

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Semiconductor converters – General requirements and line commutated converters –
Part 1-1: Specification of basic requirements**

**Convertisseurs à semiconducteurs – Exigences générales et convertisseurs commutés par le réseau –
Partie 1-1: Spécification des exigences de base**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SEMICONDUCTOR CONVERTERS – GENERAL REQUIREMENTS
AND LINE COMMUTATED CONVERTERS –****Part 1-1: Specification of basic requirements**

FOREWORD

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IEC 60146-1-1 has been prepared by IEC technical committee 22: Power electronic systems and equipment. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2009. This fifth edition constitutes a technical revision.

This fifth edition introduces four main changes:

- a) re-edition of the whole standard according to the current directives;
- b) deletion of safety-related descriptions considering coordination with IEC 62477 series;
- c) changes of calculation methods of inductive voltage regulation;
- d) changes considering coordination with IEC 61378 series.

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

Draft	Report on voting
22/374/FDIS	22/378/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 of the IEC 60146 series, under the general title *Semiconductor converters – General requirements and line commutated converters*, can be found on the IEC website.

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,
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INTRODUCTION

The main purposes of the IEC 60146-1 series are as follows.

IEC 60146-1-1, Specification of basic requirements:

- to establish basic terms and definitions;
- to specify service conditions which influence the basis of rating;
- to specify test requirements for electronic power converters and assemblies, standard design (for special design, see IEC TR 60146-1-2);
- to specify basic performance requirements;
- to give application oriented requirements for semiconductor power converters.

IEC TR 60146-1-2, Application guidelines:

- to give additional information on test conditions and components (for example: semiconductor valve devices), when required for their use in semiconductor power converters, in addition to or as a modification on existing standards;
- to provide useful reference, calculation factors, formulae and diagrams pertaining to power converter practice.

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SEMICONDUCTOR CONVERTERS – GENERAL REQUIREMENTS AND LINE COMMUTATED CONVERTERS –

Part 1-1: Specification of basic requirements

1 Scope

This part of IEC 60146 specifies the requirements for the performance of all semiconductor power converters and semiconductor power switches using controllable and/or non-controllable electronic valve devices.

The electronic valve devices mainly comprise semiconductor devices, either not controllable (i.e. rectifier diodes) or controllable (i.e. thyristors, triacs, turn-off thyristors and power transistors). The controllable devices can be reverse blocking or reverse conducting and controlled by means of current, voltage or light. Non-bistable devices are assumed to be operated in the switched mode.

This document is primarily intended to specify the basic requirements for converters in general and the requirements applicable to line commutated converters for conversion of AC power to DC power or vice versa. Parts of this document are also applicable to other types of electronic power converter provided that they do not have their own product standards.

These specific equipment requirements are applicable to semiconductor power converters that either implement power conversion or use commutation (for example semiconductor self-commutated converters) or involve particular applications (for example semiconductor converters for DC motor drives) or include a combination of said characteristics (for example direct DC converters for electric rolling stock).

This document is applicable to all power converters not covered by a dedicated product standard, or if special features are not covered by the dedicated product standard. Generally dedicated product standards for power converters refer to this document.

NOTE 1 This document is not intended to define EMC requirements. It covers all phenomena and therefore introduces references to dedicated standards which are applicable according to their scope.

NOTE 2 For the information on converter transformers, related to this document, see IEC 61378-1.

NOTE 3 All the terms listed in Clause 3 are not necessarily used in this document, however they are necessary to establish a common understanding in the application of semiconductor converters.

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 60050-551:1998, *International Electrotechnical Vocabulary (IEV) – Part 551: Power electronics*, available at www.electropedia.org

IEC 60050-551-20:2001, *International Electrotechnical Vocabulary (IEV) – Part 551-20: Power electronics – Harmonic analysis*, available at www.electropedia.org

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

IEC 61000-2-4:2002, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC 61000-3-2:2018, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*

IEC 61000-3-12:2011, *Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current ≤ 16 A and ≤ 75 A per phase*

IEC 61000-4-7:2002, *Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

IEC 61000-6-1:2016, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*

IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-4:2018, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61378-1:2011, *Converter transformers – Part 1: Transformers for industrial applications*

IEC 62477-1:2022, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

IEC 62477-2:2018, *Safety requirements for power electronic converter systems and equipment – Part 2: Power electronic converters from 1 000 V AC or 1 500 V DC up to 36 kV AC or 54 kV DC*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-551, IEC 60050-551-20, IEC 60664-1 and the following apply.

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

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

NOTE The policy adopted is as follows:

- when an existing IEC 60050 definition needs amplification or additional information, the title, the reference and the additional text are given;
- explanations and figures are given in 4.2;
- terms used in connection with converter faults are defined in IEC TR 60146-1-2.

3.1 Semiconductor devices and combinations

3.1.1

semiconductor device

device, the essential electric characteristics of which are due to the flow of charge carriers within one or more semiconductor materials

[SOURCE: IEC 60050-151:2001, 151-13-63]

3.1.2**electronic power switch****electronic switch**

operative unit for electronic power switching comprising at least one controllable valve device

[SOURCE: IEC 60050-551:1998, 551-13-01]

3.1.3**semiconductor switch**

electronic power switch with semiconductor valve devices

Note 1 to entry: Similar terms are used for electronic switches or power controllers with specific electronic valve devices, for example thyristor controller, transistor switch.

[SOURCE: IEC 60050-551:1998, 551-13-05]

3.1.4**non-controllable valve device****rectifier diode**

reverse blocking valve device the current path of which conducts in its conducting direction without any control signal being applied

[SOURCE: IEC 60050-551:1998, 551-14-04]

3.1.5**thyristor**

bi-stable semiconductor device comprising three or more junctions which can be switched from the off-state to the on-state or vice versa

Note 1 to entry: Devices having only three layers but having switching characteristics similar to those of four-layer thyristors may also be called thyristors.

Note 2 to entry: The term "thyristor" is used as a generic term to cover the whole range of PNP type devices. It may be used by itself for any member of the thyristor family when such use does not result in ambiguity or misunderstanding. In particular, the term "thyristor" is widely used for reverse blocking triode thyristor, formerly called "silicon controlled rectifier".

[SOURCE: IEC 60050-521:2002, 521-04-61, modified – Note 2 to entry added]

3.1.6**reverse blocking triode thyristor**

three-terminal thyristor which for negative anode voltage does not switch, but exhibits a reverse blocking state

[SOURCE: IEC 60050-521:2002, 521-04-63]

3.1.7**reverse conducting triode thyristor**

three-terminal thyristor which for negative anode voltage does not switch and conducts large currents at voltages comparable in magnitude to the forward on-state voltage

[SOURCE: IEC 6005-521:2002, 521-04-65]

3.1.8**bidirectional triode thyristor****triac**

three-terminal thyristor having substantially the same switching behaviour in the first and third quadrants of the current-voltage characteristic

[SOURCE: IEC 60050-521:2002, 521-04-67]

3.1.9

turn-off thyristor

thyristor which can be switched from the on-state to the off-state and vice versa by applying control signals of appropriate polarity to the gate terminal

Note 1 to entry: The gate turn-off thyristor (GTO) and the integrated gate commutated thyristor (IGCT) are types of turn-off thyristor.

[SOURCE: IEC 60050-521:2002, 521-04-68, modified – Note to entry added]

3.1.10

power transistor

transistor designed for switching from the on-state to the off-state and vice versa by applying control signals of appropriate polarity to the base or gate terminal

Note 1 to entry: The structure of the device intrinsically provides the capability of amplification (see IEC 60050-521:2002, 521-04-46).

Note 2 to entry: Different technologies of power transistors are used, such as bipolar transistors, insulated gate bipolar transistors (IGBT), metal-oxide-semiconductor field-effect transistors (MOSFET), etc.

3.1.11

valve device stack

single structure of one or more electronic valve devices with its (their) associated mounting(s) and auxiliaries if any

[SOURCE: IEC 60050-551:1998, 551-14-12]

3.1.12

valve device assembly

electrically and mechanically combined assembly of electronic valve devices or stacks, complete with all its connections and auxiliaries in its own mechanical structure

Note 1 to entry: Similar terms are applied to stacks or assemblies comprising specific electronic valve devices, for example diode stack (rectifier diodes only), thyristor assembly (thyristors only or in combination with rectifier diodes).

[SOURCE: IEC 60050-551:1998, 551-14-13]

3.1.13

electronic valve device

indivisible electronic device for electronic power conversion or electronic power switching, comprising a non-controllable or bistably controlled unidirectionally conducting current path

[SOURCE: IEC 60050-551:1998, 551-14-02, modified – Notes to entry deleted]

3.1.14

semiconductor valve device

electronic valve device which is a semiconductor device

Note 1 to entry: Typical semiconductor valve devices are thyristors, rectifier diodes, bipolar transistors, metal-oxide-semiconductor field-effect transistors (MOSFET) and insulated-gate bipolar transistors (IGBT).

Note 2 to entry: Two or more semiconductor valve devices may be integrated on a common semiconductor chip (examples: a thyristor and a rectifier diode in a reverse conducting thyristor, a power switching field effect transistor with its reverse diode) or packaged in a common case (semiconductor power module). These combinations are considered as separate semiconductor valve devices.

[SOURCE: IEC 60050-551:1998, 551-14-09, modified – Notes to entry added]

3.1.15
electronic power conversion
power conversion
conversion

change of one or more of the characteristics of an electric power system essentially without appreciable loss of power by means of electronic valve devices

Note 1 to entry: Characteristics include, for example, voltage amplitude, number of phases and frequency, including zero frequency.

[SOURCE: IEC 60050-551:1998, 551-11-02]

3.1.16
electronic power converter
power converter
converter

operative unit for electronic power conversion, comprising one or more electronic valve devices, and auxiliaries if any

Note 1 to entry: Converter transformers and filters related to network interfacing in terms of electrical characteristics are excluded from the converter itself. Such devices are part of the system aspect. Any device necessary to the correct operation of the converter itself is included in the converter, for example filters for limitation of the du/dt applied to the valve devices, surge arrestors, etc. Any auxiliary necessary to the correct operation of the converter itself is included in the converter, for example fans or cooling system.

[SOURCE: IEC 60050-551:1998, 551-12-01, modified, – Words "transformers and filters if necessary" removed from the definition, note to entry replaced, and figure removed]

3.1.17
trigger equipment
gating equipment

equipment which provides suitable trigger pulses from a control signal for controllable valve devices in a converter or power switch including timing or phase shifting circuits, pulse generating circuits and usually power supply circuits

3.1.18
system control equipment

equipment associated with a power conversion equipment or system which performs automatic adjustment of the converter output characteristics as a function of a controlled quantity

Note 1 to entry: Examples of controlled quantity include motor speed and traction force.

3.1.19
semiconductor converter

electronic power converter with semiconductor valve devices

Note 1 to entry: Similar terms for converters in general or for specific kinds of converters or for converters with other or specific valve devices, for example thyristor converter, transistor inverter.

[SOURCE: IEC 60050-551:1998, 551-12-42, modified – Figure removed]

3.1.20
power conversion equipment
PCE

equipment including the electronic power converter and auxiliaries necessary for operation of the converter itself, or even other parts dedicated to the application, and where these parts cannot be physically separated without preventing the operation of the converter