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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Capacitors for power electronics

Condensateurs pour électronique de puissance

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CAPACITORS FOR POWER ELECTRONICS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61071 has been prepared by IEC technical committee 33: Power capacitors and their applications.

This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision.

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

- Introduction of new terms and definitions
- clarifications for surge discharge test
- indications for measuring procedure during thermal stability test
- clarifications for self-healing test
- clarifications for endurance test
- clarifications for destruction test
- update of normative references
- general editorial review

The text of this International Standard is based on the following documents:

FDIS	Report on voting
33/610/FDIS	33/612/RVD

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

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://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.

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 15 kHz, while the pulse frequencies may be up to 5 to 10 times the operating frequency.

The document distinguishes between AC and DC capacitors which are considered as components when mounted in enclosures.

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

The following are excluded from this document:

- capacitors for induction heat-generating plants operating at frequencies range up to 50 kHz (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 AC 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 AC power systems having a rated voltage above 1 000 V (see the IEC 60871 standards);
- shunt power capacitors of the self-healing type for AC 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 AC systems having a rated voltage up to and including 1 000 V (see the IEC 60931 standards);
- 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 9.1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 2-6: Tests – Test Fc: Vibration (sinusoidal)*

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

IEC 60068-2-20, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

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

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

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/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

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

IEC 60947-1:2007, *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.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

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

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

3.2
capacitor unit (or 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
capacitor bank
number of capacitor units connected so as to act together

[SOURCE: IEC 60050-436:1990, 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 1 to entry: 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 1 to entry: In the event of local breakdown of the dielectric, the electric properties of the capacitor are rapidly and essentially self-restored.

3.9
AC capacitor
capacitor essentially designed for operation with alternating voltage

Note 1 to entry: AC capacitors may be used with DC voltage up to the rated voltage only when authorized by the capacitor manufacturer.

3.10
DC capacitor
capacitor essentially designed for operation with direct voltage

Note 1 to entry: DC capacitors may be used with a specified AC 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 to entry: The model unit may be of a different size from the complete unit.

Note 2 to entry: 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

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

3.13
safety devices

3.13.1
overpressure disconnector
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
pattern 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 Us guarantee the full functionality of the unit with a negligible loss of capacitance.

3.14
safety protection
protected capacitor
capacitor that can be submitted to the destruction test as described at 5.16

Note 1 to entry: protected capacitors alone are not sufficient to prevent all possible dangers in case of malfunction.

3.15
unprotected capacitor
capacitor that don't meet the destruction test as described at 5.16

3.16
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 ("to a given value" replaced by "practically to zero")]

3.17
rated AC 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 to entry: The waveform can have many shapes. Examples are given in Annex A.

Note 2 to entry: The mean value of the waveform may be positive or negative.

Note 3 to entry: It is important to note that the rated AC voltage is not an r.m.s. value.

3.18
rated DC 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 to entry: Damping capacitors, for gate turn-off thyristor (GTO) can be regarded as DC capacitors with a ripple voltage equal to the rated DC voltage $U_{NDC} = U_r$.

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

Note 2 to entry: 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 Urev, the reversal voltage.

3.19
ripple voltage
U_r
peak-to-peak alternating component of the unidirectional voltage

3.20
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

3.21
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

3.22
maximum peak current
$\hat{I}$
maximum repetitive peak current that can occur during continuous operation

3.23
maximum current
I_{max}
maximum r.m.s. current for continuous operation

3.24
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

3.25
pulse frequency
f_p
repetition rate of periodic current pulses

3.26
current pulse width
τ
time of current flow during charging or discharging from one voltage value to another, of the capacitor

Note 1 to entry: Pulse current waveform examples are shown in Annex A.

3.27
resonance frequency
f_r
lowest frequency at which the impedance of the capacitor becomes minimum

3.28
duty cycle

3.28.1
continuous duty
operation time such that a capacitor is at thermal equilibrium for most of the time

3.28.2
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

3.29
thermal equilibrium
state of a capacitor when the temperature measured anywhere on its case or internally is less than 3K above or below that temperature which would be reached after waiting an infinitely long time under fixed conditions of ambient temperature, cooling, and internal power loss

3.30
thermal time constant
measure of the time required for a capacitor to reach thermal equilibrium after a change in ambient temperature, cooling, or internal power loss

3.31
lowest operating temperature
θ_{min}
lowest temperature of the dielectric at which the capacitor may be energized

3.32
container temperature rise
$\Delta\theta_{case}$
difference between the temperature of the hottest point of the container and the temperature of the cooling air

3.33
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 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.

3.33.1
outlet fluid temperature for forced-cooled capacitors
temperature of the cooling fluid as it leaves the capacitor, measured at the hottest point

3.33.2
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

3.34
maximum operating temperature
θ_{max}
highest temperature of the case at which the capacitor may be operated under steady state condition

3.35
hotspot temperature
the highest temperature present inside the capacitor dielectric

3.36
steady-state conditions
thermal equilibrium attained by the capacitor at constant output and at constant cooling conditions

3.37
capacitor losses
active power dissipated in the capacitor

Note 1 to entry: 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.

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

3.38
tangent of the loss angle of a capacitor
tan δ
ratio between the equivalent series resistance and the capacitive reactance of a capacitor at a specified sinusoidal alternating voltage, frequency and temperature

Note 1 to entry: $\tan\delta = R_{esr}\,\omega C = \tan\delta_d + R_s\,\omega C$

$\tan\delta_d$ = dielectric loss factor

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

3.39
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

3.40
series resistance
R_s
effective ohmic resistance of the conductors of a capacitor under specified operating conditions

3.41
maximum power loss
P_{max}
maximum power loss at which the capacitor may be operated at the maximum case temperature