

BS EN 60146-1-1:2010



BSI Standards Publication

Semiconductor converters — General requirements and line commutated converters

Part 1-1: Specification of basic requirements

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National foreword

This British Standard is the UK implementation of EN 60146-1-1:2010. It is identical to IEC 60146-1-1:2009. It supersedes BS EN 60146-1-1:1993 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/22, Power electronics.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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English version

**Semiconductor converters -
General requirements and line commutated converters -
Part 1-1: Specification of basic requirements
(IEC 60146-1-1:2009)**

Convertisseurs à semiconducteurs -
Exigences générales et convertisseurs
commutés par le réseau -
Partie 1-1: Spécification des exigences
de base
(CEI 60146-1-1:2009)

Halbleiter-Stromrichter -
Allgemeine Anforderungen
und netzgeführte Stromrichter -
Teil 1-1: Festlegung
der Grundanforderungen
(IEC 60146-1-1:2009)

This European Standard was approved by CENELEC on 2010-07-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 22/146/FDIS, future edition 4 of IEC 60146-1-1, prepared by IEC TC 22, Power electronic systems and equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60146-1-1 on 2010-07-01.

This European Standard supersedes EN 60146-1-1:1993 + A1:1997.

This EN 60146-1-1:200X 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 EN 61000 series;
- d) the insulation tests have been revised considering the insulation co-ordination;
- e) addition of three annexes.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2011-04-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2013-07-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60146-1-1:2009 was approved by CENELEC as a European Standard without any modification.

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

IEC 60071-1	NOTE Harmonized as EN 60071-1.
IEC 60071-2	NOTE Harmonized as EN 60071-2.
IEC 60076-1	NOTE Harmonized as EN 60076-1.
IEC 60146-1-3	NOTE Harmonized as EN 60146-1-3.
IEC 60146-2	NOTE Harmonized as EN 60146-2.
IEC 60664-3	NOTE Harmonized as EN 60664-3.
IEC 60664-4	NOTE Harmonized as EN 60664-4.
IEC 60664-5	NOTE Harmonized as EN 60664-5.
IEC 61287-1	NOTE Harmonized as EN 61287-1.
IEC 61378-1	NOTE Harmonized as EN 61378-1.

IEC 61378-2	NOTE Harmonized as EN 61378-2.
IEC 61439-1	NOTE Harmonized as EN 61439-1.
IEC/TR 61800-6	NOTE Harmonized as CLC/TR 61800-6.
IEC 62068-1	NOTE Harmonized as EN 62068-1.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60050-101	1998	International Electrotechnical Vocabulary (IEV) - Part 101: Mathematics	-	-
IEC 60050-551	1998	International Electrotechnical Vocabulary (IEV) - 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	HD 60364-1	-
IEC 60529	-	Degrees of protection provided by enclosures (IP Code)	EN 60529	-
IEC 60664-1	2007	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests	EN 60664-1	2007
IEC 60700-1	-	Thyristor valves for high voltage direct current (HVDC) power transmission - Part 1: Electrical testing	EN 60700-1	-
IEC 61000	Series	Electromagnetic compatibility (EMC)	EN 61000	Series
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	EN 61000-2-2	2002
IEC 61000-2-4	2002	Electromagnetic compatibility (EMC) - Part 2-4: Environment - Compatibility levels in industrial plants for low-frequency conducted disturbances	EN 61000-2-4	2002
IEC 61000-3-2	-	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	EN 61000-3-2	-

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
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	EN 61000-3-3	-
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	EN 61000-3-11	-
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	EN 61000-3-12	2005
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	EN 61000-4-7	-
IEC 61000-6-1	-	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments	EN 61000-6-1	-
IEC 61000-6-2	-	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments	EN 61000-6-2	-
IEC 61000-6-3	-	Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments	EN 61000-6-3	-
IEC 61000-6-4	-	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments	EN 61000-6-4	-
IEC 61140	-	Protection against electric shock - Common aspects for installation and equipment	EN 61140	-
IEC 61180-1	1992	High-voltage test techniques for low-voltage equipment - Part 1: Definitions, test and procedure requirements	EN 61180-1	1994
IEC 61204-3	-	Low-voltage power supplies, d.c. output - Part 3: Product EMC standard	EN 61204-3	-
IEC 61204-7	-	Low voltage power supplies, d.c. output - Part 7: Safety requirements	EN 61204-7	-
IEC 61800-3	-	Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods	EN 61800-3	-

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61800-5-1	-	Adjustable speed electrical power drive systems - Part 5-1: Safety requirements - Electrical, thermal and energy	EN 61800-5-1	-
IEC 61954	-	Power electronics for electrical transmission and distribution systems - Testing of thyristor valves for static VAR compensators	EN 61954	-
IEC/PAS 61975	-	System tests for high-voltage direct current (HVDC) installations	-	-
IEC 62040-1	-	Uninterruptible Power Systems (UPS) - Part 1: General and safety requirements for UPS	EN 62040-1	-
IEC 62040-2	-	Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements	EN 62040-2	-
IEC 62103	-	Electronic equipment for use in power installations	-	-
IEC 62310-1	-	Static transfer systems (STS) - Part 1: General and safety requirements	EN 62310-1	-
IEC 62310-2	-	Static transfer systems (STS) - Part 2: Electromagnetic compatibility (EMC) requirements	EN 62310-2	-

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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, IEC 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 IEC 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 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".

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 du/dt 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.

3.2.9**basic converter connection**

the electrical arrangement of principal arms in a converter

[IEV 551-15-11] [df 8]

3.2.10**single-way connection (of a converter)**

a converter connection such that the current through each of the phase terminals of the a.c. circuit is unidirectional

[IEV 551-15-12] [df 170]

3.2.11**double-way connection (of a converter)**

a converter connection such that the current through each of the phase terminals of the a.c. circuit is bidirectional

[IEV 551-15-13] [df 52]

3.2.12**bridge connection**

a double-way connection of pairs of arms such that the centre terminals are the phase terminals of the a.c. circuit, and that the outer terminals of like polarity are connected together and are the d.c. terminals

[IEV 551-15-14] [df 13]

3.2.13**uniform connection**

a connection with either all principal arms controllable or all principal arms non-controllable

[IEV 551-15-15] [df 197]

3.2.14**non-uniform connection**

a connection with both controllable and non-controllable principal arms

[IEV 551-15-18] [df 106]

3.2.15**series connection**

connection of two-terminal networks so that they form a single path

[IEV 131-12-75] [df 167]

3.2.16**series connection of converters**

a series connection in which two or more converters are connected in such a way that their voltages add [df 168]

3.2.17**boost and buck connection**

a series connection of two or more converter connections the direct voltages of which may be added or subtracted depending on the control of the individual connections

[IEV 551-15-21] [df 12]

3.3 Controllability of converter arms and quadrants of operation (on d.c. side)

3.3.1

controllable arm

converter arm including controllable valve device(s) [df 27]

3.3.2

non-controllable arm

converter arm including only no-controllable valve device(s) [df 104]

3.3.3

quadrant of operation (on the d.c. side)

quadrant of the voltage current plane defined by the d.c. voltage polarity and the current direction [df 130]

3.3.4

one-quadrant converter

an a.c./d.c. or d.c. converter with one possible direction of d.c. power flow

[IEV 551-12-34] [df 107]

3.3.5

two-quadrant converter

an a.c./d.c. or d.c. converter with two possible directions of d.c. power flow associated with one direction of direct current and two directions of direct voltage or vice versa

[IEV 551-12-35] [df 196]

3.3.6

four-quadrant converter

an a.c./d.c. or d.c. converter with two directions of d.c. power flow, associated with two directions of direct voltage and two directions of direct current

[IEV 551-12-36] [df 74]

3.3.7

reversible converter

bi-directional converter

a converter in which the direction of the power flow is reversible

[IEV 551-12-37] [df 10] [df 160]

NOTE The term bi-directional converter corresponds to common practice, and provides a better picture of the bi-directional power flow in the converter.

3.3.8

single converter

a current stiff reversible a.c./d.c. converter with direct current in one direction

[IEV 551-12-38] [df 169]

3.3.9

double converter

a current stiff reversible a.c./d.c. converter with direct current in both directions

[IEV 551-12-39] [df 50]

3.3.10**converter section of a double converter**

that part of a double converter in which the main direct current when viewed from the d.c. terminals always flows in the same direction

[IEV 551-12-40] [df 39]

3.3.11**phase control**

the process of varying the instant within the cycle at which current conduction in an electronic valve device or valve arm begins

[IEV 551-16-23] [df 115]

3.3.12**triggering**

the control action to achieve firing of a latching valve device or an arm consisting of such devices

[IEV 551-16-61] [df 192]

3.4 Commutation, quenching and commutation circuitry**3.4.1****commutation**

in an electronic power converter the transfer of current from one conducting arm to the next to conduct in sequence, without interruption of the current, both arms conducting simultaneously during a finite time interval

[IEV 551-16-01] [df 17]

3.4.2**quenching**

the termination of current flow in an arm without commutation

[IEV 551-16-19] [df 131]

3.4.3**direct commutation**

a commutation between two principal arms without transfer through any auxiliary arms

[IEV 551-16-09] [df 46]

3.4.4**indirect commutation**

a series of commutations from one principal arm to another or back to the original one by successive commutations via one or more auxiliary arms

[IEV 551-16-10] [df 90]

3.4.5**external commutation**

a commutation where the commutating voltage is supplied by a source outside the converter or electronic switch

[IEV 551-16-11] [df 70]

3.4.6

line commutation

an external commutation where the commutating voltage is supplied by the line

[IEV 551-16-12] [df 99]

3.4.7

load commutation

an external commutation where the commutating voltage is taken from a load other than the line

[IEV 551-16-13] [df 100]

3.4.8

machine commutation

external commutation where the commutating voltage is supplied by a rotating machine

[IEV 551-16-14] [df 101]

3.4.9

resonant load commutation

method of load commutation in which the commutating voltage is supplied by the load, using its resonant property [df 157]

3.4.10

self-commutation

a commutation where the commutating voltage is supplied by components within the converter or the electronic switch

[IEV 551-16-15] [df 161]

3.4.11

capacitor commutation

method of self-commutation in which the commutating voltage is supplied by capacitors included in the commutation circuit

[IEV 551-16-17] [df 15]

3.4.12

inductively coupled capacitor commutation

method of capacitor commutation in which the capacitor circuit is inductively coupled to the commutation circuit [df 93]

3.4.13

valve device commutation

a method of self-commutation in which the commutating voltage is created by turning off the conducting electronic valve device by a control signal

NOTE Simultaneously the next electronic valve device to conduct is turned on.

[IEV 551-16-16] [df 202]

3.4.14

valve device quenching

a method of quenching in which the quenching is performed by the electronic valve device itself

[IEV 551-16-20] [df 204]

3.4.15**external quenching**

a method of quenching in which the quenching results from causes external to the device

[IEV 551-16-21] [df 71]

NOTE External quenching occurs in line-commutated converters under discontinuous conduction operation.

3.5 Commutation characteristics**3.5.1****commutation circuit**

the circuit consisting of the commutating arms and the source providing the commutating voltage

[IEV 551-16-03] [df 18]

3.5.2**commutation voltage**

the voltage which causes the current to commute

[IEV 551-16-02] [df 25]

3.5.3**commutation inductance**

the resulting inductance in the commutation circuit

[IEV 551-16-07] [df 20]

NOTE For line or machine commutated converters, the commutation reactance is the impedance of the commutation inductance at the fundamental frequency.

3.5.4**commutation interval**

the time interval in which commutating arms are carrying principal current simultaneously

[IEV 551-16-04] [df 21]

3.5.5**angle of overlap**

μ

the commutation interval expressed in angular measure

[IEV 551-16-05] [df 2]

NOTE Also known as overlap angle μ .

3.5.6**commutation notch**

a periodic voltage transient that may appear in the a.c. side voltage of a line or machine-commutated converter due to the commutation

[IEV 551-16-06] [df 22]

3.5.7**commutation repetitive transient**

voltage oscillation associated with the commutation notch [df 24]

3.5.8**commutating group**

a group of principal arms which commute cyclically among themselves without intermediate commutation of the current to other principal arms

[IEV 551-16-08] [df 19]

3.5.9**commutation number q**

the number of commutations from one principal arm to another during one elementary period in each commutating group

[IEV 551-17-03] [df 23]

3.5.10**pulse number p**

the number of non-simultaneous symmetrical direct or indirect commutations from one principal arm to another which occur during one elementary period

[IEV 551-17-01] [df 129]

3.5.11**trigger delay angle**

α

the time expressed in angular measure by which the trigger pulse is delayed with respect to the reference instant in the case of phase control

NOTE With line, machine or load commutated converters the reference instant is the zero crossing instant of the commutating voltage. With a.c. controllers it is the zero crossing instant of the supply voltage. For a.c. controllers with inductive loads, the trigger delay angle is the sum of the phase shift and the current delay angle.

[IEV 551-16-33] [df 190]

3.5.12**trigger advance angle**

β

the time expressed in angular measure by which the trigger pulse is advanced with respect to the reference instant

NOTE With line, machine or load commutated converters the reference instant is the zero crossing instant of the commutating voltage.

[IEV 551-16-34] [df 189]

3.5.13**inherent delay angle**

α_p

the current delay angle occurring, even without phase control, caused by multiple overlap

[IEV 551-16-35] [df 94]

NOTE Multiple overlap occurs in line commutated converters at high angles of overlap.

3.5.14**extinction angle**

γ

the time, expressed in angular measure, between the instant when the current of the arm falls to zero and the instant when the arm is required to withstand steeply rising off-state voltage
[df 72]

3.5.15**hold-off interval**

the interval between the instant when the on-state current of a latching valve device has decreased to zero and the instant when the same valve device is subjected to reapplied off-state voltage

[IEV 551-16-45] [df 86]

3.6 Rated values**3.6.1****rated value**

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system

[IEV 151-16-08] [df 145]

NOTE 1 The quantity may describe electrical, thermal, mechanical, or environmental properties.

NOTE 2 In the case of semiconductor converters, rated values usually apply to a semiconductor valve device, a valve device assembly or a converter.

NOTE 3 The nominal value of a system (for example nominal voltage – IEC 601-01-21) is often equal to the corresponding rated value of the equipment, where both values are within the tolerance band of a quantity.

NOTE 4 Unlike many other electrical components, semiconductor devices may be irreparably damaged, even within a very short time of operation, in excess of maximum rated values.

NOTE 5 Variations of rated values should be specified. Certain of the values assigned are limiting values. These limiting values may be either maximum or minimum values.

3.6.2**rated frequency (for converters and their transformers)**

f_N

specified frequency on the a.c. side of a converter [df 142]

3.6.3**rated voltage on the line side (for converters and their transformers)**

U_{LN}

specified r.m.s. value of the voltage between conductors on the line side of the converter [df 146]

If the line side transformer winding is provided with taps, the rated value of the voltage of the line side shall refer to a specified tap, which is the principal tap.

3.6.4**rated voltage on the valve side of the transformer (for converters and their transformers)**

U_{vN}

r.m.s. value of the no-load voltage between vectorially consecutive commutating phase terminals of the valve windings of a commutating group at rated voltage on the line side of the transformer [df 147]

NOTE If no transformer is provided, within the converter case of a directly connected converter, the rated voltage on the valve side is the rated voltage on the line side of the converter.

3.6.5**rated current on the line side (for converters and their transformers)**

I_{LN}

maximum r.m.s. value of the current on the line side of the converter under rated conditions [df 137]

NOTE 1 It takes into account rated load and the most onerous combination of all other conditions within their specified ranges, for example line voltage and frequency deviations.

NOTE 2 For polyphase equipment, this value is computed from the rated direct current on the basis of rectangular shaped currents of the converter arms.

For single phase equipment, the basis of calculation should be specified.

NOTE 3 The rated line current includes currents supplied to the auxiliary circuits of the converter. It also takes into account the effect of d.c. current ripple and circulating current, if any.

3.6.6

rated current on the valve side (for converters and their transformers)

I_{vN}

maximum r.m.s. value of the current on the valve side of the converter under rated conditions [df 138]

NOTE 1 It takes into account rated load and the most onerous combination of all other conditions within their specified ranges, for example line voltage and frequency deviations.

NOTE 2 For polyphase equipment, this value is computed from the rated direct current on the basis of rectangular shaped currents of the converter arms.

NOTE 3 For single phase equipment, the basis of calculation should be specified.

3.6.7

rated apparent power on the line side (for converters and their transformers)

S_{LN}

total apparent power, at the line side terminals, at rated frequency, rated voltage on the line side and rated current on the line side [df 132]

3.6.8

rated direct voltage

U_{dN}

mean value, at rated d.c. current, specified by the manufacturer, of the direct voltage between the d.c. terminals of the assembly or equipment [df 141]

3.6.9

rated direct current

I_{dN}

mean value of the direct current specified by the manufacturer for specified load and service conditions [df 140]

NOTE It may be referred to as the 1,0 p.u. value, to which other values of I_d are compared.

3.6.10

rated continuous direct current (maximum value)

I_{dMN}

mean value of the direct current which an assembly or converter is capable of carrying continuously without damage, for specified service conditions [df 133]

NOTE 1 The rated continuous direct current of an assembly is very often essentially higher than the rated direct current of the corresponding complete equipment.

NOTE 2 The rated continuous direct current of an assembly may be limited by parts other than the semiconductor.

3.6.11

peak maximum direct current

I_{dSMN}

mean value of the direct current which an assembly or converter is capable of carrying without damage, for a specified short duration, starting from an undefined duration at the rated current and followed by a no-load period of short duration [df 113]

NOTE The value and duration of the peak current (peak maximum direct current I_{dSMN}), as well as the minimum time of no-load before again carrying any current, are associated parts of the definition of the peak maximum direct current.

3.6.12**intermittent peak maximum direct current** **I_{dRMN}**

mean value of the direct current which an assembly or converter is capable of carrying without damage, for a specified short duration and intermittently, starting from any value of current equal or below the rated current, and back to any value of current equal or below the rated current [df 98]

NOTE The value and duration of the peak current (intermittent peak maximum direct current I_{dRMN}), as well as the minimum time between applications of intermittent peak loads are associated parts of the definition of the intermittent peak maximum direct current.

3.6.13**rated current for peak load duty (short-time duty)**

mean value of the direct current which an assembly or converter is capable of carrying for specified duration under specified service conditions, associated with a short-time peak maximum direct current [df 135]

NOTE The characteristics of the associated maximum direct current I_{dSMN} are parts of the definition of the short time duty.

3.6.14**rated current for continuous duty with superimposed peak loads**

mean value of the direct current which an assembly or converter is capable of carrying for unlimited duration under specified service conditions and with intermittently applied intermittent peak maximum direct current of specified magnitudes and durations [df 134]

NOTE The characteristics of the associated intermittent peak maximum direct current (I_{dRMN}) are parts of the definition of the rated current for continuous duty with superimposed peak loads.

3.6.15**rated current for repetitive load duty (periodic duty)**

rated direct current of the assembly or converter, specified as the r.m.s. value of the load current evaluated over the period of the load duty cycle [df 136]

NOTE The duty class should be specified as a sequence of current values together with their durations.

3.6.16**rated d.c. power**

product of the rated direct voltage and the rated direct current [df 139]

NOTE The measured d.c. power may differ from the rated d.c. power as defined because of voltage and current ripple.

3.7 Specific voltages, currents and factors**3.7.1****ideal no-load direct voltage** **U_{di}**

the theoretical no-load direct voltage of an a.c./d.c. converter assuming no reduction by phase control, no threshold voltages of electronic valve devices, and no voltage rise at small loads

[IEV 551-17-15] [df 87]

3.7.2**controlled ideal no-load direct voltage** **$U_{di\alpha}$**

the theoretical no-load direct voltage of an a.c./d.c. converter corresponding to a specified trigger delay angle assuming no threshold voltages of electronic valve devices and no voltage rise at small loads

[IEV 551-17-16] [df 29]

3.7.3**conventional no-load direct voltage** **U_{d0}**

the mean value of the direct voltage which would be obtained by extrapolating the direct voltage/current characteristic from the region of continuous flow of direct current to zero current at zero trigger delay angle, i.e. without phase control

[IEV 551-17-17] [df 31]

NOTE U_{di} is equal to the sum of U_{d0} and the no-load voltage drop in the assembly.

3.7.4**controlled conventional no-load direct voltage** **$U_{d0\alpha}$**

mean value of the direct voltage corresponding to a specified trigger delay angle which would be obtained by extrapolating the direct voltage/current characteristic from the region of continuous flow of direct current to zero current

[IEV 551-17-18] [df 28]

NOTE $U_{di\alpha}$ is equal to the sum of $U_{d0\alpha}$ and the no-load voltage drop in the assembly.

3.7.5**real no-load direct voltage** **U_{d00}**

the actual mean direct voltage at zero direct current

[IEV 551-17-19] [df 148]

3.7.6**direct voltage regulation**

the difference between the conventional no-load direct voltage and the direct voltage at load at the same trigger delay angle excluding the correcting effect of stabilizing means if any

[IEV 551-17-21] [df 48] [df 154]

NOTE 1 If voltage stabilizing means are used, refer also to 3.7.9.

NOTE 2 The nature of the d.c. circuit (for example capacitors, back e.m.f. load) may affect the voltage change significantly. Where this is the case, special consideration may be required.

3.7.7**inherent direct voltage regulation**

the direct voltage regulation excluding the effect of the a.c. system impedance

[IEV 551-17-22] [df 95]

3.7.8**total direct voltage regulation**

the direct voltage regulation including the effect of the a.c. system impedance

[IEV 551-17-23] [df 180]

3.7.9**output voltage tolerance band**

specified range of steady-state values of a stabilized output voltage around its nominal or preset value [df 108]

3.7.10**transition current**

the mean direct current of a converter connection when the direct current(s) of the commutating group(s) become(s) intermittent when decreasing the current

[IEV 551-17-20] [df 187]

3.7.11**conversion factor**

the ratio of the fundamental output power or d.c. output power to the fundamental input power or d.c. input power

[IEV 551-17-10] [df 34]

NOTE 1 The fundamental power (IEV 551-17-08) is the active power determined by the fundamental components of voltage and current.

NOTE 2 For the purposes of this definition, the d.c. power is the product of the mean value of the voltage and mean value of the current.

3.7.12**power efficiency**

ratio of the output power to the input power of the converter [df 120]

NOTE 1 In the conversion factor, the power of the a.c. components on the d.c. side is not taken into account. In the power efficiency, it is included in the d.c. power. Therefore, for a.c. to d.c. conversion, the conversion factor has a lower value. For a single phase, two-pulse (full wave) converter with resistive load, the theoretical maximum conversion factor is 0,81 p.u., where the maximum power efficiency is 1,0 p.u.

NOTE 2 The conversion factor may be correctly obtained only by measurement of the fundamental a.c. power and d.c. voltage and current. The power efficiency may be correctly obtained either by measurement of a.c. power and d.c. power or by calculation or measurement of internal losses.

NOTE 3 The active power (mean value of the power) on the a.c. side, and the mean value of the power the on the d.c. side are to be considered.

3.7.13**power factor**

λ

under periodic conditions, ratio of the absolute value of the active power P to the apparent power S

$$\lambda = \frac{|P|}{S}$$

NOTE Under sinusoidal conditions, the power factor is the absolute value of the active factor.

[IEV 131-11-46] [df 121]

3.7.14**power factor of the fundamental wave****displacement factor**

$\cos \varphi_1$

under periodic conditions, ratio of the active power of the fundamental components P_1 to the apparent power of the fundamental components S_1

$$\cos \varphi_1 = \frac{P_1}{S_1}$$

[df 49] [df 122]

NOTE IEC 131-11-48 defines the displacement angle as "under sinusoidal conditions, phase difference between the voltage applied to a linear two-terminal element or two-terminal circuit and the electric current in the element or circuit". A note is added "The cosine of the displacement angle is the active factor."

3.7.15**deformation factor** ν ratio of the total power factor λ to the displacement factor $\cos \varphi_1$

$$\nu = \frac{\lambda}{\cos \varphi_1} \quad [\text{df } 44]$$

NOTE Under sinusoidal voltage condition, the deformation factor is equal to the fundamental factor. See Note 2 of 3.10.14.

3.8 Cooling**3.8.1****cooling medium**

liquid (for example water) or gas (for example air) which removes the heat from the equipment [df 40]

3.8.2**heat transfer agent**

liquid (for example water) or gas (for example air) within the equipment to transfer the heat from its source to a heat exchanger from where the heat is removed by the cooling medium [df 85]

3.8.3**direct cooling**

method of cooling by which the cooling medium is in direct contact with the parts of the equipment to be cooled, i.e. no heat transfer agent is used [df 47]

3.8.4**indirect cooling**

method of cooling in which a heat transfer agent is used to transfer heat from the part to be cooled to the cooling medium [df 91]

3.8.5**natural cooling****convection**

method of circulating the cooling fluid (cooling medium or heat transfer agent) which uses the change of volumetric mass (density) with temperature [df 30] [df 103]

3.8.6**forced cooling**

method of circulating the cooling medium or heat transfer agent by means of blower(s), fan(s) or pump(s) [df 73]

3.8.7**mixed cooling**

method of circulating the cooling medium or heat transfer agent, which uses, alternatively, natural and forced circulation [df 102]

NOTE Mixed circulation may be used for light load/overload periods or in the case of an emergency.

3.8.8**equilibrium temperature**

steady-state temperature reached by a component of a converter under specified conditions of load and cooling [df 65]

NOTE The steady-state temperatures are in general different for different components. The times necessary to establish steady-state are also different and proportional to the thermal time constants.