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INTERNATIONAL STANDARD

colour inside

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SEMICONDUCTOR CONVERTERS – GENERAL REQUIREMENTS AND LINE COMMUTATED CONVERTERS –

Part 1-1: Specification of basic requirements

FOREWORD

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This commented version (CMV) of the official standard IEC 60146-1-1:2024 edition 5.0 allows the user to identify the changes made to the previous IEC 60146-1-1:2009 edition 4.0. Furthermore, comments from IEC TC 22 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

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,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

The content of the corrigendum 1 (2025-03) has been included in this copy.

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.

SEMICONDUCTOR CONVERTERS – GENERAL REQUIREMENTS AND LINE COMMUTATED CONVERTERS –

Part 1-1: Specification of basic requirements

1 Scope ~~and object~~

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 ~~may~~ 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 ~~should~~ 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 ~~A large part of this standard, particularly for power transformers, is covered in IEC 61378-1.~~ 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. 1

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

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 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~~2020, *Insulation coordination for equipment within low-voltage supply 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 61000-3-2:2018, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment 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~~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 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*~~

IEC 61000-6-4:2018, *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 61378-1:2011, *Converter transformers – Part 1: Transformers for industrial applications*

~~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*~~

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* **2**

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

IEC 60146-1-1

Edition 5.0 2024-03

INTERNATIONAL STANDARD

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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 60146-1-1:2024-03(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTRODUCTION

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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.

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- 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.

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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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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CONVERTISSEURS À SEMICONDUCTEURS – EXIGENCES GÉNÉRALES ET CONVERTISSEURS COMMUTÉS PAR LE RÉSEAU –

Partie 1-1: Spécification des exigences de base

AVANT-PROPOS

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L'IEC 60146-1-1 a été établie par le comité d'études 22 de l'IEC: Systèmes et équipements électroniques de puissance. Il s'agit d'une Norme internationale.

Cette cinquième édition annule et remplace la quatrième édition parue en 2009. Cette cinquième édition constitue une révision technique.

Cette cinquième édition introduit quatre modifications principales:

a) réédition de l'ensemble de la norme conformément aux directives en vigueur;
b) suppression des descriptions relatives à la sécurité, pour prendre en compte la coordination avec la série IEC 62477;
c) modifications des méthodes de calcul de la variation inductive de tension;
d) modifications pour prendre en compte la coordination avec la série IEC 61378.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
22/374/FDIS	22/378/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

Une liste de toutes les parties de la série IEC 60146, publiées sous le titre général *Convertisseurs à semiconducteurs – Exigences générales et convertisseurs commutés par le réseau*, se trouve sur le site Web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site Web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

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Le contenu du corrigendum 1 (2025-03) a été pris en considération dans cet exemplaire.

INTRODUCTION

Les principaux objectifs de la série IEC 60146-1 sont les suivants.

IEC 60146-1-1, Spécification des exigences de base:

- stipuler les termes de base et leurs définitions;
- spécifier les conditions de service qui ont une influence sur le dimensionnement;
- spécifier les exigences d'essai applicables aux convertisseurs et ensembles électroniques de puissance, ainsi qu'aux convertisseurs normaux (pour les convertisseurs spéciaux, voir l'IEC TR 60146-1-2);
- spécifier les exigences de fonctionnement de base;
- fournir les exigences d'emploi applicables aux convertisseurs de puissance à semiconducteurs.

IEC TR 60146-1-2, Lignes directrices d'application:

- apporter des informations supplémentaires relatives aux conditions d'essai et aux composants (par exemple: valves à semiconducteurs), lorsque ces informations sont exigées pour leur utilisation dans les convertisseurs de puissance à semiconducteurs, pour compléter ou modifier les normes existantes;
- fournir les références utiles, les coefficients de calcul, les formules et les diagrammes utilisés dans la pratique des convertisseurs de puissance.

CONVERTISSEURS À SEMICONDUCTEURS – EXIGENCES GÉNÉRALES ET CONVERTISSEURS COMMUTÉS PAR LE RÉSEAU –

Partie 1-1: Spécification des exigences de base

1 Domaine d'application

La présente partie de l'IEC 60146 spécifie les exigences relatives aux caractéristiques de fonctionnement de tous les convertisseurs de puissance à semiconducteurs, ainsi que des commutateurs de puissance à semiconducteurs utilisant des valves électroniques, commandables et/ou non commandables.

Les valves électroniques comprennent principalement des dispositifs à semiconducteurs, non commandables (c'est-à-dire des diodes de redressement) ou commandables (c'est-à-dire des thyristors, triacs, thyristors blocables et transistors de puissance). Les dispositifs commandables peuvent être à blocage inverse ou à conduction inverse et commandés par un courant, une tension ou par la lumière. Les dispositifs qui ne sont pas bistables sont présumés être utilisés en mode commuté.

Le présent document est prévu en premier lieu pour spécifier les exigences de base applicables aux convertisseurs en général, ainsi que les exigences applicables aux convertisseurs commutés par le réseau, pour la conversion de puissance alternative en puissance continue ou vice versa. Certaines parties du présent document s'appliquent également à d'autres types de convertisseurs électroniques de puissance, sous réserve qu'il n'existe pas de normes de produit qui leur soient propres.

Ces exigences spécifiques relatives aux équipements s'appliquent aux convertisseurs de puissance à semiconducteurs qui, soit mettent en œuvre différents modes de conversion, soit utilisent différents types de commutation (par exemple convertisseurs autocommutés à semiconducteurs), soit correspondent à des applications particulières (par exemple convertisseurs à semiconducteurs pour moteurs à courant continu), voire englobent diverses propriétés spécifiques (par exemple convertisseurs directs en courant continu pour matériel roulant à traction électrique).

Le présent document s'applique à tous les convertisseurs de puissance non couverts par une norme de produit spécifique, ou si ladite norme ne couvre pas des caractéristiques particulières. Généralement, les normes de produit spécifiques aux convertisseurs de puissance font référence au présent document.

NOTE 1 Le présent document n'est pas destiné à définir des exigences de CEM. Il couvre tous les phénomènes et introduit par conséquent des références aux normes spécifiques applicables conformément à leur domaine d'application.

NOTE 2 Pour les informations relatives aux transformateurs de conversion, relatives au présent document, voir l'IEC 61378-1.

NOTE 3 Tous les termes cités dans l'Article 3 ne sont pas nécessairement utilisés dans le présent document. Ils sont toutefois nécessaires pour établir une compréhension commune de l'application des convertisseurs à semiconducteurs.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule

l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-551:1998, *Vocabulaire Électrotechnique International – Partie 551: Électronique de puissance*, disponible à l'adresse www.electropedia.org

IEC 60050-551-20:2001, *Vocabulaire Électrotechnique International – Partie 551-20: Électronique de puissance – Analyse harmonique*, disponible à l'adresse www.electropedia.org

IEC 60664-1:2020*, Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

IEC 61000-2-4:2002, *Compatibilité électromagnétique (CEM) – Partie 2-4: Environnement – Niveaux de compatibilité dans les installations industrielles pour les perturbations conduites à basse fréquence*

IEC 61000-3-2:2018, *Compatibilité électromagnétique (CEM) – Partie 3-2: Limites – Limites pour les émissions de courant harmonique (courant appelé par les appareils ≤ 16 A par phase)*

IEC 61000-3-12:2011, *Compatibilité électromagnétique (CEM) – Partie 3-12: Limites – Limites pour les courants harmoniques produits par les appareils connectés aux réseaux publics basse tension ayant un courant appelé > 16 A et ≤ 75 A par phase*

IEC 61000-4-7:2002, *Compatibilité électromagnétique (CEM) – Partie 4-7: Techniques d'essai et de mesure – Guide général relatif aux mesures d'harmoniques et d'interharmoniques, ainsi qu'à l'appareillage de mesure, applicable aux réseaux d'alimentation et aux appareils qui y sont raccordés*

IEC 61000-6-1:2016, *Compatibilité électromagnétique (CEM) – Partie 6-1: Normes génériques – Norme d'immunité pour les environnements résidentiels, commerciaux et de l'industrie légère*

IEC 61000-6-2:2016, *Compatibilité électromagnétique (CEM) – Partie 6-2: Normes génériques – Norme d'immunité pour les environnements industriels*

IEC 61000-6-4:2018, *Compatibilité électromagnétique (CEM) – Partie 6-4: Normes génériques – Norme sur l'émission pour les environnements industriels*

IEC 61378-1:2011, *Transformateurs de conversion – Partie 1: Transformateurs pour applications industrielles*

IEC 62477-1:2022, *Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance – Partie 1: Généralités*

IEC 62477-2:2018, *Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance – Partie 2: Convertisseurs électroniques de puissance entre 1 000 V en courant alternatif ou 1 500 V en courant continu et 36 kV en courant alternatif ou 54 kV en courant continu*