BS EN 60831-1:2014

Incorporating corrigendum May 2014

BSI Standards Publication

Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1000 V

Part 1: General — Performance, testing and rating — Safety requirements — Guide for installation and operation

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National foreword

This British Standard is the UK implementation of EN 60831-1:2014. It is identical to IEC 60831-1:2014, incorporating corrigendum May 2014. It supersedes BS EN 60831-1:1998 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/33, Power capacitors.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Date	Text affected
31 July 2014	Implementation of IEC corrigendum May 2014: Clause B.4.3 amended.

EUROPEAN STANDARD

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EN 60831-1

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Supersedes EN 60831-1:1996

English Version

Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1 000 V - Part 1: General - Performance, testing and rating - Safety requirements - Guide for installation and operation (IEC 60831-1:2014)

Condensateurs shunt de puissance autoregénérateurs pour réseaux à courant alternatif de tension assignée inférieure ou égale à 1 000 V - Partie 1: Généralités - Caractéristiques fonctionnelles, essais et valeurs assignées - Règles de sécurité - Guide d'installation et d'exploitation (CEI 60831-1:2014)

Selbstheilende Leistungs-Parallelkondensatoren für Wechselstromanlagen mit einer Bemessungsspannung bis 1 000 V - Teil 1: Allgemeines - Leistungsanforderungen, Prüfung und Bemessung - Sicherheitsanforderungen - Anleitung für Errichtung und Betrieb (IEC 60831-1:2014)

This European Standard was approved by CENELEC on 2014-03-18. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC

European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 33/543/FDIS, future edition 3 of IEC 60831-1, prepared by IEC/TC 33, "Power capacitors and their applications" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60831-1:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-12-18
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-03-18

This document supersedes EN 60831-1:1996 + A1:2003.

EN 60831-1:2014 includes the following significant technical changes with respect to EN 60831-1:1996 + A1:2003:

a) Updating of the normative references;

b) Test conditions have been clarified;

c) Thermal stability test has been clarified;

d) Maximum permissible voltage and current have been clarified;

e) The protection of the environment has been amended with safety concerns and plastic quality requirements.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

This standard covers the Principle Elements of the Safety Objectives for Electrical Equipment Designed for Use within Certain Voltage Limits (LVD - 2006/95/EC).

Endorsement notice

The text of the International Standard IEC 60831-1:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60060-2:2010	NOTE	Harmonised as EN 60060-2:2011 (not modified).
IEC 60110-1:1998	NOTE	Harmonised as EN 60110-1:1998 (not modified).
IEC 60143-1	NOTE	Harmonised as EN 60143-1 (not modified).
IEC 60143-2	NOTE	Harmonised as EN 60143-2 (not modified).
IEC 60143-3	NOTE	Harmonised as EN 60143-3 (not modified).
IEC 60143-4	NOTE	Harmonised as EN 60143-4 (not modified).
IEC 60252-1:2010	NOTE	Harmonised as EN 60252-1:2011 (not modified).

IEC 60358-1	NOTE	Harmonised as EN 60358-1 (not modified).
IEC 61048:2006	NOTE	Harmonised as EN 61048:2006 (not modified).
IEC 61049:1991	NOTE	Harmonised as EN 61049:1993 (modified).
IEC 61071 (series)	NOTE	Harmonised as EN 61071 (series) (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60060-1	2010	High-voltage test techniques - Part 1: General definitions and test requirements	EN 60060-1	2010
IEC 60269-1	2006	Low-voltage fuses - Part 1: General requirements	EN 60269-1	2007
IEC 60695-2-12	2010	Fire hazard testing - Part 2-12: Glowing/hot-wire based test methods - Glow-wire flammability index (GWFI) test method for materials	EN 60695-2-12	2010
IEC 60831-2	2014	Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1000 V - Part 2: Ageing test, self-healing test and destruction test	EN 60831-2	2014
IEC 61000-2-2	2002	Electromagnetic compatibility (EMC) - Part 2-2: Environment - Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems	EN 61000-2-2	2002
IEC 61000-4-1	2006	Electromagnetic compatibility (EMC) - Part 4-1: Testing and measurement techniques - Overview of IEC 61000-4 series	EN 61000-4-1	2007

CONTENTS

SHUNT POWER CAPACITORS OF THE SELF-HEALING TYPE FOR A.C. SYSTEMS HAVING A RATED VOLTAGE UP TO AND INCLUDING 1 000 V –

Part 1: General – Performance, testing and rating – Safety requirements – Guide for installation and operation

1 Scope

This part of the IEC 60831 series is applicable to both capacitor units and capacitor banks intended to be used, particularly, for power-factor correction of a.c. power systems having a rated voltage up to and including 1 000 V and frequencies of 15 Hz to 60 Hz.

This part of IEC 60831 also applies to capacitors intended for use in power filter circuits. Additional definitions, requirements, and tests for power filter capacitors are given in Annex A.

The following capacitors are excluded from this part of IEC 60831:

– Shunt power capacitors of the non-self-healing type for a.c. systems having a rated voltage up to and including 1 000 V (IEC 60931-, -2 and -3).
– Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V (IEC 60871-1, -2, -3 and -4).
– Capacitors for inductive heat-generating plants operating at frequencies between 40 Hz and 24 000 Hz (IEC 60110-1 and -2)
– Series capacitors (IEC60143-1, -2, -3 and -4)
– AC motor capacitors (IEC 60252-1 and -2)
– Coupling capacitors and capacitor dividers (IEC 60358-1)
– Capacitors for power electronic circuits (IEC 61071).
– Small a.c. capacitors to be used for fluorescent and discharge lamps (IEC 61048 and IEC 61049).
– Capacitors for suppression of radio interference (under consideration).
– Capacitors intended to be used in various types of electrical equipment, and thus considered as components.
– Capacitors intended for use with d.c. voltage superimposed on the a.c. voltage.

Accessories such as insulators, switches, instrument transformers, fuses, etc., should be in accordance with the relevant IEC standards and are not covered by the scope of this part of IEC 60831.

The object of this part of IEC 60831 is to:

a) formulate uniform rules regarding performances, testing and rating;
b) formulate specific safety rules;
c) provide a guide for installation and operation.

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 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

IEC 60831-2:2013, *Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1 000 V – Part 2: Ageing test, self-healing test and destruction test*

IEC 60695-2-12:2010, *Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability index (GWFI) test method for materials*

IEC 61000-2-2:2002, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC 61000-4-1:2006, *Electromagnetic compatibility (EMC) – Part 4-1: Testing and measurement techniques – Overview of IEC 61000-4 series*

3 Terms and definitions

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

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

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

3.2
capacitor unit
unit
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
self-healing capacitor
capacitor of which the electrical properties, after local breakdown of the dielectric, are rapidly and essentially restored

[SOURCE: IEC 60050-436:1990, 436-03-12]

3.4
capacitor bank
bank
number of capacitor units connected so as to act together

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

3.5
capacitor
generic term, encompassing the notions of capacitor unit and capacitor bank

Note 1 to entry: In this part of IEC 60831, the word capacitor is used when it is not necessary to lay particular stress upon the different meanings of the words capacitor unit or capacitor bank.

3.6
capacitor installation
one or more capacitor banks and their accessories

[SOURCE: IEC 60050-436:1990, 436-01-07]

3.7
discharge device of a capacitor
device which may be incorporated in a capacitor, capable of reducing the voltage between the terminals practically to zero, within a given time, after the capacitor has been disconnected from a network

[SOURCE: IEC 60050-436:1990, 436-03-15, modified ("intended to reduce … value" has been replaced by "capable of reducing … zero")]

3.8
internal fuse of a capacitor
fuse connected inside a capacitor unit, in series with an element or a group of elements

[SOURCE: IEC 60050-436:1990, 436-03-16]

3.9
overpressure disconnector for a capacitor
disconnecting device designed to switch off the capacitor in the case of abnormal increase of the internal pressure

[SOURCE: IEC 60050-436:1990, 436-03-17, modified ("to interrupt … in the event" has been replaced by "to switch off … in the case")]

3.10
overtemperature disconnector for a capacitor
disconnecting device designed to switch off the capacitor in the case of abnormal increase of the internal temperature

3.11
line terminal
terminal intended for connection to a line conductor of a network

Note 1 to entry: In polyphase capacitors, a terminal intended to be connected to the neutral conductor is not considered to be a line terminal.

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

3.12
rated capacitance of a capacitor
C_N
capacitance value for which the capacitor has been designed

[SOURCE: IEC 60050-436:1990, 436-01-12, modified (symbol C_N added and "the r.m.s. value of the alternating current" has been replaced by "capacitance value")]

3.13
rated output of a capacitor
Q_N
reactive power derived from the rated values of capacitance, frequency and voltage

[SOURCE: IEC 60050-436:1990, 436-01-16, modified (symbol Q_N added and "for which the capacitor has been designed" has been replaced by "derived ... voltage")]

3.14
rated voltage of a capacitor
U_N
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 (such as single-phase units intended for use in polyphase connection, or polyphase units with separate circuits), U_N refers to the rated voltage of each circuit.

For polyphase capacitors with internal electrical connections between the phases, and for polyphase capacitor banks, U_N refers to the phase-to-phase voltage.

[SOURCE: IEC 60050-436:1990, 436-01-15]

3.15
rated frequency of a capacitor
f_N
frequency for which the capacitor has been designed

[SOURCE: IEC 60050-436:1990, 436-01-14]

3.16
rated current of a capacitor
I_N
r.m.s. value of the alternating current for which the capacitor has been designed

[SOURCE: IEC 60050-436:1990, 436-01-13]

3.17
capacitor losses
active power dissipated in the capacitor

Note 1 to entry: All loss-producing components should be included, for example:

– for a unit, losses from dielectric, internal fuses, internal discharge resistor, connections, etc.;
– for a bank, losses from units, external fuses, busbars, discharge and damping reactors, etc.

[SOURCE: IEC 60050-436:1990, 436-04-10]

3.18
tangent of the loss angle of a capacitor
tan δ
ratio between the equivalent series resistance and the capacitive reactance of the capacitor at specified sinusoidal alternating voltage and frequency

[SOURCE: IEC 60050-436:1990, 436-04-11]

3.19
maximum permissible a.c. voltage of a capacitor
maximum r.m.s. alternating voltage which the capacitor can sustain for a given time in specified conditions

[SOURCE: IEC 60050-436:1990, 436-04-07]

3.20
maximum permissible a.c. current of a capacitor
maximum r.m.s. alternating current which the capacitor can sustain for a given time in specified conditions

[SOURCE: IEC 60050-436:1990, 436-04-09]

3.21
ambient air temperature
temperature of the air at the proposed location of the capacitor

3.22
cooling air temperature
temperature of the cooling air measured at the hottest position in the bank, under steady-state conditions, midway between two units

Note 1 to entry: If only one unit is involved, it is the temperature measured at a point approximately 0,1 m away from the capacitor container and at two-thirds of the height from its base.

3.23
steady-state condition
thermal equilibrium attained by the capacitor at constant output and at constant ambient air temperature

3.24
residual voltage
voltage remaining on the terminals of a capacitor at a certain time following disconnection

4 Service conditions

4.1 Normal service conditions

This standard gives requirements for capacitors intended for use under the following conditions:

a) Residual voltage at energization

   Not to exceed 10 % rated voltage (Clause 22, Clause 32, and Annex B).

b) Altitude

   Not exceeding 2 000 m.

c) Ambient air temperature categories

Capacitors are classified in temperature categories, each category being specified by a number followed by a letter. The number represents the lowest ambient air temperature at which the capacitor may operate.

The letters represent upper limits of temperature variation ranges, having maximum values specified in Table 1. The temperature categories cover the temperature range of –50 °C to +55 °C.

The lowest ambient air temperature at which the capacitor may be operated should be chosen from the five preferred values +5 °C, –5 °C, –25 °C, –40 °C, –50 °C.

For indoor use, a lower limit of –5 °C is normally applicable.

Table 1 is based on service conditions in which the capacitor does not influence the ambient air temperature (for example outdoor installations).

Table 1 – Letter symbols for upper limit of temperature range

Symbol	Ambient temperature °C		
	Maximum	Highest mean over any period of	
		24 h	1 year
A	40	30	20
B	45	35	25
C	50	40	30
D	55	45	35

NOTE 1 The temperature values according to Table 1 can be found in the meteorological temperature table covering the installation site.

NOTE 2 Higher temperature values than those indicated in Table 1 can be considered in special applications by mutual agreement between manufacturer and purchaser. In that case, the temperature category should be indicated by the combination of minimum and maximum temperature values, for example, –40/60.

If the capacitor influences the air temperature, the ventilation and/or choice of capacitor shall be such that the Table 1 limits are maintained. The cooling air temperature in such an installation shall not exceed the temperature limits of Table 1 by more than 5 °C.

Any combination of minimum and maximum values can be chosen for the standard temperature category of a capacitor, for example –40/A or –5/C.

Preferred temperature categories are:

–40/A, –25/A, –5/A and –5/C.

4.2 Unusual service conditions

Unless otherwise agreed between manufacturer and purchaser, this standard does not apply to capacitors, the service conditions of which, in general, are incompatible with the requirements of the present standard.

5 Test requirements

5.1 General

Clause 5 gives the test requirements for capacitor units and, when specified, for capacitor elements.

Supporting insulators, switches, instrument transformers, fuses, etc, shall be in accordance with relevant IEC standards.

5.2 Test conditions

Unless otherwise specified for a particular test or measurement, the temperature of the capacitor dielectric at the start of the test shall be in the range of +5 °C to +35 °C.

It may be assumed that the dielectric temperature is the same as the ambient temperature, provided that the capacitor has been left in an unenergized state at constant ambient temperature for an adequate period.

The a.c. tests and measurements shall be carried out at a frequency of 50 Hz or 60 Hz independent of the rated frequency of the capacitor, if not otherwise specified.

Capacitors having a rated frequency below 50 Hz shall be tested and measured at 50 Hz or 60 Hz, if not otherwise specified.

6 Classification of tests

6.1 Routine tests

The following tests are routine tests. For details, reference should be made to the relevant clauses or subclauses:

a) capacitance measurement and output calculation (see Clause 7);
b) measurement of the tangent of the loss angle (tan δ) of the capacitor (see Clause 8);
c) voltage test between terminals (see 9.1);
d) voltage test between terminals and container (see 10.1);
e) test of the internal discharge device (see Clause 11);
f) sealing test (see Clause 12).

Routine tests shall have been carried out by the manufacturer on every capacitor before delivery. If the purchaser so requests, he shall be supplied with a certificate detailing the results of such tests.

In general, the indicated sequence of the tests is not mandatory.

6.2 Type tests

The following tests are type tests. For details, reference should be made to the relevant clauses or subclauses:

a) thermal stability test (see Clause 13);
b) measurement of the tangent of the loss angle (tan δ) of the capacitor at elevated temperature (see Clause 14);
c) voltage test between terminals (see 9.2);
d) voltage test between terminals and container (see 10.2);
e) lightning impulse voltage test between terminals and container (see Clause 15);
f) discharge test (see Clause 16);
g) ageing test (see Clause 17);
h) self-healing test (see Clause 18);
i) destruction test (see Clause 19).

Type tests are carried out in order to ascertain that, as regards design, size, materials and construction, the capacitor complies with the specified characteristics and operation requirements detailed in this standard.

Unless otherwise specified, every capacitor sample to which the type test is applied shall first have withstood satisfactorily the application of all the routine tests.

The type tests shall have been carried out by the manufacturer, and the purchaser shall, on request, be supplied with a certificate detailing the results of such tests.

The successful completion of each type test is also valid for units having the same rated voltage and lower output, provided that they do not differ in any way that may influence the properties to be checked by the test. It is not essential that all type tests be carried out on the same capacitor sample.

The number of samples for the type test shall be subjected to agreement between the manufacturer and user.

6.3 Acceptance tests

Some or all of the routine and/or type tests may be repeated by the manufacturer in connection with any contract by agreement with the purchaser. The kind of tests, the number of samples that may be subjected to such repeated tests, and the acceptance criteria shall be subject to agreement between manufacturer and purchaser, and shall be stated in the contract.

7 Capacitance measurement and output calculation

7.1 Measuring procedure

The capacitance shall be measured at the voltage and at the frequency chosen by the manufacturer. The method used shall not include errors due to harmonics, or to accessories external to the capacitor to be measured, such as reactors and blocking circuits in the measuring circuit. The accuracy of the measuring method and the correlation with the values measured at rated voltage and frequency shall be given.

The capacitance measurement shall be carried out after the voltage test between terminals (see Clause 9).

Measurement at a voltage between 0,9 and 1,1 times the rated voltage, and at a frequency between 0,8 and 1,2 times the rated frequency, shall be performed on the capacitor previously used for the thermal stability test (see Clause 13), the ageing test (see Clause 17), and the self-healing test (see Clause 18), and could be performed on other capacitors at the request of the purchaser in agreement with the manufacturer.

7.2 Capacitance tolerances

The capacitance shall not differ from the rated capacitance by more than

–5 % to +10 % for units and banks up to 100 kvar;

–5 % to +5 % for units and banks above 100 kvar.

The capacitance value is that measured under the conditions of 7.1.

In three-phase units, the ratio of maximum to minimum value of the capacitance measured between any two-line terminals shall not exceed 1,08.

NOTE A formula for the calculation of the output of a three-phase capacitor from a single-phase capacitance measurement is given in Annex B.

8 Measurement of the tangent of the loss angle (tan δ) of the capacitor

8.1 Measuring procedure

The capacitor losses (or tan δ) shall be measured at the voltage and at the frequency chosen by the manufacturer. The method used shall not include errors due to harmonics, or to accessories external to the capacitor to be measured, such as reactors and blocking circuits in the measuring circuit. The accuracy of the measuring method and the correlation with the values measured at the rated voltage and frequency shall be given.

The measurement of the capacitor losses shall be carried out after the voltage test between terminals (see Clause 9).

Measurement at a voltage between 0,9 and 1,1 times the rated voltage, and at a frequency between 0,8 and 1,2 times the rated frequency shall be performed on the capacitor before the thermal stability test (see Clause 13), and may be performed on other capacitors upon request of the purchaser in agreement with the manufacturer.

When testing a large number of capacitors, statistical sampling may be used for measuring tan δ. The statistical sampling plan should be by agreement between manufacturer and purchaser.

The tan δ value of certain types of dielectric is a function of the energization time before the measurement. In that case, test voltage and energization time should be by agreement between manufacturer and purchaser.

8.2 Loss requirements

The value of tan δ, measured in accordance with 8.1, shall not exceed the value declared by the manufacturer for the temperature and voltage of the test, or the value agreed upon between manufacturer and purchaser.

9 Voltage tests between terminals

9.1 Routine test

Each capacitor shall be subjected to an a.c. test at U_t = 2,15 U_N for a minimum time of 2 s.

The a.c. test shall be carried out with a substantially sinusoidal voltage at a frequency between 15 Hz and 100 Hz, and preferably as near as possible to the rated frequency.

During the test, no permanent puncture or flashover shall occur. Self-healing breakdowns are permitted.

When the unit is composed of a number of elements, or a group of elements connected in parallel, and which are tested separately, it is not necessary to repeat the test on the unit.

For polyphase capacitors, the test voltages should be adjusted as appropriate.

NOTE Operation of internal element fuses is permitted, provided the capacitance tolerances are still met and that not more than two fuses have operated per unit.

9.2 Type test

Each capacitor shall be subjected to an a.c. test at U_t = 2,15 U_N for 10 s.

The a.c. test shall be carried out with a substantially sinusoidal voltage.

During the test, no permanent puncture or flashover shall occur. Self-healing breakdowns are permitted.

For polyphase capacitors, the test voltages should be adjusted as appropriate.

NOTE Operation of internal element fuses is permitted, provided capacitance tolerances are still met, and that not more than two fuses have operated per unit.

10 Voltage tests between terminals and container

10.1 Routine test

Units having all terminals insulated from the container shall be subjected to an a.c. voltage applied between the terminals (joined together) and the container. The voltage to be applied is 2 U_N + 2 kV or 3 kV, whichever is the higher, for 10 s or 20 % higher for a minimum time of 2 s.

If the units are intended to be connected directly to the aerial power line and by agreement between the manufacturer and the user, the test shall be performed with a voltage of 6 kV.

During the test, neither puncture nor flashover shall occur.

The test shall be performed, even if, in service, one of the terminals is intended to be connected to the container.

Three-phase units having separate phase capacitance can be tested with respect to the container with all the terminals joined together. Units having one terminal permanently connected to the container shall not be subjected to this test.

When the unit container consists of insulating material, this test shall be omitted.

If a capacitor has separate phases or sections, a test of the insulation between phases or sections shall be made at the same voltage value as for the terminals-to-container test.

10.2 Type test

Units having all terminals insulated from the container shall be subjected to a test according to 10.1 for a duration of 1 min.

The test on units having one terminal permanently connected to the container shall be limited to the bushing(s) and container (without elements) or to a fully insulated unit with identical internal insulation.

If the capacitor container is of insulating material, the test voltage shall be applied between the terminals and a metal foil wrapped closely round the surface of the container.

The test shall be made under dry conditions for indoor units, and with artificial rain (see IEC 60060-1) for units to be used outdoors.

During the test, neither puncture nor flashover shall occur.

Units intended for outdoor installation may be subjected to a dry test only.

The manufacturer should in such a case supply a separate type test report showing that the bushing with enclosure, if used, will withstand the wet test voltage.

NOTE For filter capacitors, the voltage appearing at the capacitor terminals is always higher than the network voltage.

For filter capacitors, and provided the arithmetic sum of the r.m.s values of the harmonic voltages does not exceed 0,5 times the nominal network voltage, the test voltage between terminals and container refers to the nominal network voltage to which the filter is connected (and not to the voltage appearing at the capacitor terminals).

If the factor of 0,5 times is exceeded, then the test voltage between terminals and container refers to the rated voltage of the capacitor.

11 Test of internal discharge device

The resistance of the internal discharge device, if any, shall be checked either by a resistance measurement or by measuring the self-discharging rate (see Clause 22). The choice of the method is left to the manufacturer.

The test shall be made after the voltage tests of Clause 9.

12 Sealing test

The unit (in non-painted state) shall be exposed to a test that will effectively detect any leak of the container and bushing(s). The test procedure is left to the manufacturer, who shall describe the test method concerned.

If no procedure is stated by the manufacturer, the following test procedure shall apply:

Unenergized capacitor units shall be heated throughout so that all parts reach a temperature not lower than 20 °C above the maximum value in Table 1 corresponding to the capacitor symbol, and shall be maintained at this temperature for 2 h. No leakage shall occur.

It is recommended that a suitable indicator is used.

NOTE If the capacitor contains no liquid materials at the test temperature, the test may be omitted as a routine test.

13 Thermal stability test

The capacitor unit subjected to the test shall be placed between two other units of the same rating which shall be energized at the same voltage as the test capacitor. Alternatively, two dummy capacitors each containing resistors may be used. The dissipation in the resistors shall be adjusted to a value so that the container temperatures of the dummy capacitors near the top opposing faces are equal to, or greater than, those of the test capacitor. The separation between the units shall be equal to normal spacings as specified by manufacturer’s instructions.

The assembly shall be placed in still air (without forced air ventilation) in a heated enclosure in the most unfavourable thermal position according to the manufacturer's instructions for mounting on site. The ambient air temperature shall be maintained at or above the appropriate temperature shown in Table 2. It shall be checked by means of a thermometer having a thermal time constant of approximately 1 h.

The ambient air thermometer should be shielded so that it is subjected to the minimum possible thermal radiation from the three energized samples.

Table 2 – Ambient air temperature for the thermal stability test

Symbol	Ambient air temperature °C
A	40
B	45
C	50
D	55

After all parts of the capacitor have attained the temperature of the ambient air, the capacitor shall be subjected for a period of at least 48 h to an a.c. voltage of substantially sinusoidal form. The magnitude of the voltage throughout the last 24 h of the test shall be adjusted to give a calculated output, using the measured capacitance (see 7.1), of at least 1,44 times its rated output.

The test will stop in one of the following two conditions:

– For a period of 6 h, the temperature of the container measured at 2/3 of the height from the bottom (excluding terminals) shall not increase by more than 1 °C. In this case, the test is considered as positive.
– If the temperature increases of three successive periods of 6 h do not decrease in magnitude. In this case, the test is considered as having failed.

At the end of the stability test, the difference between the measured temperature of the container and the ambient air temperature shall be recorded.

Before and after the test the capacitance shall be measured (see 7.1) within the standard temperature range for testing (see 5.2), and these two measurements shall be corrected to the same dielectric temperature. No change of capacitance greater than 2 % shall be apparent from these measurements.

A measurement of the tangent of the loss angle ($\tan \delta$) shall be made before and after the thermal stability test, at a temperature of 25°C ± 5°C.

The value of the second measurement of the tangent of the loss angle shall be not greater than that of the first by more than 2×10^{-4}.

When interpreting the results of the measurements, two factors shall be taken into account:

– the repeatability of the measurements;
– the fact that internal change in the dielectric may cause a small change of capacitance, without the puncture of any element of the capacitor, or the blowing of an internal fuse having occurred.

When checking whether the capacitor losses or temperature conditions are satisfied, fluctuations of voltage, frequency and ambient air temperature during the test should be taken into account. For this reason, it is advisable to plot these parameters and the tangent of the loss angle and the temperature rise as a function of time.

Units intended for 60 Hz installation may be tested at 50 Hz and units intended for 50 Hz may be tested at 60 Hz provided that the specified output is applied. For units rated below 50 Hz, the test conditions should be agreed between purchaser and manufacturer.

NOTE For polyphase units, two possibilities are allowed:

– use of a three-phase source;

– modification of the internal connections in order to have only one phase with the same output.

14 Measurement of the tangent of the loss angle (tan δ) of the capacitor at elevated temperature

14.1 Measuring procedure

The capacitor losses (tan δ) shall be measured at the end of the thermal stability test (see Clause 13). The measuring voltage shall be that of the thermal stability test.

14.2 Requirements

The value of tan δ, measured in accordance with 14.1, shall not exceed the value declared by the manufacturer for the temperature and voltage of the test, or the value agreed upon between manufacturer and purchaser.

15 Lightning impulse voltage test between terminals and container

Only units having all terminals insulated from the container shall be subjected to this test.

The impulse test shall be performed with a wave of 1,2/50 μs to 5/50 μs having a peak value of 8 kV if the rated voltage of the capacitor is $U_N \leq 690$ V or having a peak value of 12 kV if $U_N > 690$ V.

If the units are intended to be connected directly to exposed installations such as overhead lines and by agreement between the manufacturer and the user, the impulse test shall be performed with a wave of 1,2/50 μs to 5/50 μs having a peak value of 15 kV if the rated voltage of the capacitor is $U_N \leq 690$ V or having a peak value of 25 kV if $U_N > 690$ V.

Three impulses of positive polarity followed by three impulses of negative polarity shall be applied between the terminals joined together and the container.

After the change of polarity, it is permissible to apply some impulses of lower amplitude before the application of the test impulses.

The absence of failure during the test shall be verified by an oscillograph, which is used to record the voltage and to check the wave shape.

If the capacitor container is of insulating material, the test voltage shall be applied between the terminals and a metal foil wrapped closely round the surface of the container.

NOTE Partial discharge in the insulation to the container may be indicated by the modification of the waveshapes between the different impulses.

16 Discharge test

The unit shall be charged by means of d.c. and then discharged through a gap situated as close as possible to the capacitor.

It shall be subjected to five such discharges within 10 min.

The test voltage shall be equal to 2 U_N.

Within 5 min after this test, the unit shall be subjected to a voltage test between terminals (see 9.1).

The capacitance shall be measured before the discharge test and after the voltage test. The measurements shall not differ by an amount corresponding either to the breakdown of an element, or to the blowing of an internal fuse, or by more than 2 %.

For polyphase units, the test shall be carried out in the following manner:

– In the case of units with three-phase delta connection, two terminals shall be short-circuited and the test carried out between the third terminal and the short-circuited terminals at 2 U_N.
– In the case of units with three-phase star connection, the test shall be carried out between two terminals with the third terminal left unconnected. The test voltage shall be 4 $U_N/\sqrt{3}$ to achieve the same test voltage across the elements.

If the first peak of the test current exceeds the value of 200 I_N (r.m.s.), it may be kept at this limit by means of an external coil.

17 Ageing test

The requirements for this test are given in IEC 60831-2.

18 Self-healing test

The requirements for this test are given in IEC 60831-2.

19 Destruction test

The requirements for this test are given in IEC 60831-2.

20 Maximum permissible voltage

20.1 Long-duration voltages

Capacitor units shall be suitable for operation at voltage levels according to Table 3 (see also Clauses 29 and 32).

Table 3 – Admissible voltage levels in service

Type	Voltage factor × U_N r.m.s.	Maximum duration	Observations
Power frequency	1,00	Continuous	Highest average value during any period of capacitor energization. For energization periods less than 24 h, exceptions apply as indicated below (see Clause 29).
Power frequency	1,10	8 h in every 24 h	System voltage regulation and fluctuations.
Power frequency	1,15	30 min in every 24 h	System voltage regulation and fluctuations.
Power frequency	1,20	5 min	Voltage rise at light load (see Clause 29).
Power frequency	1,30	1 min	
Power frequency plus harmonics	So that the current does not exceed the value given in clause 21 (see also Clauses 33 and 34).		

It should be noted that operation of capacitors with overload, even within the limit indicated above, may adversely affect the life duration of these capacitors. It is assumed that the overvoltages given in Table 3 and having a value higher than 1,15 U_N occur 200 times in the life of the capacitor.

20.2 Switching voltages

The switching of a capacitor bank by a restrike-free circuit breaker usually causes a transient overvoltage, the first peak of which does not exceed 2 $\sqrt{2}$ times the applied voltage (r.m.s. value) for a maximum duration of 1/2 cycle.

About 5 000 switching operations per year are acceptable under these conditions, taking into account the fact that some of them may take place when the internal temperature of the capacitors is less than 0 °C, but is within the temperature category. (The associated peak transient overcurrent may reach 100 times the value I_N (see Clause 33)).

In the case of capacitors that are switched more frequently, the values of the overvoltage amplitude and duration and the transient overcurrent shall be limited to lower levels (see Clause 34).

These limitations and/or reductions shall be agreed between manufacturer and purchaser.

21 Maximum permissible current

Capacitor units shall be suitable for continuous operation at an r.m.s. line current of 1,3 times the current that occurs at rated sinusoidal voltage and rated frequency, excluding transients. Taking into account the capacitance tolerances of 1,1 C_N, the maximum current can reach 1,43 I_N.

These overcurrent factors are intended to take into account the combined effects of harmonics, overvoltages and capacitance tolerance according to 20.1.

22 Discharge device

Each capacitor unit and/or bank shall be provided with a means for discharging each unit in 3 min to 75 V or less, from an initial peak voltage of $\sqrt{2}$ times the rated voltage U_N.

There shall be no switch, fuse cut-out, or any other isolating device between the capacitor unit and this discharge device.

A discharge device is not a substitute for short-circuiting the capacitor terminals together and to earth before handling.

Capacitors connected directly and permanently to other electrical equipment providing a discharge path should be considered properly discharged, provided that the circuit characteristics are such as to ensure the discharge of the capacitor within the time specified above.

Attention is drawn to the fact that in some countries smaller discharge times and voltages are required. In that event, the purchaser should inform the manufacturer.

Discharge circuits should have adequate current-carrying capacity to discharge the capacitor from the peak of the 1,3 U_N overvoltage according to Clause 20.

Since the residual voltage at energization should not exceed 10 % of the rated voltage (see 4.1), discharge resistors with lower resistance or additional switched discharge devices may be needed, if the capacitors are automatically controlled.

NOTE A formula for the calculation of the discharge resistance is given in Annex B.

23 Container connections

To enable the potential of the metal container of the capacitor to be fixed, and to be able to carry the fault current in the event of a breakdown to the container, the metallic container shall be provided with a connection capable of carrying the fault current.

24 Protection of the environment

When capacitors are impregnated with products that shall not be dispersed into the environment, the necessary precautions shall be taken. In some countries, there exist legal requirements in this respect (see 26.3). The units and the bank shall be labelled accordingly, if so required.

Products of combustion of the terminals shall be environmentally acceptable. Self-extinguishing materials with a minimum Glow-Wire Flammability Index (GWFI) of 750 °C shall be used for the terminals (see IEC 60695-2-12).

25 Other safety requirements

The purchaser shall specify at the time of enquiry any special requirements with regard to the safety regulations that apply to the country in which the capacitor is to be installed.

26 Marking of the unit

26.1 Rating plate

The following information shall be marked indelibly, either directly or by means of a plate, on each capacitor unit:

a) Manufacturer.

b) Identification number and manufacturing year.

(The year may be a part of the identification number or be in code form)

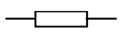
c) Rated output Q_N in kilovars (kvar).

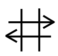
For three-phase units, the total output shall be given (see Annex B).

d) Rated voltage U_N in volts (V).

e) Rated frequency f_N in hertz (Hz).

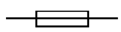
f) Temperature category.

g) Discharge device, if internal, shall be indicated by wording or by the symbol  or by the rated resistance in kilohms (kΩ) or megohms (MΩ).

h) Reference of self-healing design: "SH" or  or "self-healing".

i) Connection symbol.

(All capacitors, except single-phase units having one capacitance only, shall have their connection indicated. For standardized connection symbols, see 26.2).

j) Internal fuses, if included, shall be indicated by wording or by the symbol  .

k) Indication for the overpressure or thermal disconnector, if such disconnector is fitted.

l) Insulation level U_i in kilovolts (kV). (Only for units having all terminals insulated from the container).

The insulation level shall be marked by means of two numbers separated by a stroke, the first number giving the r.m.s. value of the power frequency test voltage, in kilovolts, and the second number giving the peak value of the lightning impulse test voltage, in kilovolts (for example 3/15 kV).

For units having one terminal permanently connected to the container, and not tested according to Clause 15, this information should be 3/- kV.

m) Reference to IEC 60831-1 (plus year of issue of the edition).

In the case of filter capacitors, a reference to Annex A shall be made.

For small units, which are permanently connected together by the manufacturer or the manufacturer's representative to form a bank or a large unit, certain of the above items may be deleted. This bigger bank or unit should in this case carry a complete rating plate.

A warning notice should be included as follows: "Warning: wait 5 minutes after isolating supply before handling".

The purchaser should specify any additional marking requirement.

26.2 Standardized connection symbols

The type of connection shall be indicated either by letters or by the following symbols:

D or △ = delta

Y or Y = star

YN or Y = star, neutral brought out

III or ||| = three sections without interconnections.

26.3 Warning plate

When capacitors are impregnated with products that shall not be dispersed into the environment (see Clause 24), the capacitor shall carry markings in accordance with the laws or regulations in force in the user's country, the onus being on the user to inform the manufacturer of such laws or regulations.

27 Marking of the bank

27.1 Instruction sheet or rating plate

The following minimum information shall be given by the manufacturer in an instruction sheet, or alternatively, on request of the purchaser, on a rating plate:

a) Manufacturer.

b) Rated output Q_N in kilovars (kvar).

(Total output to be given.)

c) Rated voltage U_N in volts (V).

d) Connection symbol.

(For standardized connection symbols, see 26.2. The connection symbol may be part of a simplified connection diagram.)

e) Minimum time required between disconnection and reclosure of the bank.

f) Weight in kilograms (kg).

NOTE The choice between a rating plate and an instruction sheet is left to the purchaser.

27.2 Warning plate

Subclause 26.3 is also valid for the bank.

28 General

Unlike most electrical apparatus, shunt capacitors, whenever energized, operate continuously at full load, or at loads that deviate from this value only as a result of voltage and frequency variations.

Overstressing and overheating shorten the life of a capacitor, and therefore the operating conditions (that is, temperature, voltage and current) should be strictly controlled.

It should be noted that the introduction of concentrated capacitance in a system may produce unsatisfactory operating conditions (for example amplification of harmonics, self-excitation of machines, overvoltage due to switching, unsatisfactory working of audio-frequency remote-control apparatus, etc.).

Because of the different types of capacitors and the many factors involved, it is not possible to cover, by simple rules, installation and operation in all possible cases. The following information is given with regard to the more important points to be considered. In addition, the instructions of the manufacturer and the power supply authorities shall be followed, especially those concerning the switching of capacitors when the network is under light load conditions.

29 Choice of the rated voltage

The rated voltage of the capacitor shall be at least equal to the service voltage of the network to which the capacitor is to be connected, account being taken of the influence of the presence of the capacitor itself.

In certain networks, a considerable difference may exist between the service and rated voltage of the network, details of which should be furnished by the purchaser, so that due allowance can be made by the manufacturer. This is of importance for capacitors, since their performance and life may be adversely affected by an undue increase of the voltage across the capacitor dielectric.

Where circuit elements are inserted in series with the capacitor to reduce the effects of harmonics, etc., the resultant increase in the voltage at the capacitor terminals above the service voltage of the network necessitates a corresponding increase in the rated voltage of the capacitor.

If no information to the contrary is available, the service voltage shall be assumed as equal to the rated (or declared) voltage of the network.

When determining the voltage to be expected on the capacitor terminals, the following considerations shall be taken into account:

a) shunt-connected capacitors may cause a voltage rise from the source to the point where they are located (see Annex B); this voltage rise may be greater due to the presence of harmonics. Capacitors are therefore liable to operate at a higher voltage than that measured before connecting the capacitors;
b) the voltage on the capacitor terminals may be particularly high at times of light load conditions (see Annex B); in such cases, some or all of the capacitors should be switched out of circuit in order to prevent overstressing of the capacitors and undue voltage increase in the network.

Only in case of emergency should capacitors be operated at maximum permissible voltage and maximum ambient temperature simultaneously, and then only for short periods of time.

An excessive safety margin in the choice of the rated voltage U_N should be avoided, because this would result in a decrease of output when compared with the rated output.

NOTE See Clause 20 concerning maximum permissible voltage.

30 Operating temperature

30.1 General

Attention should be paid to the operating temperature of the capacitor, because this has a great influence on its life. In this respect, the temperature of the hot spot is a determining factor, but it is difficult to measure this temperature in practical operation.

Temperature in excess of the upper limit accelerates electrochemical degradation of the dielectric.

30.2 Installation

Capacitors shall be so placed that there is adequate dissipation by convection and radiation of the heat produced by the capacitor losses.

The ventilation of the operating room and the arrangement of the capacitor units shall provide good air circulation around each unit. This is of special importance for units mounted in rows one above the other.

The temperature of capacitors subjected to radiation from the sun or from any high-temperature surface will be increased. Depending on the cooling air temperature, the intensity of the cooling and the intensity and duration of the radiation, it may be necessary to opt for one of the following remedies:

– to protect the capacitors from radiation;
– to choose a capacitor designed for a higher ambient air temperature (for example, category –5/B instead of –5/A, which is otherwise suitably designed);
– to employ capacitors with rated voltage higher than that laid down in Clause 29.

Capacitors installed at high altitude (more than 2 000 m) will be subjected to decreased heat dissipation, which shall be considered when determining the output of the units (see item e), Clause 31).

30.3 High ambient air temperature

Symbol C capacitors are suitable for the majority of applications under tropical conditions. In some locations, however, the ambient temperature may be such that a symbol D capacitor is required. The latter may also be needed for those cases where the capacitors are frequently subjected to the radiation of the sun for several hours (for example in desert areas), even though the ambient temperature is not excessive (see 30.2).

In exceptional cases, the maximum ambient temperature may be higher than 55 °C, or the daily average higher than 45 °C. Where it is impossible to increase the cooling conditions, capacitors of special design shall be used.

30.4 Evaluation of losses

If losses are to be evaluated, all accessories producing losses, such as external fuses, reactors, etc., shall be included in the calculation of total bank losses.

31 Special service conditions

Apart from the conditions prevailing at both limits of the temperature category (see 30.1), the most important conditions, which the manufacturer shall be informed about, are the following:

a) *High relative humidity*

It may be necessary to use insulators of special design. Attention is drawn to the possibility of external fuses being shunted by a deposit of moisture on their surfaces.

b) *Rapid mould growth*

Mould growth does not develop on metals, ceramic materials and some kinds of paints and lacquers. For other materials, mould growth may develop in humid places, especially where dust, etc., can settle.

The use of fungicidal products may improve the behaviour of these materials, but such products do not retain their poisoning property for more than a certain period.

c) *Corrosive atmosphere*

Corrosive atmosphere is found in industrial and coastal areas. It should be noted that in climates of higher temperature the effects of such atmospheres may be more severe than in temperate climates. Highly corrosive atmosphere may be present even in indoor installations.

d) *Pollution*

When capacitors are mounted in a location with a high degree of pollution, special precautions shall be taken.

e) *Altitude exceeding 2 000 m*

Capacitors used at altitudes exceeding 2 000 m are subject to special conditions. The choice of the type should be made by agreement between purchaser and manufacturer.

32 Overvoltages

Clause 20 specifies overvoltage factors.

With the manufacturer's agreement, the overvoltage factor may be increased if the estimated number of overvoltages is lower, or if the temperature conditions are less severe. These power frequency overvoltage limits are valid, provided that transient overvoltages are not superposed on them. The peak voltage shall not exceed $\sqrt{2}$ times the given r.m.s. value.

Capacitors that are liable to be subjected to high overvoltages due to lightning should be adequately protected. If lightning arresters are used, they should be located as near as possible to the capacitors.

Special arresters may be required to take care of the discharge current from the capacitor, especially from large banks.

When a capacitor is permanently connected to a motor, difficulties may arise after disconnecting the motor from the supply. The motor, while still revolving, may act as a generator by self-excitation and may give rise to voltages considerably in excess of the system voltage.

This, however, can usually be prevented by ensuring that the capacitor current is less than the magnetizing current of the motor; a value of about 90 % is suggested. As a precaution, live parts of a motor to which a capacitor is permanently connected should not be touched before the motor stops.

NOTE 1 The maintained voltage due to self-excitation after the machine is switched off is particularly dangerous for induction generators and for motors with a braking system intended to be operated by loss of voltage (for example lift motors).

NOTE 2 In the case where the motor stops immediately after having been disconnected from the supply, the compensation may exceed 90 %.

When a capacitor is connected to a motor associated with a star-delta starter, the arrangement should be such that no overvoltage can occur during the operation of the starter.

33 Overload currents

Capacitors should never be operated with currents exceeding the maximum value specified in Clause 21.

Overload currents may be caused either by excessive voltage at the fundamental frequency, or by harmonics, or both. The chief sources of harmonics are rectifiers, power electronics, and saturated transformer cores.

If the voltage rise at times of light load is increased by capacitors, the saturation of transformer cores may be considerable. In this case, harmonics of abnormal magnitude are produced, one of which may be amplified by resonance between the transformer and capacitor. This is a further reason for recommending the disconnection of capacitors at times of light load, as referred to in item b), Clause 29.

If the capacitor current exceeds the maximum value specified in Clause 21, while the voltage is within the permissible limit of 1,10 U_N specified in Clause 20, the predominant harmonic should be determined in order to find the best remedy.

The following remedies should be considered:

a) moving some or all of the capacitors to other parts of the system;
b) connection of a reactor in series with the capacitor, to lower the resonant frequency of the circuit to a value below that of the disturbing harmonic;
c) increase of the capacitance value when the capacitor is connected close to power semiconductors.

The voltage waveform and the network characteristics should be determined before and after installing the capacitor. When sources of harmonics such as large semiconductors are present, special care should be taken.

Transient overcurrents of high amplitude and frequency may occur when capacitors are switched into circuit. Such transient effects are to be expected when a section of a capacitor bank is switched in parallel with other sections that are already energized (see Annex B).

It may be necessary to reduce these transient overcurrents to acceptable values in relation to the capacitor and to the equipment by switching on the capacitors through a resistor (resistance switching), or by the insertion of reactors in the supply circuit to each section of the bank.

If the capacitors are provided with fuses, the peak value of the overcurrents due to switching operations shall be limited to a maximum of 100 I_N (r.m.s. value).

34 Switching and protective devices and connections

The switching and protective devices and the connections shall be designed to carry continuously a current of 1,3 times the current that would be obtained with a sinusoidal voltage of an r.m.s. value equal to the rated voltage at the rated frequency. As the capacitor may have a capacitance equal to 1,1 times the value corresponding to its rated output (see 7.2), this current may have a maximum value of $1,3 \times 1,1$ times the rated current.

Moreover, harmonic components, if present, may have a greater heating effect than the corresponding fundamental component, due to skin effect.

The switching and protective devices and the connections shall be capable of withstanding the electrodynamic and thermal stresses caused by the transient overcurrents of high amplitude and frequency that may occur when switching on.

Such transients are to be expected when a capacitor (unit or bank) is switched in parallel with other capacitor(s) that are already energized. It is common practice to increase the inductance of the connections in order to reduce the switching current, although this increases the total losses. Care should be taken not to exceed the maximum permissible switching current.

When consideration of the electrodynamic and thermal stresses would lead to excessive dimensions, special precautions, such as those mentioned in Clause 33 for the purpose of protection against overcurrents, should be taken.

In certain cases, for example when the capacitors are automatically controlled, repeated switching operations may occur at relatively short intervals of time. Switchgear and fuses should be selected to withstand these conditions (see Clause 22).

Breakers connected to the same busbar which is also connected to a bank of capacitors may be subjected to special stress in the event of switching on a short-circuit.

Breakers for switching of parallel banks shall be able to withstand the inrush current (amplitude and frequency) resulting when one bank is connected to a busbar to which other bank(s) are already connected.

It is recommended that capacitors be protected against overcurrent by means of suitable overcurrent relays, which are adjusted to operate the circuit-breakers when the current exceeds the permissible limit specified in Clause 21. Fuses do not generally provide suitable overcurrent protection.

Depending on the design of the capacitors, their capacitance will vary more or less with temperature.

Attention should be paid to the fact that the capacitance may change rapidly after the energization of cold capacitors. This may cause needless functioning of the protective equipment.

If iron-cored reactors are used, attention should be paid to possible saturation and overheating of the core by harmonics.

Any bad contacts in capacitor circuits may give rise to arcing, causing high-frequency oscillations that may overheat and overstress the capacitors. Regular inspection of all capacitor equipment contacts is therefore recommended.

35 Choice of creepage distance

No requirement at present.

36 Capacitors connected to systems with audio-frequency remote control

The impedance of capacitors at audio-frequencies is very low. When they are connected to systems having audio-frequency remote control, overloading of the remote control transmitter and unsatisfactory working may, therefore, result.

There are various methods of avoiding these deficiencies. The choice of the best method should be made by agreement between all parties concerned.

37 Electromagnetic compatibility (EMC)

37.1 Emission

Under normal service conditions, power capacitors according to this standard do not produce any electromagnetic disturbances. Therefore, the requirements for electromagnetic emissions are deemed to be satisfied, and no verification by test is necessary.

Self-healing breakdowns are considered to create no electromagnetic emission because their effect is short-circuited by the parallel capacitance.

Due to the decreasing impedance of capacitors with frequency, measures should be taken to avoid inadmissible influence on ripple control systems.

When using capacitors and inductances in a network which is loaded with harmonic voltages or currents, care should be taken because the harmonics may be amplified.

37.2 Immunity

37.2.1 General

Power capacitors are provided for an EMC environment in residential, commercial, and light-industrial locations (being supplied directly at low voltage from the public mains) as well as in industrial locations (being part of a non-public low voltage industrial network).

Under normal service conditions, the following immunity requirements and tests are considered to be relevant:

37.2.2 Low-frequency disturbances

Capacitors shall be suitable for continuous operation in the presence of harmonics and interharmonics within the limits required in Clauses 2 and 3 of IEC 61000-2-2. A verification by test is not necessary.

NOTE To stay within the requirements of Clauses 20 and 21, it is common to use inductances in series with the capacitors.

37.2.3 Conducted transients and high-frequency disturbances

The high capacitance of power capacitors absorbs conducted transients and high-frequency disturbances without harmful effect. A severity level not exceeding level 3, as per IEC 61000-4-1, is deemed to be fulfilled and a verification by test is not necessary.

37.2.4 Electrostatic discharges

Power capacitors are not sensitive to electrostatic discharges. A severity level not exceeding level 3, as per IEC 61000-4-1, is deemed to be fulfilled and a verification by test is not necessary.

37.2.5 Magnetic disturbances

Power capacitors are not sensitive to magnetic disturbances. A severity level not exceeding level 3, as per IEC 61000-4-1, is deemed to be fulfilled and a verification by test is not necessary.

37.2.6 Electromagnetic disturbances

Power capacitors are not sensitive to electromagnetic disturbances. A severity level not exceeding level 3, as per IEC 61000-4-1, is deemed to be fulfilled and a verification by test is not necessary.

Annex A
(normative)

Additional definitions, requirements and tests for power filter capacitors

When the following clauses are added to the text of this standard, the standard will apply to filter capacitors (see Clause 1).

A.1 Terms and definitions

A.1.1
band-pass and high-pass filter capacitor
filter capacitor
capacitor (or capacitor bank) that, when connected with other components, such as reactor(s) and resistor(s), gives a low impedance for one or more harmonic currents

A.1.2
rated voltage (see 3.14)
U_N
arithmetic sum of the r.m.s. voltages arising from the fundamental and harmonic frequencies

A.1.3
rated output (see 3.13)
Q_N
arithmetic sum of output generated by the fundamental frequency and by the harmonics

A.1.4
rated current (see 3.16)
I_N
square root of the sum of the squared values of the rated currents at the fundamental and harmonic frequencies

Note 1 to entry: For accessories such as busbars, etc., the r.m.s. value for all currents should be considered.

A.2 Quality requirements and tests

A.2.1 Capacitance tolerance

For filter capacitors, especially for band-pass filters, symmetrical tolerances are recommended for both units and banks.

Standard units have non-symmetrical tolerance bands (see 7.2). This fact shall be taken into account when determining the capacitance value and tolerances.

When determining the bank tolerances in a filter capacitor, the following factors should be considered:

– tolerances of the associated equipment, especially the reactor(s);
– fundamental frequency variations in the network to which the filter capacitor is connected;
– capacitance variation due to ambient temperature and load;
– the allowed capacitance variation for short periods during, for example, warming up, or unusual service conditions;
– capacitance variation due to an internal protection operation, if any.

A.2.2 Voltage test between terminals (see Clause 9)

AC test.

For filter capacitors:

$$U_t = 2,15\ U_N$$

where

U_N is the rated voltage defined for the filter capacitors.

A.2.3 Thermal stability test (see Clause 13)

If for filter capacitors 1,44 Q_N is lower than the output determined for 1,1 U_N at fundamental frequency, the latter test voltage shall be used in the thermal stability test.

A.3 Overloads – Maximum permissible current (see Clause 21)

For filter capacitors, the maximum permissible current shall be agreed between purchaser and manufacturer.

A.4 Markings – Instruction sheet or rating plate (see 27.1)

For filter capacitors, the tuned harmonic frequency shall preferably be marked after the rated frequency, for example:

50 Hz + 250 Hz (narrow band-pass filter)

50 Hz + 550/650 Hz (broad band-pass filter)

50 Hz + ≥ 750 Hz (high-pass filter).

A.5 Guide for installation and operation – Choice of the rated voltage (see Clause 29)

A reactor in series with the filter capacitor will cause voltage rise on the capacitor terminals at the fundamental frequency voltage.

Annex B
(informative)

Formulae for capacitors and installations

B.1 Computation of the output of three-phase capacitors from three single-phase capacitance measurements

The capacitances measured between any two-line terminals of a three-phase capacitor of either delta or star connection are denoted as C_a, C_b, and C_c. If the symmetry requirements laid down in 7.2 are fulfilled, the output Q of the capacitor can be computed with sufficient accuracy from the formula:

$$Q = \frac{2}{3}\left(C_a + C_b + C_c\right)\omega U_N{}^2 \times 10^{-12}$$

where

C_a, C_b and C_c are expressed in microfarads (μF);

U_N is expressed in volts (V);

Q is expressed in megavars (Mvar).

B.2 Resonance frequency

A capacitor will be in resonance with a harmonic in accordance with the following equation in which n is an integer:

$$n = \sqrt{\frac{S}{Q}}$$

where

S is the short-circuit power (MVA) where the capacitor is to be installed;

Q is expressed in megavars (Mvar);

n is the harmonic number: that is, the ratio between the resonant harmonic (Hz) and the network frequency (Hz).

B.3 Voltage rise

Connection of a shunt capacitor will cause the steady-state voltage rise given by the following expression:

$$\frac{\Delta U}{U} \approx \frac{Q}{S}$$

where

ΔU is the voltage rise in volts (V);

U is the voltage before connection of the capacitor (V);

S is the short-circuit power (MVA) where the capacitor is to be installed;

Q is expressed in megavars (Mvar).

B.4 Inrush transient current

B.4.1 Switching in of single capacitor

$$\hat{I}_S \approx I_N \sqrt{\frac{2S}{Q}}$$

where

$\hat{I}_S$ is the peak of inrush capacitor current in amperes (A);

I_N is the rated capacitor current (r.m.s.) in amperes (A);

S is the short-circuit power (MVA) where the capacitor is to be installed;

Q is expressed in megavars (Mvar).

B.4.2 Switching of capacitors in parallel with energized capacitor(s)

$$\hat{I}_S = \frac{U\sqrt{2}}{\sqrt{X_C X_L}}$$

$$f_S = f_N \sqrt{\frac{X_C}{X_L}}$$

where

$\hat{I}_S$ is the peak of inrush capacitor current in amperes (A);

U is the phase-to-earth voltage in volts (V);

X_C is the series-connected capacitive reactances per phase in ohms (Ω);

X_L is the inductive reactance per phase between the banks in ohms (Ω);

f_S is the frequency of the inrush current in hertz (Hz);

f_N is the rated frequency in hertz (Hz).

B.4.3 Discharge resistance in single-phase units or in one-phase or polyphase units

$$R \leq \frac{t}{k \times C \times \ln\left(\frac{U_N \sqrt{2}}{U_R}\right)}$$

where

t is the time for discharge from $U_N \sqrt{2}$ to U_R in seconds (s);

R equals discharge resistance in megohms (MΩ)

C is the rated capacitance in microfarads (μF) per phase;

U_N is the rated voltage of unit in volts (V);

U_R is the permissible residual voltage in volts (V) (see Clause 22 for limits of t and U_R);

k is the coefficient depending on the method of connection of the resistors to the capacitor units (see Figure B.1).

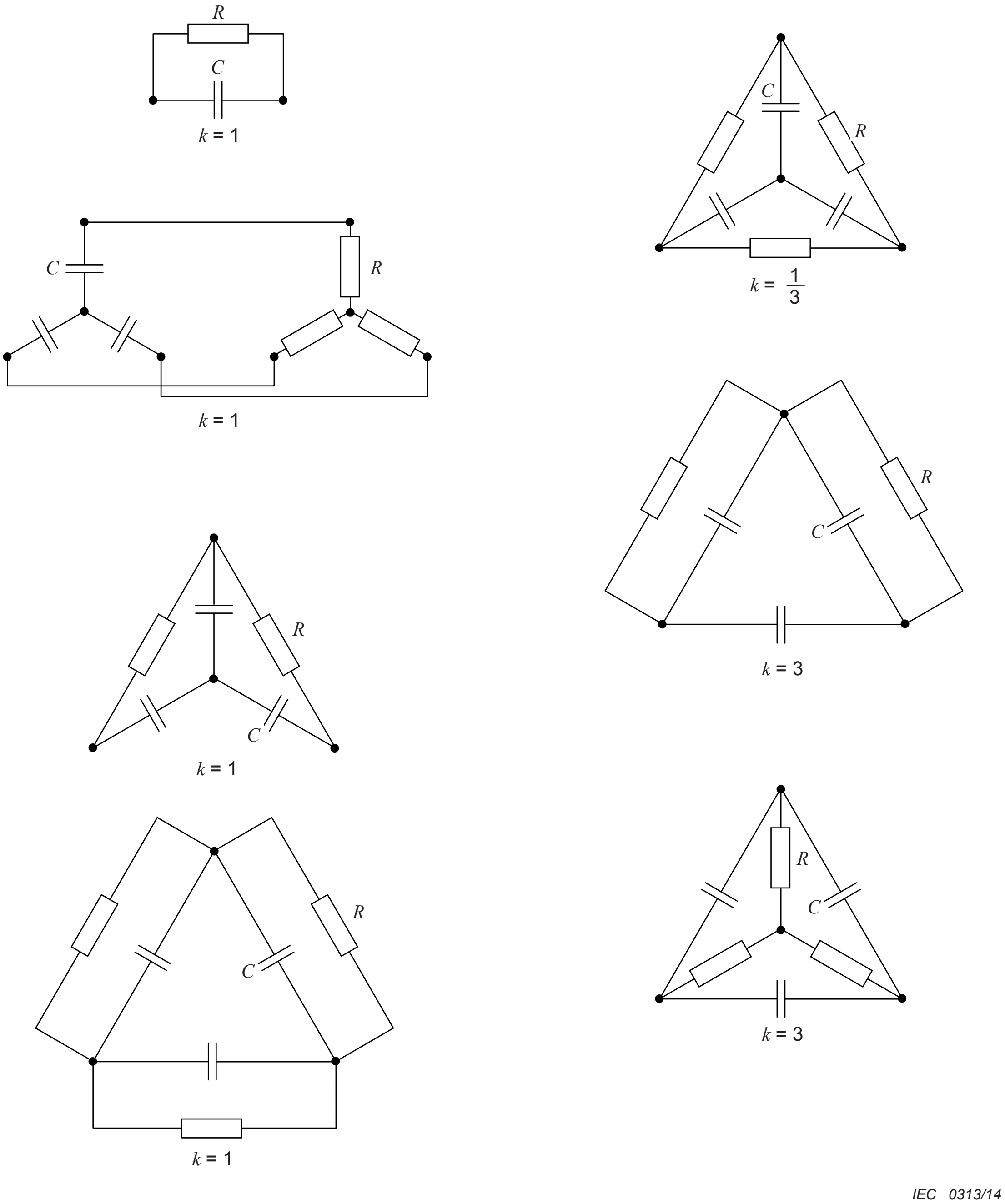


Figure B.1 – *k* values depending on the method of connection of the resistors with the capacitor units

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