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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

IEC 60146-1-1:2009

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR CONVERTERS – GENERAL REQUIREMENTS AND LINE COMMUTATED CONVERTERS –

Part 1-1: Specification of basic requirements

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 60146-1-1 has been prepared by IEC technical committee 22: Power electronic systems and equipment.

This fourth edition cancels and replaces the third edition published in 1991, Corrigendum 1 (1993) and Amendment 1 (1996). This fourth edition constitutes a technical revision.

This fourth edition introduces five main changes:

a) re-edition of the whole standard according to the current directives;
b) correction of definitions and addition of new terms, especially terms concerning EMC, harmonic distortion and insulation co-ordination;
c) the service condition tolerances have been revised according to the IEC 61000 series;
d) the insulation tests have been revised considering the insulation co-ordination;
e) addition of three annexes.

The text of this standard is based on the following documents:

FDIS	Report on voting
22/146/FDIS	22/149/RVD

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

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

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

Part 1-1, 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.

Part 1-2, IEC/TR 60146-1-2, Application guide:

– 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.

Part 1-3, IEC 60146-1-3, Transformers and reactors:

– to give additional information on characteristics wherein converter transformers differ from ordinary power transformers. In all other respects, the rules specified in IEC 60076 shall apply to converter transformers, insofar as they are not in contradiction with this International Standard.

A list of all parts of the IEC 60146 series, under the general title: *Semiconductor converters*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

SEMICONDUCTOR CONVERTERS – GENERAL REQUIREMENTS AND LINE COMMUTATED CONVERTERS –

Part 1-1: Specification of basic requirements

1 Scope and object

This International Standard 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 may 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 standard is primarily intended to specify the basic requirements for converters in general and the requirements applicable to line commutated converters for conversion of a.c. power to d.c. power or vice versa. Parts of this standard 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 d.c. motor drives) or include a combination of said characteristics (for example direct d.c. converters for electric rolling stock).

This standard 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. Dedicated product standards for power converters should refer to this International Standard.

NOTE 1 This standard 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 A large part of this standard, particularly for power transformers, is covered in IEC 61378-1.

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 60050-101:1998, *International Electrotechnical Vocabulary – Part 101: Mathematics*

IEC 60050-551:1998, *International Electrotechnical Vocabulary – Part 551: Power electronics*

IEC 60050-551-20:2001, *International Electrotechnical Vocabulary – Part 551-20: Power electronics – Harmonic analysis*

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60700-1, *Thyristor valves for high voltage direct current (HVDC) power transmission – Part 1: Electrical testing*

IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

IEC 61000-2-2:2002, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

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

IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤ 75 A and subject to conditional connection*

IEC 61000-3-12:2004, *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, *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, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments*

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

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

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

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61180-1:1992, *High-voltage test techniques for low voltage equipment – Part 1: Definitions, test and procedure requirements*

IEC 61204-3, *Low-voltage power supplies, d.c. output – Part 3: Electromagnetic compatibility (EMC)*

IEC 61204-7, *Low voltage power supplies, d.c. output – Part 7: Safety requirements*

IEC 61800-3, *Adjustable speed electrical power drive systems – Part 3: EMC requirements and specific test methods*

IEC 61800-5-1, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*

IEC 61954, *Power electronics for electrical transmission and distribution systems – Testing of thyristor valves for static VAR compensators*

IEC/PAS 61975, *Guide to the specification and design evaluation of a.c. filters for HVDC systems*

IEC 62040-1, *Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS*

IEC 62040-2, *Uninterruptible power systems (UPS) – Part 2: Electromagnetic compatibility (EMC) requirements*

IEC 62103, *Electronic equipment for use in power installations*

IEC 62310-1, *Static transfer systems (STS) – Part 1: General and safety requirements*

IEC 62310-2, *Static transfer systems (STS) – Part 2: Electromagnetic compatibility (EMC) requirements*

NOTE Some other IEC publications are quoted for information in the Bibliography.

3 Terms and definitions

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

In this standard, IEV definitions are used wherever possible, particularly those in IEC 60050 (551).

All the terms listed in this clause are not necessarily used in this International Standard, however they are necessary to establish a common understanding in the application of semiconductor converters.

The policy adopted is as follows:

a) when an existing IEV definition needs amplification or additional information, the title, the reference and the additional text are given;

b) explanations and figures are given in 4.3;

c) terms used in connection with converter faults are defined in IEC/TR 60146-1-2.

An alphabetical index is given in the Index of definitions.

NOTE For easier use of this index, a cross reference numbering is set up, noted [df *n*], in which *n* is the natural integer following the alphabetical order of the definitions.

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

[IEV 151-13-63] [df 164]

3.1.2
electronic (power) switch
an operative unit for electronic power switching comprising at least one controllable valve device

[IEV 551-13-01] [df 60] [df 123] [df 173]

3.1.3
semiconductor switch
an electronic power switch with semiconductor valve devices

[IEV 551-13-05] [df 165] [df 174]

NOTE Similar terms are used for electronic switches or power controllers with specific electronic valve devices, for example thyristor controller, transistor switch.

3.1.4
non-controllable valve device
rectifier diode
a reverse blocking valve device the current path of which conducts in its conducting direction without any control signal being applied

[IEV 551-14-04] [df 45] [df 105] [df 149]

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

[IEV 521-04-61] [df 178]

NOTE 1 Devices having only three layers but having switching characteristics similar to those of four layers thyristors may also be called thyristors.

NOTE 2 The term "thyristor" is used as a generic term to cover the whole range of PNPN 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".

3.1.6
reverse blocking triode thyristor
three-terminal thyristor which for negative anode voltage does not switch, but exhibits a reverse blocking state

[IEV 521-04-63] [df 158] [df 179] [df 193]

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

[IEV 521-04-65] [df 159]

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

[IEV 521-04-67, modified] [df 11] [df 188]

3.1.9
turn-off thyristor
GTO
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

[IEV 521-04-68] [df 79] [df 81] [df 195]

NOTE Also known as gate turn-off thyristor.

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 [df 124] [df 186]

NOTE 1 The structure of the device intrinsically provides the capability of amplification (see IEV 521-04-46)

NOTE 2 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
a single structure of one or more electronic valve devices with its (their) associated mounting(s) and auxiliaries if any

[IEV 551-14-12] [df 171] [df 203]

3.1.12
valve device assembly
an electrically and mechanically combined assembly of electronic valve devices or stacks, complete with all its connections and auxiliaries in its own mechanical structure

NOTE 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).

[IEV 551-14-13] [df 6] [df 201]

3.1.13
electronic valve device
an indivisible electronic device for electronic power conversion or electronic power switching, comprising a non-controllable or bistably controlled unidirectionally conducting current path

[IEV 551-14-02] [df 61] [df 199]

3.1.14
semiconductor valve device
an electronic valve device which is a semiconductor device

[IEV 551-14-09] [df 166] [df 200]

NOTE 1 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 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.

3.1.15
(electronic) (power) 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

[IEV 551-11-02] [df 32] [df 58] [df 116]

NOTE Characteristics include, for example, voltage amplitude, number of phases and frequency, including zero frequency.

3.1.16
(electronic) (power) converter
an operative unit for electronic power conversion, comprising one or more electronic valve devices, and auxiliaries if any

[IEV 551-12-01, modified] [df 36] [df 59] [df 119]

NOTE 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 are included in the converter, for example filters for limitation of the d*u*/d*t* applied to the valve devices, surge arrestors, etc. Any auxiliary necessary to the correct operation of the converter itself are included in the converter, for example fans or cooling system.

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 [df 80] [df 191]

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 (for example motor speed, traction force, etc.) [df 26] [df 176]

3.1.19
semiconductor converter
an electronic power converter with semiconductor valve devices

[IEV 551-12-42] [df 37] [df 163]

NOTE 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.

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 [df 33] [df 66] [df 117]

3.1.21
power conversion system
system consisting of a power conversion equipment and associated components for the application for example switchgear, reactors or transformers, dedicated filters, etc. [df 35] [df 118] [df 175]

3.2 Arms and connections

3.2.1
(valve) arm
a part of the circuit of an electronic power converter or switch bounded by any two a.c. or d.c. terminals and including one or more simultaneously conducting electronic valve devices connected together and other components if any

[IEV 551-15-01] [df 5] [df 198]

3.2.2
principal arm
a valve arm involved in the major transfer of power from one side of the converter or electronic switch to the other

[IEV 551-15-02] [df 4] [df 125]

3.2.3
auxiliary arm
any valve arm other than a principal arm

NOTE Sometimes an auxiliary arm temporarily fulfils more than one of the following functions: by-pass arm, free-wheeling arm, turn-off arm or regenerative arm.

[IEV 551-15-05] [df 3] [df 7]

3.2.4
by-pass arm
an auxiliary arm providing a conductive path which allows the current to circulate without an interchange of power between source and load

[IEV 551-15-06] [df 14]

3.2.5
free-wheeling arm
a by-pass arm containing only non-controllable valve devices

[IEV 551-15-07] [df 75]

3.2.6
turn-off arm
an auxiliary arm which temporarily takes over the current directly from a conducting valve arm, consisting of one or more latching valve devices which cannot be turned off by a control signal

[IEV 551-15-08] [df 194]

3.2.7
regenerative arm
a valve arm which transfers a part of the power from the load side to the source side

[IEV 551-15-09] [df 153]

3.2.8
converter connection
the electrical arrangement of valve arms and other components essential for the function of the main power circuit of a converter

[IEV 551-15-10] [df 38]

NOTE Common practice also uses the term “topology” of the converter with the same sense.