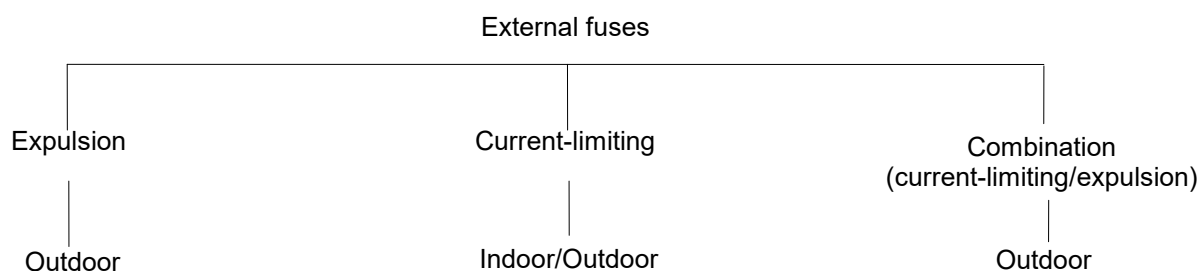
5.2.4 Discharge capability

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.



IEC

Figure 1 – Fuse types

5.3.2 Expulsion fuses

The following information on expulsion fuses should be noted:

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

- 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): $\text{Energy} = C \times (U_{\text{rms}})^2$

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

It follows then that: $\text{energy} = 159 \times \text{kvar}/\text{frequency}$

- 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.

5.3.3 Current-limiting fuses

The following information on current-limiting fuses should be noted:

- a) Current-limiting fuses may be used for indoor and outdoor applications.
- b) Current-limiting fuses will limit the power frequency short-circuit current to less than the prospective value and will reduce the current to zero before the normal working frequency current zero.
- c) Generally, current-limiting fuses impose no upper limit on the parallel stored energy available to a shorted capacitor. However, some current-limiting fuses have a maximum limit for parallel energy. The fuse manufacturer should be consulted regarding the discharge energy interrupting rating.
- d) It should be noted that some fuses will not clear on power frequency current. The fuse manufacturer should be consulted regarding the interrupting rating for power frequency current.

5.3.4 Combination current-limiting/expulsion fuses

As the name implies, these fuses combine a totally enclosed current-limiting fuse with an expulsion fuse.

- a) As with expulsion fuses, combination fuses are normally used in outdoor applications due to noise and gases released during fuse operation.
- b) As with current-limiting fuses, combination fuses will limit the power frequency short-circuit current to less than the prospective value and will reduce the current to zero before the normal working frequency current zero.
- c) As with current-limiting fuses, combination fuses generally have no upper limit on the parallel stored energy available to a shorted capacitor. However, some combination fuses have a maximum limit for parallel energy. The fuse manufacturer should be consulted regarding the discharge energy interrupting rating.
- d) It should be noted that some fuses will not clear on power frequency current. The fuse manufacturer should be consulted regarding the interrupting rating for power frequency current.

5.4 Influence of capacitor bank configuration on fuse selection

5.4.1 Single series section grounded star and delta banks

Current-limiting or combination fuses are normally required because a shorted capacitor is subjected to high fault currents that may cause the fuse holder or capacitor case to rupture.

5.4.2 Single series section ungrounded star banks

The available energy from parallel connected capacitors will probably be the determining factor in selecting either expulsion or one of the current-limiting options.

5.4.3 Multiple series section banks

Available short-circuit current is not a factor in these banks since the multiple series sections will limit the fault current through a shorted capacitor. In large banks having many capacitors in parallel per series section, expulsion type fuses may often be used if the bank configuration is changed, e.g. to double star, to limit the parallel energy.

5.5 Coordination with case rupture curves

In addition to the considerations in fuse selection already dealt with, the fuse should coordinate with the rupture curves for the bank capacitor units.