

Railway applications — Rolling stock equipment — Capacitors for power electronics

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Summary of pages

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Bahnanwendungen
Betriebsmittel auf Bahnfahrzeugen
Kondensatoren für Leistungselektronik
(IEC 61881:1999)

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CENELEC

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Foreword

The text of document 9/522/FDIS, future edition 1 of IEC 61881, prepared by IEC TC 9, Electric railway equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61881 on 1999-10-01.

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- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2000-07-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2002-10-01

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given for information only. In this standard, annexes B, C and ZA are normative and annexes A and D are informative. Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61881:1999 was approved by CENELEC as a European Standard without any modification.

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

IEC 60146-1-1 NOTE Harmonized as EN 60146-1-1:1993 (not modified).

IEC 61071 NOTE Harmonized in the EN 61071 series (modified).

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RAILWAY APPLICATIONS – ROLLING STOCK EQUIPMENT – CAPACITORS FOR POWER ELECTRONICS

1 General

1.1 Scope and object

This International Standard applies to capacitors for power electronics intended to be used on rolling stock.

The rated voltage of capacitors covered by this part is limited to 10 000 V.

The operating frequency of the systems in which these capacitors are used is usually below 2 500 Hz, while the pulse frequencies may go up to several thousand hertz, in some cases beyond 10 000 Hz.

It distinguishes between a.c. and d.c. capacitors.

They are considered as components mounted in enclosures.

NOTE – This standard covers an extremely wide range of capacitor technologies for numerous applications: 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);
- capacitors for motor applications and the like (see IEC 60252);
- 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 (see IEC 60080 and IEC 60166);
- series capacitors for power systems (see IEC 60143);
- coupling capacitors and capacitors dividers (see IEC 60358);
- capacitors for applications requiring energy storage/high current discharge such as photocopies and lasers;
- capacitors for microwave ovens.

Examples are given in clause 6.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60068-2-3, *Environmental testing – Part 2: Tests. Test Ca: Damp heat, steady state*

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 60077-1, *Railway applications – Electrotechnical components – Part 1: General service conditions* ¹⁾

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

IEC 60721-3-5, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Ground vehicle installations*

IEC 61373, *Railway applications – Rolling stock equipment – Shock and vibration tests*

1.3 Definitions

For the purpose of this International Standard, the following definitions apply.

1.3.1

capacitor element (or element)

indivisible part of a capacitor consisting of two electrodes separated by a dielectric

1.3.2

capacitor unit (or unit)

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

1.3.3

capacitor bank

assembly of two or more capacitor units, electrically connected to each other

1.3.4

capacitor

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

¹⁾ To be published.

1.3.5

capacitor equipment

assembly of capacitor units and their accessories intended for connection to a network

1.3.6

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

1.3.7

metal-foil capacitor (non self-healing)

capacitor in which the electrodes usually consist of metal foils separated by a dielectric, in the event of a breakdown of the dielectric; the capacitor does not restore itself

1.3.8

self-healing metallized dielectric capacitor

capacitor, the electrodes of which are metallized (usually by evaporation); in the event of dielectric breakdown, the capacitor restores itself

1.3.9

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.

1.3.10

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.

1.3.11

model capacitor

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

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

1.3.12

internal (element) fuse

device incorporated in the capacitor which disconnects an element or a group of elements in the event of breakdown

1.3.13

overpressure devices

1.3.13.1

overpressure disconnecter

disconnecting device inside a capacitor, designed to interrupt the current path in case of capacitor failure

1.3.13.2

overpressure detector

device designed to detect abnormal increase of the internal pressure by an electrical switch/signal and indirectly interrupt the current path

1.3.14

internal discharge device

device incorporated in the capacitor connected between the terminals of the unit, capable of reducing the residual voltage effectively to zero after the capacitor has been disconnected from the supply

1.3.15

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.

NOTE 4 – Definitions used in this standard can be different from those of IEC 60077-1.

1.3.16

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

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, the use should be agreed between purchaser and manufacturer.

NOTE – If the reversal voltage is small (less than 10 %), the voltage waveform can be considered to be not reversing. For test purposes, U_{NDC} and U_r should be increased by U , the reversal voltage.

1.3.17

ripple voltage (U_r)

peak-to-peak alternating component of the unidirectional voltage

1.3.18

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

1.3.19

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. If not specified, the r.m.s. value of the insulating voltage is equivalent to the rated voltage divided by $\sqrt{2}$

1.3.20

maximum peak current ($\hat{I}$)

maximum peak current that can occur during continuous operation

1.3.21

maximum current ($I_{\max}$)

maximum r.m.s. current for continuous operation

1.3.22

maximum surge current (I_s)

admissible peak current induced by switching or any other disturbance of the system which is allowed for a limited number of times

1.3.23

pulse frequency (f_p)

repetition rate of periodic current pulses

1.3.24

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.

1.3.25

resonance frequency (f_r)

lowest frequency at which the impedance of the capacitor becomes minimum

1.3.26

duty cycle

1.3.26.1

continuous duty

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

1.3.26.2

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

1.3.27

operating temperature

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

1.3.28

lowest operating temperature ($\theta_{\min}$)

lowest temperature at which the capacitor may be energized

1.3.29

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

1.3.30

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

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.

1.3.31

maximum operating temperature ($\theta_{\max}$)

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

1.3.32

steady-state conditions

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

1.3.33

capacitor losses

active power consumed by a capacitor

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.

1.3.34

tangent of the loss angle ($\tan \delta$) of a capacitor

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

1.3.35

equivalent series resistance of a capacitor

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

1.3.36

maximum power loss ($P_{\max}$)

maximum power loss with which the capacitor may be loaded at the maximum case temperature

1.3.37

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

1.4 Service conditions

NOTE – See IEC 60077-1.

1.4.1 Normal service conditions

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

1.4.1.1 Altitude

Not exceeding 1 200 m.

NOTE – The effect of altitude on convection cooling and external insulation should be taken into consideration, if the altitude exceeds 1 200 m.

1.4.1.2 Temperature

The climatic ambient temperatures are derived from IEC 60721-3-5 class 5k2 which has a range from $-25\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$.

Where ambient temperature lies outside this range, it shall be agreed between the user and the manufacturer.

The upper limit of case temperature $\theta_{\max}$ at which the capacitor may be operated, shall be chosen among the values 55 °C, 70 °C and 85 °C.

1.4.1.3 Operating temperature with forced ventilation

If capacitors are intended for forced cooling with a fluid medium, the operating temperature conditions specified in 1.4.1.2 shall be observed.

The following table 1 of preferred temperatures of cooling fluid shall be applied.

Table 1 – Maximum temperature of cooling medium for unlimited time

Inlet temperature °C	Outlet temperature °C
35	40
45	50
55	60

The lowest inlet temperature for the cooling fluid may be –25 °C.

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

1.4.2 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 purchaser.

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

2 Quality requirements and tests

2.1 Test requirements

2.1.1 General

This subclause gives the test requirements for capacitor units.

2.1.2 Test conditions

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

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

NOTE – 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, 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 sinusoidal voltage of 50 Hz or 60 Hz, unless otherwise specified.

2.2 Classification of tests

The test are classified as follows:

2.2.1 Routine tests

Routine tests are the following:

- a) external inspection (2.14.2);
- b) voltage test between terminals (2.5.2);
- c) voltage test between terminals and case (2.6.1);
- d) capacitance and $\tan \delta$ measurements (2.3);
- e) test of internal discharge device (2.7);
- f) sealing test (2.8).

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

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

The sequence of the tests is as indicated.

2.2.2 Type tests

Unless otherwise specified, every capacitor sample to which it is intended to apply the type test shall first have withstood satisfactorily the application of all the routine tests. Type tests are the following:

- a) mechanical tests (2.14);
- b) voltage test between terminals (2.5.3);
- c) voltage test between terminals and case (2.6.2);
- d) surge discharge test (2.9);

- e) self-healing test (2.11);
- f) environmental testing (2.13); mechanical testing (2.14);
- g) capacitor tangent of the loss angle ($\tan \delta$) measurement (2.4);
- h) thermal stability test (2.10);
- i) test of internal discharge device (2.7);
- j) resonance frequency measurement (2.12);
- k) endurance test between terminals (2.15);
- l) disconnection test on fuses (2.17);
- m) destruction test (2.16).

Type tests are intended to prove the soundness of the design of the capacitor and its suitability for operation under the considerations detailed in this standard.

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

These tests shall be made upon a capacitor of a design identical to that of the capacitor under contract, or on a capacitor of a design that gives during the test the same or more severe test conditions.

It is not essential that all type tests be carried out on the same capacitor sample.

2.2.3 Acceptance tests

The routine and/or type test, or some of them, may be carried out by the manufacturer, on agreement with the purchaser.

The number of samples that may be subjected to such repeat tests, the acceptance criteria, as well as permission to deliver any of these units shall be subject to agreement between the manufacturer and the purchaser, and shall be stated in the contract.

2.3 Capacitance and $\tan \delta$ measurements (routine test)

2.3.1 Measuring procedure

The capacitance and $\tan \delta$ shall be measured at a voltage and at a 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 shall be given and shall be better than 0,2 % for capacitance and 10 % for $\tan \delta$ but not necessarily better than 1×10^{-4} if the measurement is made at 50-60 Hz.

The capacitance measurement shall be carried out after the voltage test between terminals (see 2.5).

For capacitors with internal fuses, capacitance measurement shall also be made before the voltage tests.