

Capacitors for power electronics

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National foreword

This British Standard is the UK implementation of EN 61071:2007. It is identical to IEC 61071:2007. It supersedes BS EN 61071-1:1997 and BS EN 61071-2:1996, which are withdrawn.

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

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Foreword

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Endorsement notice

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CAPACITORS FOR POWER ELECTRONICS

1 Scope

This International Standard applies to capacitors for power electronics applications.

The operating frequency of the systems in which these capacitors are used is usually up to 15kHz, while the pulse frequencies may be up to 5 to 10 times the operating frequency.

The standard distinguishes between a.c. and d.c. capacitors which are considered as components when mounted in enclosures.

This standard covers an extremely wide range of capacitor technologies for numerous applications, e.g. overvoltage protection, d.c. and a.c. filtering, switching circuits, d.c. energy storage, auxiliary inverters, etc.

The following are excluded from this standard:

- capacitors for induction heat-generating plants operating at frequencies between 40 Hz and 24 000 Hz (see IEC 60110-1 and IEC 60110-2);
- capacitors for motor applications and the like (see IEC 60252-1 and IEC 60252 -2);
- capacitors to be used in circuits for blocking one or more harmonics in power supply networks;
- small a.c. capacitors as used for fluorescent and discharge lamps (see IEC 61048 and IEC 61049);
- capacitors for suppression of radio interference (see IEC 60384-14);
- shunt capacitors for a.c. power systems having a rated voltage above 1 000 V (see IEC 60871-1 and IEC 60871-2);
- shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1 000 V (see IEC 60831-1 and IEC 60831-2);
- shunt power capacitor of the non-self-healing type for a.c. systems having a rated voltage up to and including 1 000 V (see IEC 60931-1 and IEC 60931-2);
- electronic capacitors not used in power circuits;
- series capacitors for power systems (see IEC 60143);
- coupling capacitors and capacitors dividers (see IEC 60358);
- capacitors for microwave ovens (see IEC 61270-1);
- capacitors for railway applications (see IEC 61881).

Examples of applications are given in Clause 9.1.

2 Normative references

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

IEC 60068-2-6, *Environmental testing – Part 2: Tests. Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14, *Environmental testing – Part 2: Tests. Test N: Change of temperature*

IEC 60068-2-20, *Environmental testing – Part 2: Tests. Test T: Soldering*

IEC 60068-2-21, *Environmental testing – Part 2: Tests. Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-78, *Environmental testing – Part 2: Tests. Test Cab: Damp heat, steady state*

IEC 60071-1, *Insulation coordination – Part 1: Definitions, principle and rules*

IEC 60071-2, *Insulation coordination – Part 2: Application guide*

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

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60695-2-11, *Fire hazard testing – Part 2-11: Glowing/hotwire based test methods, Glow-wire flammability test method for end-products*

IEC 60695-2-12, *Fire hazard testing – Part 2-12: Glowing/hotwire based test methods, Glow-wire flammability test method for materials*

IEC 60947-1, *Low-voltage switchgear and controlgear – Part 1: General rules*

3 Terms and definitions

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

3.1

capacitor element (or element)

a device consisting essentially of two electrodes separated by a dielectric

[IEV 436-01-03]

3.2

capacitor unit (or unit)

assembly of one or more capacitor elements in the same container with terminals brought out

[IEV 436-01-04]

3.3

capacitor bank

number of capacitor units connected so as to act together

[IEV 436-01-06]

3.4

capacitor

general term used when it is not necessary to state whether reference is made to an element, a unit or a capacitor bank

3.5

capacitor equipment

assembly of capacitor units and their accessories intended for connection in power electronic equipment

3.6

capacitor for power electronics

power capacitor intended to be used in power electronic equipment and capable of operating continuously under sinusoidal and non-sinusoidal current and voltage

3.7

metal-foil capacitor (non-self-healing)

capacitor in which the electrodes usually consist of metal foils separated by a dielectric

NOTE In the event of a breakdown of the dielectric, the capacitor does not restore itself.

3.8

self-healing metallized dielectric capacitor

capacitor, of which at least one electrode consists of a metallic deposit on the dielectric

NOTE In the event of local breakdown of the dielectric, the electric properties of the capacitor are rapidly and essentially self-restored.

3.9

a.c. capacitor

capacitor essentially designed for operation with alternating voltage

NOTE AC capacitors may be used with d.c. voltage up to the rated voltage only when authorized by the capacitor manufacturer.

3.10

d.c. capacitor

capacitor essentially designed for operation with direct voltage

NOTE DC capacitors may be used with a specified a.c. voltage only where authorized by the capacitor manufacturer.

3.11

model capacitor

unit which simulates a complete unit or element in an electrical test, without reducing the severity of the electrical, thermal or mechanical conditions

NOTE 1 The model unit may be of a different size from the complete unit.

NOTE 2 The combined sum of stresses should always be considered, for instance the sum of temperature and mechanical conditions as well as electrical stresses.

3.12

internal (element) fuse

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

[IEV 436-03-16]

3.13 safety devices

3.13.1

overpressure disconnecter

disconnecting device inside a capacitor, designed to interrupt the current path in case of abnormal increase of internal overpressure

3.13.2

overpressure detector

device designed to detect abnormal increase of the internal pressure, usually used to operate an electrical switch and indirectly interrupt the current path

3.13.3

segmented metallization design

design of the metal layer over the dielectric shaped in a way to allow a small part of it to be isolated in case of local short circuit or breakdown, in order to restore the full functionality of the unit with a negligible loss of capacitance

3.13.4

special unsegmented metallization design

design of the metal layer over the dielectric shaped in a way that safe self-healing features operating at a voltage up to U_s guarantee the full functionality of the unit with a negligible loss of capacitance.

3.14

discharge device of a capacitor

a 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

[IEV 436-03-15 modified]

3.15

rated a.c. voltage

U_N

maximum operating peak recurrent voltage of either polarity of a reversing type waveform for which the capacitor has been designed

NOTE 1 The waveform can have many shapes. Examples are given in Annex A.

NOTE 2 The mean value of the waveform may be positive or negative.

NOTE 3 It is important to note that the rated a.c. voltage is not an r.m.s. value.

3.16

rated d.c. voltage

U_{NDC}

maximum operating peak voltage of either polarity but of a non-reversing type waveform, for which the capacitor has been designed, for continuous operation

NOTE 1 Damping capacitors, for gate turn-off thyristor (GTO) can be regarded as d.c. capacitors with a ripple voltage equal to the rated d.c. voltage $U_{NDC} = U_r$.

In the case of reversal voltage (U_{rev}), the use should be agreed between user and manufacturer.

NOTE 2 If the reversal voltage is small (less than 10 %), the voltage waveform can be considered to be non-reversing. For test purposes, U_{NDC} and U_r should be increased by U_{rev} , the reversal voltage.

3.17

ripple voltage

U_r

peak-to-peak alternating component of the unidirectional voltage

3.18

non-recurrent surge voltage

U_s

peak voltage induced by a switching or any other disturbance of the system which is allowed for a limited number of times and for durations shorter than the basic period

3.19

insulation voltage

U_i

r.m.s. value of the sine wave voltage designed for the insulation between terminals of capacitors to case or earth

3.20

maximum peak current

$\hat{I}$

maximum repetitive peak current that can occur during continuous operation

3.21

maximum current

$I_{\max}$

maximum r.m.s. current for continuous operation

3.22

maximum surge current

$\hat{I}_s$

peak non-repetitive current induced by switching or any other disturbance of the system which is allowed for a limited number of times, for durations shorter than the basic period

3.23

pulse frequency

f_p

repetition rate of periodic current pulses

3.24

current pulse width

τ

time of current flow during charging or discharging from one voltage value to another, of the capacitor

NOTE Pulse current waveform examples are shown in Annex A.

3.25

resonance frequency

f_r

lowest frequency at which the impedance of the capacitor becomes minimum

3.26

duty cycle

3.26.1

continuous duty

operation time such that a capacitor is at thermal equilibrium for most of the time

3.26.2

intermittent duty

discontinuous working or operation with variable loads which should be described in terms of ON/OFF or HIGH/LOW periods with their durations

3.27**highest operating temperature**

temperature of the hottest point on the case of the capacitor when in thermal equilibrium

3.28**lowest operating temperature** $\theta_{\min}$

lowest temperature of the dielectric at which the capacitor may be energized

3.29**container temperature rise** $\Delta\theta_{\text{case}}$

difference between the temperature of the hottest point of the container and the temperature of the cooling air

3.30**cooling-air temperature** θ_{amb}

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

NOTE 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.

3.30.1**outlet fluid temperature for forced-cooled capacitors**

temperature of the cooling fluid as it leaves the capacitor, measured at the hottest point

3.30.2**inlet fluid temperature for forced-cooled capacitors**

temperature of the cooling fluid measured in the middle of the inlet fluid channel at a point not influenced by the heat dissipation of the capacitor

3.31**maximum operating temperature** $\theta_{\max}$

highest temperature of the case at which the capacitor may be operated

3.32**steady-state conditions**

thermal equilibrium attained by the capacitor at constant output and at constant cooling-air temperature

3.33**capacitor losses**

active power dissipated in the capacitor

[IEV 436-04-10]

NOTE Unless otherwise stated, the capacitor losses are understood to include losses in fuses and discharge resistors forming an integral part of the capacitor. At high frequency, the capacitor losses are predominantly due to losses in connections, contacts and electrodes.

3.34**tangent of the loss angle of a capacitor** $\tan \delta$

ratio between the equivalent series resistance and the capacitive reactance of a capacitor at a specified sinusoidal alternating voltage, frequency and temperature

[IEV 436-04-11]

$$\tan \delta = R_{\text{esr}} \omega C = \tan \delta + R_s \omega C$$

$\tan \delta$ = dielectric loss factor

3.35

equivalent series resistance of a capacitor

R_{esr}

effective resistance which, if connected in series with an ideal capacitor of capacitance value equal to that of the capacitor in question, would have a power loss equal to active power dissipated in that capacitor under specified operating conditions

3.36

series resistance

R_s

effective ohmic resistance of the conductors of a capacitor under specified operating conditions

3.37

maximum power loss

P_{max}

maximum power loss at which the capacitor may be operated at the maximum case temperature

3.38

maximum frequency for maximum power loss and maximum current

f_2

frequency at which the maximum current (I_{max}) produces the maximum power loss (P_{max}) in the capacitor

NOTE For explanation of f_2 , see Annexe B.

4 Service conditions

4.1 Normal service conditions

This standard gives requirements for capacitors intended for use in the following conditions.

4.1.1 Altitude

Altitude shall not exceed 1 000 m unless the effects on cooling and external insulation are taken into account.

NOTE The effect of altitude on convection cooling and external insulation should be taken into consideration, if the altitude exceeds 1 000 m.

4.1.2 Operating temperature (θ_{max})

The upper limit of the case temperature θ_{max} at which the capacitor may be operated, shall normally be chosen from the values 45 °C, 55 °C, 70 °C and 85 °C. A different maximum operating temperature shall be subject to agreement between manufacturer and user.

4.1.3 Operating temperature with forced cooling

If capacitors are intended for use with forced cooling using a fluid medium, the operating temperature conditions specified in 4.1.2 shall be observed.

The lowest inlet temperature for the cooling fluid should be defined, taking into account the viscosity of the fluid.

There are two methods for specifying the upper temperature limit of the cooling medium, using either the inlet or the outlet cooling fluid temperature.

Unless otherwise agreed, the choice of method shall be left to the capacitor manufacturer.

For the inlet method, the flow of cooling medium shall be specified.

4.2 Unusual service conditions

This standard does not apply to capacitors, whose service conditions are such as to be in general incompatible with its requirements, unless otherwise agreed between the manufacturer and the user.

Unusual service conditions require additional measurements, which ensure that the conditions of this standard are complied with even under such unusual service conditions.

If such unusual service conditions exist then they must be notified to the manufacturer of the capacitor.

Unusual service conditions can include:

- unusual mechanical shocks and vibrations.
- cooling water with corrosive or obstructing particles (sea water, very hard water).
- corrosive and abrasive particles in the cooling air.
- dust in the cooling air, particularly if conductive.
- explosive dust or gas.
- oil or water vapour or corrosive substances.
- nuclear radiation.
- unusual storage or transport temperature.
- unusual humidity (tropical or subtropical region).
- excessive and rapid changes of temperature (more than 5 °C/h) or of humidity (more than 5 %/h).
- service areas higher than 1 000 m above sea level.
- superimposed electromagnetic fields.
- excessive overvoltages, as far as they exceed the limits given in Clause 6.

5 Quality requirements and tests

5.1 Test requirements

5.1.1 General

This subclause gives the test requirements for capacitor units.

5.1.2 Test conditions

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

If corrections are necessary, the reference temperature shall be +20 °C, unless otherwise agreed between the manufacturer and the user.

NOTE It is assumed that the dielectric temperature is the same as the ambient temperature, provided that the capacitor has been left in an unenergized state, in a constant ambient temperature, for an adequate period of time in order to reach thermal equilibrium.

The a.c. tests and measurements shall be carried out with a substantially sinusoidal voltage at a frequency specified by the manufacturer.

5.2 Classification of tests

The tests are classified as routine tests and type tests.

5.2.1 Routine tests

- a) Sealing test (5.8).
- b) External inspection (5.14.2).
- c) Voltage test between terminals (5.5.2).
- d) Voltage test between terminals and case (5.6.1).
- e) Capacitance and $\tan \delta$ measurements (5.3).
- f) Test of internal discharge device (5.7).

Routine tests shall be carried out by the manufacturer on every capacitor before delivery.

At his request, the user shall be supplied with a certificate detailing the results of such tests.

The sequence of the tests is as indicated above.

5.2.2 Type tests

- a) Mechanical tests (5.14).
- b) Voltage test between terminals (5.5.3).
- c) Voltage test between terminals and case (5.6.2).
- d) Surge discharge test (5.9).
- e) Self-healing test (5.11).
- f) Environmental testing (5.13).
- g) Measurement of the tangent of the loss angle ($\tan \delta$) (5.4).
- h) Thermal stability test (5.10).
- i) Test of internal discharge device (5.7).
- j) Resonance frequency measurement (5.12).
- k) Endurance test between terminals (5.15).
- l) Disconnection test on fuses (5.17).
- m) Destruction test (5.16).