IEC 62146-1

Edition 2.0 2026-07

INTERNATIONAL STANDARD

REDLINE VERSION

~~Grading~~ Capacitors for high-voltage alternating current circuit-breakers - Part 1: General and grading capacitors

ICS 31.060.01; 31.060.70

ISBN 978-2-8327-1413-3

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~~Grading~~ Capacitors for high-voltage alternating current circuit-breakers - Part 1: General and grading capacitors

FOREWORD

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IEC 62146-1 has been prepared by IEC technical committee 33: Power capacitors and their applications. It is an International Standard.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

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

a) Clause re-ordering and reworked sentences;

b) New type and special tests.

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

Draft	Report on voting
33/746/FDIS	33/750/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62146 series, published under the general title *Capacitors for high-voltage alternating current circuit-breakers*, can be found on the IEC website.

Future documents in this series will carry the new general title as cited above. Titles of existing documents in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,

– withdrawn, or

– revised.

1 Scope

This part of IEC 62146 ~~is applicable to grading~~ includes generalities of capacitors used on alternating current circuit-breakers and introduces specifications for grading capacitors. Regarding grading capacitors, their function is to control the voltage distribution across the individual interrupter units of a multi-break circuit-breaker.

~~Grading~~ Capacitors can also be used in parallel to the interrupter unit on single break circuit-breakers to modify the Transient Recovery Voltage (TRV). This TRV capacitor application is covered by IEC 62146-2:2023.

~~The grading capacitor is a sub-component for the circuit-breaker and shall be specified in accordance with the circuit-breaker specifications.~~

Capacitors for high-voltage alternating circuit breakers are sub-components for the circuit-breaker and are specified in accordance with the circuit-breaker specifications according to IEC 62271-1, IEC 62271-100, and if applicable to IEC 62271-203.

This document applies to grading capacitors falling into one or both of the following categories for:

– mounting on air-insulated circuit-breakers.

– mounting on enclosed circuit-breakers (for example immersed in ~~SF_6~~ insulating gas, in oil, etc.).

The testing for each of the above applications is in some cases different.

The object of this document is:

– to define uniform rules regarding performances, testing and rating;

– to define specific safety rules;

– to provide a guidance for installation and operation.

NOTE CIGRÉ TB-368 presents a study about the operating environment of voltage grading capacitors applied to high-voltage circuit-breakers (see [2][1]).

This document does not apply to ~~phase-to-earth capacitors installed on the circuit-breaker to modify the Transient Recovery Voltage~~ capacitors not directly associated with high-voltage alternating current circuit-breakers.

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 60050 (all parts), *International electrotechnical vocabulary* (available at http://www.electropedia.org)~~

IEC 60060-1~~:2010~~, *High-voltage test techniques - Part 1: General terminology and test requirements*

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1 Numbers in square brackets refer to the Bibliography.

IEC 60068-2-17:~~1994~~2023, ~~*Official version in Russian – Basic*~~ *Environmental testing ~~procedures~~ - Part 2-17: Tests - Test Q: Sealing*

~~IEC 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and* rules~~

IEC 60071-2:2023, *Insulation co-ordination - Part 2: Application guidelines*

IEC 60270:~~2000~~2025, *High-voltage test techniques - Charge-based measurement of partial discharge~~s measurements~~*

IEC 60296, *Fluids for electrotechnical applications - Mineral insulating oils for electrical equipment*

~~IEC 60376:2005, *Specification of technical grade sulfur hexafluoride (SF_6) for use in electrical equipment*~~

~~IEC 60507-1:1991, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*~~

IEC 60567~~:2011~~, *Oil-filled electrical equipment - Sampling of gases and analysis of free and dissolved gases in mineral oils and other insulating liquids - Guidance*

~~IEC 60721-1:2002, *Classification of environmental conditions – Part 1: Environmental parameters and their severities*~~

IEC 60815 (all parts), *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions*

IEC 60867, *Insulating liquids - Specifications for unused liquids based on synthetic aromatic hydrocarbons*

IEC 61099, *Insulating liquids - Specifications for unused synthetic organic esters for electrical purposes*

IEC 61462~~:2007~~, *Composite hollow insulators - Pressurized and unpressurized insulators for use in electrical equipment with AC rated voltage greater than 1 000 V AC and DC voltage greater than 1 500 V – Definitions, test methods, acceptance criteria and design recommendations*

IEC 62146-2:2023, *Capacitors for high-voltage alternating current circuit-breakers - Part 2: TRV capacitors*

IEC 62155:2003, *Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V*

IEC 62271-1~~:2007~~, *High-voltage switchgear and controlgear - Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100~~:2008~~, *High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers*

IEC 62271-203~~:2003~~, *High-voltage switchgear and controlgear - Part 203: AC gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC 62271-205, *High-voltage switchgear and controlgear - Part 205: Compact switchgear assemblies for rated voltages above 52 kV*

IEC 62271-300~~:2006~~, *High-voltage switchgear and controlgear - Part 300: Seismic qualification of alternating current circuit-breakers*

IEC 62770, *Fluids for electrotechnical applications - Unused natural esters for transformers and similar electrical equipment*

IEC 63012, *Insulating liquids - Unused modified or blended esters for electrotechnical applications*

~~IEC Guide 109, *Environmental aspects – Inclusion in electrotechnical product standards*~~

~~CISPR 18-2:1986, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*~~

3 Terms and definitions

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

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

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

3.1
arcing distance
shortest distance in the air external to the insulator between the metallic parts which normally have the operating voltage between them

[SOURCE: IEC 60050-471:2007, 471-01-01]

3.2
capacitor element
device consisting essentially of two electrodes separated by a dielectric

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

3.3
capacitor losses
active power dissipated in the capacitor

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

3.4
capacitor terminals
terminals intended for electrical and mechanical connection to the terminals of the interrupter units of circuit-breakers

3.5
capacitance tolerance
permissible difference between the actual capacitance and the rated capacitance under specified conditions

Note 1 to entry: The actual capacitance should be measured at, or referred to, the temperature at which the rated capacitance is defined.

[SOURCE: IEC 60050-436:1990, 436-04-01, modified by addition of Note to entry.]

3.6
capacitor unit
assembly of one or more capacitor elements connected together and in the same container with terminals brought out

Note 1 to entry: A common type of unit for grading capacitors has a cylindrical housing of insulating material and metal end flanges which serve as terminals.

[SOURCE: IEC 60050-436:1990, 436-01-04, modified by addition of Note to entry]

3.7
completely immersed capacitor
capacitor, both ends of which are intended to be immersed in insulating media other than ambient air (e.g. oil or gas)

[SOURCE: IEC 60050-471:2007, 471-02-04, modified - definition originally referred to "bushing" instead of "capacitor".]

3.8
creepage distance
shortest distance along the surface of a solid insulating material between two conductive parts

Note 1 to entry: The surface of cement or any other non-insulating jointing material is not considered as forming part of the creepage distance.

Note 2 to entry: If high-resistance coating is applied to parts of the insulating part of an insulator, such parts are considered to be effective insulating surface and the distance over them is included in the creepage distance.

[SOURCE: IEC 60050-604:1987, 604-03-61, modified by addition of Notes to entry.]

3.9
dielectric (of a capacitor)
insulating material between the electrodes of the capacitor element

Note 1 to entry: The major insulation generally consists of paper, plastic film, or a mixed of paper and plastic film subsequently treated and impregnated with oil or gas at atmospheric pressure or higher.

3.10
external insulation
distance ~~in~~ through the air and the surfaces in contact with ~~open~~ the air of ~~insulation of~~ the grading capacitor that are subjected to dielectric stresses

Note 1 to entry: They are also subject to the effects of the atmospheric and other external conditions such as pollution, humidity, ice, vermin, etc.

3.11
failure
termination of the ability of an item to perform a required function

Note 1 to entry: After failure the item has a fault.

Note 2 to entry: "Failure" is an event, as distinguished from "fault", which is a state.

Note 3 to entry: This concept as defined does not apply to items consisting of software only.

[SOURCE: IEC 60050-191:1990, 191-04-01]

3.12
flashover
electric breakdown between conductors in a gas or in a liquid or in a vacuum, at least partly along the surface of solid insulation

[SOURCE: IEC 60050-212:2012, 212-11-47]

3.13
grading capacitor
capacitor for installation on high-voltage circuit-breakers to control the voltage distribution across the individual interrupter unit

Note 1 to entry: The grading capacitors alone are accessories of the circuit-breaker.

3.14
indoor capacitor
capacitor, both ends of which are intended to be in ambient air at atmospheric pressure but not exposed to outdoor atmospheric conditions

[SOURCE: IEC 60050-471:2007, 471-02-05, modified - definition originally referred to "bushing" instead of "capacitor".]

3.15
insulating envelope
insulator which is open from end to end, with or without sheds, including end fittings

Note 1 to entry: An insulating envelope can be made from one or more permanently assembled insulating elements.

Note 2 to entry: The insulating envelope may be in ceramic, glass or analogous inorganic material, cast or moulded resin, composite insulating material, in one piece or more pieces permanently assembled.

[SOURCE: IEC 60050-471:2007, 471-01-08, modified - definition originally referred to a hollow insulator and Note 2 to entry has been added.]

3.16
outdoor capacitor
capacitor, both ends of which are intended to be in ambient air at atmospheric pressure, and exposed to outdoor atmospheric conditions

[SOURCE: IEC 60050-471:2007, 471-02-07, modified - definition originally referred to "bushing" instead of "capacitor".]

3.17
internal insulation
internal solid, liquid or gaseous parts of the insulation of the grading capacitor which are protected from the effects of atmospheric conditions

Note 1 to entry: The parts are also protected from other external conditions such as pollution, humidity, ice, vermin, etc.

~~**3.18**~~
~~**major failure (of a grading capacitor)**~~
~~failure of a grading capacitor which causes the cessation of its fundamental function.~~

~~Note 1 to entry: A major failure will result in a mandatory removal from service within 30 min for unscheduled maintenance.~~

3.18
mechanical stress
any mechanical stress applied to the insulating envelope and to the terminals of the ~~grading~~ capacitor

Note 1 to entry: It is a function of the following main forces:

– forces on the terminals due to the circuit-breaker connection;

– forces due to the wind and ice;

- seismic forces;
- forces due to the operating conditions, opening and closing, of the circuit- breaker;
- thermal forces due to the ambient medium conditions;
- forces due to the transportation of the circuit-breaker or ~~grading~~ capacitors.

~~**3.20**~~
~~**minor failure (of a grading capacitor)**~~
~~any failure of a grading capacitor which does not cause a major failure of the grading capacitor~~

3.19
puncture
disruptive discharge occurring through a solid insulation material, producing a path of permanent damage

Note 1 to entry: The term puncture is also used as a synonym for electrical breakdown in solids.

[SOURCE: IEC 60050-212:2010, 212-11-49]

3.20
rated capacitance of a capacitor
C_r
capacitance value for which the capacitor has been designed

3.21
rated chopped lightning impulse withstand voltage
required peak value of the chopped lightning impulse withstand voltage which characterises the insulation of a ~~grading~~ capacitor as regards the withstand tests

Note 1 to entry: The definitions and the standard parameters applicable to chopped impulses are specified in IEC 60060-1.

3.22
rated frequency of a capacitor
f_r
frequency for which the capacitor has been designed

[SOURCE: IEC 60050-436:1990, 436-01-14, modified by addition of symbol.]

3.23
rated insulation level
test voltages, under specified conditions, that the insulation is designed to withstand

Note 1 to entry: These test voltages can be for instance:

a) rated chopped and lightning impulse and short duration power frequency withstand voltages for capacitors installed on circuit-breaker with rated voltage lower than 300 kV.

b) rated switching, lightning, chopped impulse and short duration power frequency withstand voltages for capacitors installed on circuit-breaker with rated voltage equal to or greater than 300 kV.

Note 2 to entry: The rated insulation levels of the ~~grading~~ capacitor should be equal to or higher than the relevant requirements for the circuit-breaker interrupting unit.

[SOURCE: IEC 60050-421:1990, 421-09-02, modified Note to entry]

3.24
rated lightning impulse withstand voltage
$U_{C\,LI}$
required peak value of the lightning impulse withstand voltage which characterises the insulation of an equipment as regards the withstand tests

Note 1 to entry: The standard lightning impulse has a front time of 1,2 µs and a time-to-half-value of 50 µs as specified in IEC 60060-1.

3.25
rated short duration power frequency withstand voltage
$U_{C\ PF}$
required RMS value of sinusoidal power frequency voltage that the equipment withstands during tests made under specified conditions and for a duration of 1 min unless otherwise specified

3.26
rated switching impulse withstand voltage
$U_{C\ SI}$
required peak value of the switching impulse withstand voltage which characterises the insulation of an equipment as regards the withstand tests

Note 1 to entry: The standard switching impulse has a time-to-crest of 250 µs and a time-to-half-value of 2 500 µs as specified in IEC 60060-1.

3.27
rated temperature category (of a capacitor)
range of temperature of the ambient air or other medium in which the capacitor is immersed during the service life and for which it has been designed

3.28
rated voltage of a capacitor
U_{cr}
RMS value of the alternating voltage assigned to the capacitor for identification and at which the capacitor is designed to operate continuously

3.29
rated voltage of circuit-breaker
U_r
indicates the upper limit of the highest voltage of systems for which the circuit-breaker is intended

Note 1 to entry: See IEC 62271-1.

Note 2 to entry: U_r used in IEC 62271-1 series corresponds to Um presented in IEC 60071.

3.30
resonance frequency
frequency for which the reactance of the intrinsic capacitance of the capacitor is equal to the reactance of the self-inductance of the capacitor

3.31
sample
device for testing

Note 1 to entry: Examples of such devices are a complete small capacitor, or the housing of a grading capacitor with metal end flanges filled with impregnating fluid.

3.32
tangent of the loss angle of a capacitor
tan δ
ratio between the equivalent series resistance and the capacitive reactance of a capacitor at specified sinusoidal alternating voltage and frequency

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

3.33
voltage grading factor of a circuit-breaker
F_{VG}
value that defines the standard values of rated voltages for the grading capacitor

Note 1 to entry: This factor is the ratio between the actual maximum power frequency voltage fraction across one interrupter unit of a multi-break circuit-breaker and the calculated linear power frequency voltage distribution per interrupting unit.

Note 2 to entry: It is dependent on the circuit-breaker design, of the capacitance value of the grading capacitor and its tolerance and of the safety margin.

4 Abbreviated terms

TRV	Transient Recovery Voltage
C_r	Rated capacitance of a capacitor
f_r	Rated frequency of a capacitor
U_{cr}	Rated voltage of a capacitor
U_r	Rated voltage of circuit-breaker
tan δ	Tangent of the loss angle of a capacitor
F_{VG}	Voltage grading factor of a circuit-breaker
$U_{C\ PF}$	Rated short-duration power frequency withstand voltage for the grading capacitor
U_{PF}	Rated short-duration power frequency withstand voltage across the open circuit-breaker
~~U_{CLIWL}~~$U_{C\ LI}$	Rated lightning impulse withstand voltage for the grading capacitor
$U_{(}$~~$_{LIWL}$~~$_{LI + PF)}$	Combined lightning and power frequency withstand voltage for the circuit-breaker
~~U_{CSIWL}~~$U_{C\ SI}$	Rated switching impulse withstand voltage for the grading capacitor
$U_{(}$~~$_{SIWL}$~~$_{SI + PF)}$	Combined switching and power frequency withstand voltage for the circuit-breaker
~~$U_{CCHOPPED}$~~$U_{C\ LIC}$	Chopped lightning impulse voltage for the grading capacitor
~~BIL~~	~~Bushings insulated level~~
~~SIL~~	~~Standard insulation level~~
RIV	Radio interference voltage
ESR	Equivalent series resistance

5 ~~Normal and special~~ Service conditions

5.1 General

The ~~grading~~ capacitors mentioned in this document are intended to be installed on circuit-breakers, for which the normal and special service conditions are described in IEC 62271-1.

Additional service conditions specific to the capacitors are given in 5.2.3.