



DC POWER

D2.7 – Standardisation and regulation proposal

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IFE

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EXECUTIVE SUMMARY

A proposal for standardisation of MVDC grids is elaborated, which covers typical applications with high power and medium voltage levels as examined in this project. As a basis for this proposal, existing standardisations dealing with LVDC grids are taken into account to ensure the best possible technology compatibility.



Table of Contents

1	Introduction.....	6
2	Standardisation overview.....	6
2.1	Basic Technology.....	6
2.1.1	System descriptions.....	6
2.1.2	Roadmaps.....	8
2.1.3	Voltage Level and Power Quality.....	8
2.1.4	EMC.....	10
2.1.5	Short-Circuit.....	12
2.2	Guidelines.....	12
2.3	Construction and Operation.....	13
2.3.1	Installation.....	13
2.3.2	Safety.....	13
2.3.3	Testing.....	15
2.3.4	Insulation.....	17
2.4	Electrical Equipment.....	17
2.4.1	Cables.....	17
2.4.2	Switches and Fuses.....	18
2.4.3	Couplers.....	22
2.4.4	Power Electronics.....	22
2.4.5	Measurement and Monitoring.....	25
2.5	Application.....	26
2.5.1	General.....	26
2.5.2	Photovoltaic.....	28
2.5.3	Battery and Storage.....	32
2.5.4	Fuel Cell.....	35
2.5.5	Information Technology.....	36
2.5.6	Railway.....	36
2.5.7	Ship.....	37
	Project Partners.....	39





1 Introduction

This document provides an overview of all relevant standards that could be applied or could represent barriers for the realisation of a DC grid according to our system architecture. For the sake of clarity, the standards are categorised and briefly presented with title, scope and link.

The document also serves as a working document for Task T2.5 and is constantly being expanded. Further standards can be added, irrelevant standards can be deleted and notes on relevant topics can be added.

The overall result, including recommendations for subsequent standardisation work, will be published as an update at the end of the project as Deliverable D2.8.

2 Standardisation overview

2.1 Basic Technology

2.1.1 System descriptions

DC INDUSTRIE2 System description

System description

Describes a concept for an industrial DC grid

<https://odca.zvei.org/resources/publications/updated-system-description-for-dc-industrie2>

Note: Only applies to systems with voltages below 1000 V, but the concept can be applied to other voltages. This is also used for VDE SPEC 90037.

VDE SPEC 90037

ODCA System description

This system concept describes industrial low-voltage direct current (LVDC) installations. It has been successfully tested in many model applications in industry and on research sites and is applicable to a wide range of sectors such as manufacturing, electromobility, chemical industry, process industry, as well as commercial, office, and residential buildings.

<https://www.vde.com/resource/blob/2313984/a3a328fa14dc59fbeb4d17197124d80/vde-spec-90037-v1-0--de-en----geschaeftsplan-data.pdf>

Note: Only applies to systems with voltages below 1000 V, but the concept can be applied to other voltages.



IEC TR 63282-101

LVDC systems: DC power distribution system for typical scenarios

The purpose of this TR is to give examples of LVDC installations in a consistent structure represented as cases including voltage bands, power quality, earthing, control and protection. This document is to be used in conjunction with and as a supplement to IEC TR 63282.

https://www.iec.ch/ords/f?p=103:38:112213710171339:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:1240,23,112732

IEC TR 63282-102

LVDC systems: Technical report for low-voltage DC electric island power supply System

The scope of this document is to assess the existing technical requirements (by TC64, TC82, SyC LVDC) and close any gaps related to electric island LVDC power supply systems in rural or remote areas without electricity. Additionally, it covers the case of LVDC power supply systems for ships as a special scenario.

https://www.iec.ch/dyn/www/f?p=103:38:307786535506214:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:1240,23,112733

IEC SRD 63469

Systems Reference Document (SRD) Use Case Collection and Analysis: LVDC Systems for Public Electricity Distribution and distribution microgrids

This document applies to LVDC systems with a rated voltage of up to and including 1 500 V DC [not exceeding 1 500 V DC] and used in public electricity distribution. High voltage systems and systems used for distribution of electricity in private premises and related use cases are excluded from the scope.

https://www.iec.ch/dyn/www/f?p=103:38:606730742101893:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:20447,23,110872

IEC 60364 series

Low-voltage electrical installations

Note: Many important sections about general low-voltage installations, especially section IEC 60664-1 (see 2.5.1) and IEC TR 60664-2-1 (see 2.5.1) could be relevant for our architecture.



IEEE 1709-2018

IEEE Recommended Practice for 1 kV to 35 kV Medium-Voltage DC Power Systems on Ships
(see 2.5.6)

2.1.2 Roadmaps

IEC TR 63410

Decentralized electrical energy systems roadmap

IEC TR 63410, which is a Technical Report, aims to prepare a road map for categorizing Decentralized Electrical Energy Systems and identifying gaps in the existing standards relevant to Decentralized Electrical Energy Systems

<https://webstore.iec.ch/en/publication/65975>

2.1.3 Voltage Level and Power Quality

IEC TR 63282

LVDC systems - Assessment of standard voltages and power quality requirements

The purpose of this document is to collect information and report experience in order to make recommendations for the standardization of voltage levels and related aspects (power quality, EMC, measurement ...) for LVDC systems (systems with nominal voltage up to and including 1 500 V d.c.)

<https://webstore.iec.ch/en/publication/68957>

EN 50160

Voltage characteristics of electricity supplied by public distribution networks

The EN 50610 standard is the most important document dealing with power quality in Europe and other parts of the world. It characterizes the essential features of the electrical voltage in public distribution systems at the grid connection point in public low-voltage (LV), medium-voltage (MV) and high-voltage (HV) alternating current networks under normal operating conditions. The standard therefore defines a so-called minimum quality of voltage that is available to the user (device) at the connection point. This minimum quality is required for an installed device to function properly.



<https://www.dinmedia.de/en/standard/din-en-50160/327353625>

IEC TR 63282:2024

LVDC systems - Assessment of standard voltages and power quality requirements

IEC TR 63282:2024, which is a technical report, collects information and report experience for the standardization of voltage levels and related aspects (power quality, EMC, measurement, etc.) for LVDC systems (systems with nominal voltage up to and including 1 500 V DC).

Rationale for the proposed voltage values is given. Variation of parameters for the voltage (power quality) for their boundaries are defined. Nevertheless, some of the technical items are not exhaustively explained in this document and some gaps are identified for future work.

Attention is paid to the definition of DC voltage.

Systems in which a unipolar voltage is interrupted periodically for certain purposes, e.g. pulse voltage, are not considered.

Traction systems are excluded from this document.

<https://webstore.iec.ch/en/publication/68957>

IEC 60850

Supply voltage of traction systems

(see 2.5.5)

IEC TS 63471:2023

DC voltages for HVDC grids

IEC TS 63471:2023 provides a recommended DC voltage series for HVDC grids with a DC voltage above 1,5 kV. It concerns the selection of a nominal DC voltage of multi-terminal HVDC power transmission and distribution systems and meshed HVDC networks, grids, rather than a rated DC voltage or highest DC voltage.

There is no stringent requirement to consider this DC voltage series for the DC voltage selection for any stand-alone (not forming part of DC Grid) HVDC projects, e.g. a point-to-point HVDC power transmission and distribution system. However, in order to facilitate the later progression towards larger HVDC systems in the future the use of standardized DC voltages is very useful. At later stages, with multi-terminal systems and meshed HVDC grids, the use of harmonized voltages will indeed become essential in order to optimize both capital and



operational costs. Also, for entirely new projects, system planning should include this outlook and can benefit from the use of the recommended DC voltage series.

<https://webstore.iec.ch/en/publication/78653>

IEC 60038

IEC standard voltages

IEC 60038 specifies standard voltage values which are intended to serve as preferential values for the nominal voltage of electrical supply systems, and as reference values for equipment and system design.

<https://webstore.iec.ch/en/publication/72877>

2.1.4 EMC

IEC 61000-2-4

Electromagnetic compatibility (EMC) - Part 2-4: Environment - Compatibility levels in power distribution systems in industrial locations for low-frequency conducted disturbances

IEC 61000-2-4:2024 is related to conducted disturbances in the frequency range from 0 kHz to 150 kHz. It gives compatibility levels in differential mode (L-L and L-N) for industrial locations, with a nominal voltage up to 35 kV and a nominal frequency of 50 Hz or 60 Hz.

<https://webstore.iec.ch/en/publication/98734>

IEC TR 61000-2-5

Electromagnetic compatibility (EMC) - Part 2-5: Environment - Description and classification of electromagnetic environments

IEC/TR 61000-2-5:2017(E) is a Technical Report intended for guidance for those who are in charge of considering and developing immunity requirements. It also gives basic guidance for the selection of immunity levels. The data are applicable to any item of electrical or electronic equipment, sub-system or system that operates in one of the locations as considered in this document.

This Technical Report provides the following:

- introduces the concept of disturbance degrees and defines these for each electromagnetic phenomena;
- classifies into various location classes and describes them by means of attributes;



- provides background information on the different electromagnetic phenomena that may exist within the environment and;
- compiles tables of compatibility levels for electromagnetic phenomena that are considered to be relevant for those location classes.

<https://webstore.iec.ch/en/publication/59812>

IEC 61000-6-1

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

IEC 61000-6-1:2016 for EMC immunity requirements applies to electrical and electronic equipment intended for use in residential, commercial, public and light-industrial locations. Immunity requirements in the frequency range 0 Hz to 400 GHz are covered. No tests need to be performed at frequencies where no requirements are specified. This generic EMC immunity standard is applicable if no relevant dedicated product or product-family EMC immunity standard exists

<https://webstore.iec.ch/en/publication/25628>

IEC 61000-6-2

Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments

IEC 61000-6-2:2016 for EMC immunity requirements applies to electrical and electronic equipment intended for use in industrial locations, as described below. Immunity requirements in the frequency range 0 Hz to 400 GHz are covered. No tests need to be performed at frequencies where no requirements are specified. This generic EMC immunity standard is applicable if no relevant dedicated product or product-family EMC immunity standard exists.

<https://webstore.iec.ch/en/publication/25629>

IEC TR 63282:2024

LVDC systems - Assessment of standard voltages and power quality requirements

(see 2.1.4)



2.1.5 Short-Circuit

IEC 61660 series

Short-circuit currents in d.c. auxiliary installations in power plants and substations

- Part 1: Calculation of short-circuit currents Short-circuit currents in d.c. auxiliary installations in power plants and substations
- Part 2: Calculation of effects Short-circuit currents in d.c. auxiliary installations in power plants and substations
- Part 3: Examples of calculations

<https://webstore.iec.ch/en/publication/5700>

2.2 Guidelines

IEC SRD 63317

Systems Reference Deliverable (SRD) LVDC industry applications

This technical specification provides a practical guideline for the design and planning of industrial LVDC systems, aiming at interoperability amongst different devices

https://www.iec.ch/dyn/www/f?p=103:38:606730742101893:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:20447,23,103986

VDE SPEC 90024

Protective measures for DC applications

Schutzmaßnahmen bei DC-Anwendungen

Guideline for planning and installation of LV-DC-Applications

<https://www.vde.com/resource/blob/2232324/d0973dec7bc891bb095f62bc228f8fd6/vde-spec-90024-v1-0--de----geschaeftsplan--2----dc-schutzkonzepte-data.pdf>

IEC TS 63354

Guideline for the planning and design of the decentralized direct current distribution systems

This proposed specification is to provide the technical principle for planning and design of the decentralized direct current (DC) distribution systems at low and medium voltage levels, including the technical requirements for the DC system structure and its applicable scenarios, load forecasting, DC equipment selection, grounding and relay protection, monitoring and



automation, communication and measurement, power supply and user access, and connection to alternating current (AC) system, etc.

This specification is applicable to various decentralized DC distribution systems, including those used in industrial parks, buildings, data centers, electric vehicle charging stations, islands, and remote areas etc.

https://www.iec.ch/ords/f?p=103:38:14439386240795::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:20639,23,103711

Note: The planned CIGRE WG C6.31:2020 - Medium voltage direct current (MVDC) grid feasibility study could be important for the project and should be observed.

2.3 Construction and Operation

2.3.1 Installation

IEC 61386-1

Conduit systems for cable management - Part 1: General requirements

(see 2.4.1)

IEC 61084-1

Cable trunking systems and cable ducting systems for electrical installations

(see 2.4.1)

2.3.2 Safety

IEC 61810-1

Electromechanical elementary relays - Part 1: General and safety requirements

(see 2.4.2)

IEC 62852

Connectors for DC-application in photovoltaic systems - Safety requirements and tests

(see 2.5.2)

IEC 62109-1



Safety of power converters for use in photovoltaic power systems - Part 1: General requirements

(see 2.5.2)

IEC 62109-2

Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters

(see 2.5.2)

IEC TS 63543-1

Photovoltaic (PV) module safety qualification for DC system voltage up to 3000 V DC - Part 1: Requirements for construction

(see 2.5.2)

IEC 62477-1

Safety requirements for power electronic converter systems and equipment - Part 1: General

(see 2.4.4)

IEC 62477-2

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

(see 2.4.4)

IEC 62619

Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications

(see 2.5.3)

EN 50122

Railway applications - Fixed installations - Electrical safety, earthing and the return circuit



(see 2.5.5)

IEC 62477-1

Safety requirements for power electronic converter systems and equipment - Part 1: General

(see 2.4.4)

IEC 62109-1

Safety of power converters for use in photovoltaic power systems

(see 2.5.2)

IEC 62477-1

Safety requirements for power electronic converter systems and equipment

(see 2.4.4)

2.3.3 Testing

IEC 60664-1

Insulation coordination for equipment within low-voltage supply systems - Part 1: Principles, requirements and tests

(see 2.5.1)

IEC TS 63543-2

Photovoltaic (PV) module safety qualification for DC system voltage up to 3 000 V DC - Part 2: Requirements for testing

(see 2.5.2)

IEC TR 60664-2-1

Insulation coordination for equipment within low-voltage systems - Part 2-1: Application guide - Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing



(see 2.5.1)

IEC 62446-1

Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection

(see 2.5.2)

IEC 61180

High-voltage test techniques for low-voltage equipment - Definitions, test and procedure requirements, test equipment

IEC 61180:2016 is applicable to dielectric tests with direct voltage; dielectric tests with alternating voltage; dielectric tests with impulse voltage and test equipment used for dielectric tests on low-voltage equipment. This standard is applicable only to tests on equipment having a rated voltage of not more than 1 kV a.c. or 1,5 kV d.c. This standard is applicable to type and routine tests for objects which are subjected to high voltage tests as specified by the technical committee. The test equipment comprises a voltage generator and a measuring system. This standard covers test equipment in which the measuring system is protected against external interference and coupling by appropriate screening, for example a continuous conducting shield. Therefore, simple comparison tests are sufficient to ensure valid results. This standard is not intended to be used for electromagnetic compatibility tests on electric or electronic equipment. Tests with the combination of impulse voltages and currents are covered by IEC 61000-4-5. This standard provides the relevant technical committees as far as possible with:

- defined terms of both general and specific applicability;
- general requirements regarding test objects and test procedures;
- methods for generation and measurement of test voltages;
- test procedures;
- methods for the evaluation of test results and to indicate criteria for acceptance;
- requirements concerning approved measuring devices and checking methods and measurement uncertainty.

Alternative test procedures may be required and these should be specified by the relevant technical committees. Care should be taken if the test object has voltage limiting devices, as they may influence the results of the test. The relevant technical committees should provide guidance for testing objects equipped with voltage limiting devices. This 1st edition of IEC 61180 cancels and replaces the 1st edition of IEC 61180-1, issued in 1992, and the 1st edition



of IEC 61180-2, issued in 1994. Key words: High Voltage Test Techniques, Dielectric Tests, Disruptive Discharge, Withstand Voltage.

<https://webstore.iec.ch/en/publication/25234>

2.3.4 Insulation

EN 50124-1 and -2

Railway applications insulation coordination

(see 2.5.5)

IEC 60664-1

Insulation coordination for equipment within low-voltage supply systems

(see 2.5.1)

IEC 60502-1

Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1,2$ kV) up to 30 kV ($U_m = 36$ kV) - Part 1: Cables for rated voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV)

(see 2.4.1)

2.4 Electrical Equipment

2.4.1 Cables

IEC 60502-1

Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1,2$ kV) up to 30 kV ($U_m = 36$ kV) - Part 1: Cables for rated voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV)

IEC 60502-1:2021 specifies the construction, dimensions and test requirements of power cables with extruded solid insulation for rated AC voltages of 1 kV ($U_m = 1,2$ kV) and 3 kV ($U_m = 3,6$ kV) for fixed installations such as distribution networks or industrial installations. Cables of rated AC voltage 1 kV ($U_m = 1,2$ kV) designed and tested in accordance with this document can also be used, if declared by the manufacturer, in DC distribution systems having their nominal voltage ≤ 750 V DC (with a maximum of 900 V DC) between a live conductor and



neutral/earth, or $\leq 1\,500$ V DC (with a maximum $1\,800$ V DC) between two live conductors. Applicable core identification for DC systems are considered in accordance with local installation regulations.

<https://webstore.iec.ch/en/publication/68535>

IEC 60287 series

Electric cables - Calculation of the current rating

Electric cables - Calculation of the current rating and calculation of losses

<https://webstore.iec.ch/en/publication/62420>

IEC 61386-1

Conduit systems for cable management - Part 1: General requirements

IEC 61386-1:2008+A1:2017 specifies requirements and tests for conduit systems, including conduits and conduit fittings, for the protection and management of insulated conductors and/or cables in electrical installations or in communication systems up to $1\,000$ V a.c. and/or $1\,500$ V d.c.

<https://webstore.iec.ch/en/publication/60579>

IEC 61084-1

Cable trunking systems and cable ducting systems for electrical installations

IEC 61084-1 specifies requirements and tests for cable trunking systems (CTS) and cable ducting systems (CDS) intended for the accommodation, and where necessary for the electrically protective separation, of insulated conductors, cables and possibly other electrical equipment in electrical and/or communication systems installations. The maximum voltage of these installations is $1\,000$ V AC and $1\,500$ V DC.

This document does not apply to conduit systems, cable tray systems, cable ladder systems, power track systems or equipment covered by other standards.

<https://webstore.iec.ch/en/publication/92096>

2.4.2 Switches and Fuses

IEC PT 60947-10



Low-voltage switchgear and controlgear - Part 10: Semiconductor circuit-breakers

semiconductor circuit-breakers, intended to be installed and operated by instructed or skilled persons, the main terminals of which are intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c

https://www.iec.ch/ords/f?p=103:14:653115634231:::FSP_ORG_ID:27183

IEC 61810-1

Electromechanical elementary relays - Part 1: General and safety requirements

This part of IEC 61810 applies to electromechanical elementary relays (non-specified time all-or-nothing relays) for incorporation into low voltage equipment (circuits up to 1 000 V alternate current or 1 500 V direct current). It defines the basic functional and safety requirements and safety-related aspects for applications in all areas of electrical engineering or electronics, such as:

- general industrial equipment,
- electrical facilities,
- electrical machines,
- electrical appliances for household and similar use,
- information technology and business equipment,
- building automation equipment,
- automation equipment,
- electrical installation equipment,
- medical equipment,
- control equipment,
- telecommunications,
- vehicles,
- transportation (e.g. railways).

<https://webstore.iec.ch/en/publication/21880>

IEC 61992-1

Railway applications Fixed Installations DC Switchgear

(see 2.5.5)

IEC 60947



Low voltage switchgear and controlgear

This document applies, when required by the relevant product standard, to low-voltage switchgear and controlgear hereinafter referred to as "equipment" or "device" and intended to be connected to circuits, the rated voltage of which does not exceed 1000 V AC or 1500 V DC.

<https://webstore.iec.ch/en/publication/62425>

IEC 60269 series

Low-voltage fuses

- Part 1: General requirements
- Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)
- Part 4: Supplementary requirements for fuse-links for the protection of semiconductor devices
- Part 5: Guidance for the application of low-voltage fuses
- Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems
- Part 7: Supplementary requirements for fuse-links for the protection of batteries and battery systems

<https://webstore.iec.ch/en/publication/99295>

<https://webstore.iec.ch/en/publication/96037>

<https://webstore.iec.ch/en/publication/99297>

<https://webstore.iec.ch/en/publication/68251>

<https://webstore.iec.ch/en/publication/68843>

<https://webstore.iec.ch/en/publication/60005>

IEC 60947 series

Low-voltage switchgear and controlgear

- Part 1: General rules
- Part 2: Circuit-breakers
- Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
- Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters



- Part 4-2: Contactors and motor-starters - Semiconductor motor controllers, starters and soft-starters
- Part 4-3: Contactors and motor-starters - Semiconductor controllers and semiconductor contactors for non-motor loads
- Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices
- Part 5-2: Control circuit devices and switching elements - Proximity switches
- Part 5-3: Control circuit devices and switching elements - Requirements for proximity devices with defined behaviour under fault conditions (PDDDB)
- Part 5-4: Control circuit devices and switching elements - Method of assessing the performance of low-energy contacts - Special tests
- Part 5-5: Control circuit devices and switching elements - Electrical emergency stop device with mechanical latching function
- Part 5-6: Control circuit devices and switching elements - DC interface for proximity sensors and switching amplifiers (NAMUR)
- Part 5-7: Control circuit devices and switching elements - Proximity devices with analog output
- Part 5-8: Control circuit devices and switching elements - Three-position enabling switches
- Part 5-9: Control circuit devices and switching elements - Flow rate switches
- ...

<https://webstore.iec.ch/en/publication/62425>

IEC 61439 series

Low-voltage switchgear and controlgear assemblies

- Part 0: Guidance to specifying assemblies
- Part 1: General rules
- Part 2: Power switchgear and controlgear assemblies
- Part 3: Distribution boards intended to be operated by ordinary persons (DBO)
- Part 4: Particular requirements for assemblies for construction sites (ACS)
- Part 5: Assemblies for power distribution in public networks
- Part 6: Busbar trunking systems (busways)
- Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations

<https://webstore.iec.ch/en/publication/66003>



<https://webstore.iec.ch/en/publication/67026>

<https://webstore.iec.ch/en/publication/30043>

<https://webstore.iec.ch/en/publication/93494>

<https://webstore.iec.ch/en/publication/89514>

<https://webstore.iec.ch/en/publication/85236>

<https://webstore.iec.ch/en/publication/5463>

<https://webstore.iec.ch/en/publication/77373>

2.4.3 Couplers

IEC 62852

Connectors for DC-application in photovoltaic systems - Safety requirements and tests
(see 2.5.2)

IEC 62852

Connectors for DC-application in photovoltaic systems - Safety requirements and tests
(see 2.5.2)

IEC TS 63236-1

Direct current (DC) appliance couplers for information and communication technology (ICT) equipment installed in data centres and telecom central offices - Part 1: 2,6 kW system
(see 2.5.4)

2.4.4 Power Electronics

IEC 62477-1

Safety requirements for power electronic converter systems and equipment - Part 1: General
IEC 62477-1:2022 applies to power electronic converter systems (PECS), any specified accessories, and their components for electronic power conversion and electronic power switching, including the means for their control, protection, monitoring and measurement, such as with the main purpose of converting electric power, with rated system voltages not exceeding 1 000 V AC or 1 500 V DC.



This document also applies to PECS which intentionally emit or receive radio waves for the purpose of radio communication.

This document can also be used as a reference standard for product committees producing product standards for:

- adjustable speed electric power drive systems (PDS);
- standalone uninterruptible power systems (UPS);
- low voltage stabilized DC power supplies;
- bidirectional power converters.

<https://webstore.iec.ch/en/publication/28936>

IEC 62477-2

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

IEC 62477-2:2018 applies to power electronic converter systems (PECS) and equipment, their components for electronic power conversion and electronic power switching, including the means for their control, protection, monitoring and measurement, such as with the main purpose of converting electric power, with rated system voltages from 1 000 V AC or 1 500 V DC up to 36 kV AC or 54 kV DC.

This document can also be used as a reference standard for product committees producing product standards for

- adjustable speed electric power drive systems (PDS),
- standalone uninterruptible power systems (UPS), and
- stabilized DC power supplies.

For PECS for which no product standard exists, this document provides minimum requirements for safety aspects.

<https://webstore.iec.ch/en/publication/31546>

IEC 62477-1

Safety requirements for power electronic converter systems and equipment - Part 1: General

IEC 62477-1:2022 applies to power electronic converter systems (PECS), any specified accessories, and their components for electronic power conversion and electronic power switching, including the means for their control, protection, monitoring and measurement, such



as with the main purpose of converting electric power, with rated system voltages not exceeding 1 000 V AC or 1 500 V DC.

This document also applies to PECS which intentionally emit or receive radio waves for the purpose of radio communication.

This document can also be used as a reference standard for product committees producing product standards for:

- adjustable speed electric power drive systems (PDS);
- standalone uninterruptible power systems (UPS);
- low voltage stabilized DC power supplies;
- bidirectional power converters.

For PECS and their specified accessories for which no product standard exists, this document provides minimum requirements for safety aspects.

<https://webstore.iec.ch/en/publication/28936>

IEC 60146-1

Semiconductor converters - General requirements and line commutated converters

IEC 60146-1-1:2024 specifies the requirements for the performance of all semiconductor power converters and semiconductor power switches using controllable and/or non-controllable electronic valve devices. It 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.

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.

<https://webstore.iec.ch/en/publication/93342>

IEC 62477-1

Safety requirements for power electronic converter systems and equipment



IEC 62477-1:2022 applies to power electronic converter systems (PECS), any specified accessories, and their components for electronic power conversion and electronic power switching, including the means for their control, protection, monitoring and measurement, such as with the main purpose of converting electric power, with rated system voltages not exceeding 1 000 V AC or 1 500 V DC.

<https://webstore.iec.ch/en/publication/28936>

IEC 62909 series

Bi-directional grid connected power converters - Part 1: General requirements; Part 2: Interface of GPC and distributed energy resources

Part 1: General requirements

IEC 62909-1:2017 specifies general aspects of bi-directional grid-connected power converters (GPC), consisting of a grid-side inverter with two or more types of DC-port interfaces on the application side with system voltages not exceeding 1 000 V AC or 1 500 V DC. In special cases, a GPC will have only one DC-port interface, which is connected to a bidirectional energy-storage device. This document includes terminology, specifications, performance, safety, system architecture, and test-case definitions. The "system architecture" defines interaction between the inverter and converters. Requirements which are common, general, and independent of special characteristics of individual generators and bi-directional storages are defined.

Part 2: Interface of GPC and distributed energy resources

IEC 62909-2:2019 specifies GPC interface requirements for particular distributed energy resources, namely electric vehicle (EV), battery, and photovoltaic (PV) systems. These requirements are in addition to the general requirements given in IEC 62909-1.

<https://webstore.iec.ch/en/publication/32993>

<https://webstore.iec.ch/en/publication/26543>

2.4.5 Measurement and Monitoring

IEC TS 62898-3-5

Microgrids – Technical requirements – Testing for Microgrid Monitoring, Control, and Energy Management Systems

This proposal provides technical requirements for the hardware in the loop testing (HIL), commissioning testing, and periodic testing that allows the verification, and quantification of



the performance of Microgrid Monitoring, Control, and Energy Management Systems (MMCS & MEMS). This technical specification applies to MMCS & MEMS developed for grid-connected or islanded microgrids

https://www.iec.ch/dyn/www/f?p=103:38:606730742101893::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:20639,23,116874

IEC 61557-12

Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC - Equipment for testing, measuring or monitoring of protective measures - Part 12: Power metering and monitoring devices (PMD)

IEC 61557-12:2018+A1:2021 specifies requirements for power metering and monitoring devices (PMD) that measure and monitor the electrical quantities within electrical distribution systems, and optionally other external signals. These requirements also define the performance in single- and three-phase AC or DC systems having rated voltages up to 1 000 V AC or up to 1 500 V DC. These devices are fixed or portable. They are intended to be used indoors and/or outdoors. Power metering and monitoring devices (PMD), as defined in this document, give additional safety information, which aids the verification of the installation and enhances the performance of the distribution systems. The power metering and monitoring devices (PMD) for electrical parameters described in this document are used for general industrial and commercial applications. This document does not address functional safety and cyber security aspects.

<https://webstore.iec.ch/en/publication/69019>

IEC 63027

Photovoltaic power systems - DC arc detection and interruption

(see 2.5.2)

2.5 Application

2.5.1 General

VDE SPEC 90024

Protective measures for DC applications

(see 2.2)



IEC TS 63354

Guideline for the planning and design of the decentralized direct current distribution systems

This proposed specification is to provide the technical principle for planning and design of the decentralized direct current (DC) distribution systems at low and medium voltage levels, including the technical requirements for the DC system structure and its applicable scenarios, load forecasting, DC equipment selection, grounding and relay protection, monitoring and automation, communication and measurement, power supply and user access, and connection to alternating current (AC) system, etc.

This specification is applicable to various decentralized DC distribution systems, including those used in industrial parks, buildings, data centers, electric vehicle charging stations, islands, and remote areas etc.

IEC 60664-1

Insulation coordination for equipment within low-voltage supply systems - Part 1: Principles, requirements and tests

This part of IEC 60664 deals with insulation coordination for electrical equipment having a rated voltage up to AC 1 000 V or DC 1 500 V connected to low-voltage supply systems

<https://www.vde-verlag.de/standards/0100650/din-en-iec-60664-1-vde-0110-1-2022-07.html>

IEC TR 60664-2-1

Insulation coordination for equipment within low-voltage systems - Part 2-1: Application guide - Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing

IEC/TR 60664-2-1:2011, which is a technical report, serves as an application guide for technical committees and manufacturers specifying dimensioning requirements for products in accordance with the IEC 60664 series. The significant items for consideration are as follows:

- a) nominal system voltage(s) or rated insulation voltage(s);
- b) overvoltage category of the products (OV cat.);
- c) any type of overvoltages;
- d) frequency of the voltage;
- e) characteristics of the solid insulating material;



f) pollution degree and humidity levels.

IEC 60664-1

Insulation coordination for equipment within low-voltage supply systems

This part of IEC 60664 deals with insulation coordination for equipment having a rated voltage up to AC 1000 V or DC 1500 V connected to low-voltage supply systems.

<https://webstore.iec.ch/en/publication/59671>

2.5.2 Photovoltaic

IEC TS 63102

Grid code compliance assessment methods for grid connection of wind and PV power plants

IEC TS 63102:2021(E) highlights recommended technical methods of grid code compliance assessment for grid connection of wind and PV power plants as the basic components of grid connection evaluation. The electrical behaviour of wind and PV power plants in this technical specification includes frequency and voltage range, reactive power capability, control performance including active power based control and reactive power based control, fault ride through capability and power quality.

Compliance assessment is the process of determining whether the electrical behaviour of wind and PV power plants meets specific technical requirements in grid codes or technical regulations. The assessment methods include compliance testing, compliance simulation and compliance monitoring. The input for compliance assessment includes relevant supporting documents, testing results and validated simulation models, and continuous monitoring data. The scope of this technical specification only covers assessment methods from a technical aspect; processes related to certification are not included.

This technical specification is applicable to wind and PV power plants connected to the electrical power grid.

<https://webstore.iec.ch/en/publication/31475>

IEC TR 63534

Integrating distributed PV into LVDC systems and use cases

https://www.iec.ch/dyn/www/f?p=103:30::::FSP_ORG_ID:10072



IEC 62852

Connectors for DC-application in photovoltaic systems - Safety requirements and tests

IEC 62852:2014+A1:2020 applies to connectors for use in the d.c. circuits of photovoltaic systems according to class II of IEC 61140:2001 with rated voltages up to 1 500 V d.c. and rated currents up to 125 A per contact. It applies to connectors without breaking capacity but which might be engaged and disengaged under voltage. This consolidated version consists of the first edition (2014) and its amendment 1 (2020). Therefore, no need to order amendment in addition to this publication.

<https://webstore.iec.ch/en/publication/66763>

IEC 62109-1

Safety of power converters for use in photovoltaic power systems - Part 1: General requirements

IEC 62109-1:2010 applies to the power conversion equipment (PCE) for use in photovoltaic systems where a uniform technical level with respect to safety is necessary. Defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards. Provides general requirements applicable to all types of PV PCE.

<https://webstore.iec.ch/en/publication/6470>

IEC 62109-2

Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters

IEC 62109-2:2011 covers the particular safety requirements relevant to d.c. to a.c. inverter products as well as products that have or perform inverter functions in addition to other functions, where the inverter is intended for use in photovoltaic power systems. Inverters covered by this standard may be grid-interactive, stand-alone, or multiple mode inverters, may be supplied by single or multiple photovoltaic modules grouped in various array configurations, and may be intended for use in conjunction with batteries or other forms of energy storage. This standard must be used jointly with IEC 62109-1.

<https://webstore.iec.ch/en/publication/6471>

IEC TS 63543-1



Photovoltaic (PV) module safety qualification for DC system voltage up to 3000 V DC - Part 1: Requirements for construction

This is a draft for the safety requirement for PV modules with system voltage V_{sys} exceeding 1500 V DC and up to and including 3000V DC

https://www.iec.ch/ords/f?p=103:38:15644808394679:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:1276,23,121052

IEC TS 63543-2

Photovoltaic (PV) module safety qualification for DC system voltage up to 3 000 V DC - Part 2: Requirements for testing

The objective of this document is to provide the testing sequence intended to verify the safety of PV modules whose construction has been assessed by IEC TS 63XXX-1. The test sequence and pass criteria are designed to detect the potential breakdown of internal and external components of PV modules that would result in fire, electric shock, and/or personal injury. This document defines the basic safety test requirements and additional tests that are a function of the PV module end-use applications

https://www.iec.ch/ords/f?p=103:38:604415096188424:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:1276,23,121053

IEC 63027

Photovoltaic power systems - DC arc detection and interruption

IEC 63027:2023 applies to equipment used for the detection and optionally the interruption of electric DC arcs in photovoltaic (PV) system circuits. The document covers test procedures for the detection of series arcs within PV circuits, and the response times of equipment employed to interrupt the arcs.

<https://webstore.iec.ch/en/publication/27362>

IEC 62852

Connectors for DC-application in photovoltaic systems - Safety requirements and tests

IEC 62852:2014+A1:2020 applies to connectors for use in the d.c. circuits of photovoltaic systems according to class II of IEC 61140:2001 with rated voltages up to 1 500 V d.c. and rated currents up to 125 A per contact. It applies to connectors without breaking capacity but



which might be engaged and disengaged under voltage. This consolidated version consists of the first edition (2014) and its amendment 1 (2020). Therefore, no need to order amendment in addition to this publication.

<https://webstore.iec.ch/en/publication/66763>

IEC 62109-1

Safety of power converters for use in photovoltaic power systems

IEC 62109-1 applies to the power conversion equipment (PCE) for use in photovoltaic systems where a uniform technical level with respect to safety is necessary. Defines the minimum requirements for the design and manufacture of PCE for protection against electric shock, energy, fire, mechanical and other hazards. Provides general requirements applicable to all types of PV PCE.

<https://webstore.iec.ch/en/publication/6470>

IEC 62446-1

Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection

IEC 62446-1:2016+A1:2018 defines the information and documentation required to be handed over to a customer following the installation of a grid connected PV system. It also describes the commissioning tests, inspection criteria and documentation expected to verify the safe installation and correct operation of the system. It is for use by system designers and installers of grid connected solar PV systems as a template to provide effective documentation to a customer. This new edition cancels and replaces IEC 62446 published in 2009 and includes the following significant technical change with respect to IEC 62446:2009: expansion of the scope to include a wider range of system test and inspection regimes to encompass larger and more complex PV systems. This consolidated version consists of the first edition (2016) and its amendment 1 (2018). Therefore, no need to order amendment in addition to this publication.

<https://webstore.iec.ch/en/publication/63726>

IEC 62548-1

Photovoltaic (PV) arrays - Part 1: Design requirements

IEC 62548-1:2023 sets out design requirements for photovoltaic (PV) arrays including DC array wiring, electrical protection devices, switching and earthing provisions. The scope



includes all parts of the PV array and final power conversion equipment (PCE), but not including energy storage devices, loads or AC or DC distribution network supplying loads. The object of this document is to address the design safety requirements arising from the particular characteristics of photovoltaic systems. This document also includes extra protection requirements of PV arrays when they are directly connected with batteries at the DC level.

<https://webstore.iec.ch/en/publication/64171>

2.5.3 Battery and Storage

IEC TS 62898-3-6

Microgrids – Technical Requirements – Emergency supply of microgrids by electric vehicles

This technical specification comprises the concept of vehicle-to-microgrid (which inherently includes vehicle-to-load) specifically for the emergency use case of electric vehicles as mobile back-up power supply when the regular power source is unavailable. This document describes the dual use of the energy storage of electric vehicles as a grid-forming power source in a stationary microgrid application, which is an add-on to the main propulsion purpose

https://www.iec.ch/dyn/www/f?p=103:38:606730742101893:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:20639,23,117372

IEC 62619

Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications

IEC 62619:2022 specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications, including stationary applications. When there exists an IEC International Standard specifying test conditions and requirements for cells used in special applications and which is in conflict with this document, the former takes precedence (e.g., IEC 62660 series on road vehicles). The following are some examples of applications that utilize cells and batteries under the scope of this document:

- Stationary applications: telecom, uninterruptible power supplies (UPS), electrical energy storage system, utility switching, emergency power, and similar applications.
- Motive applications: forklift truck, golf cart, automated guided vehicle (AGV), railway vehicles, and marine vehicles, with the exception of road vehicles.

<https://webstore.iec.ch/en/publication/76174>



IEC 62040 series

Uninterruptible power systems (UPS)

- Part 1: Safety requirements
- Part 2: Electromagnetic compatibility (EMC) requirements
- Part 3: Method of specifying the performance and test requirements
- Part 4: Environmental aspects - Requirements and reporting
- Part 5-3: DC output UPS - Performance and test requirements

<https://webstore.iec.ch/en/publication/80573>

<https://webstore.iec.ch/en/publication/59482>

<https://webstore.iec.ch/en/publication/60140>

<https://webstore.iec.ch/en/publication/6346>

<https://webstore.iec.ch/en/publication/26118>

IEC 61427-2

Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 2: On-grid applications

IEC 61427-2:2015+AMD1:2024 CSV relates to secondary batteries used in on-grid Electrical Energy Storage (EES) applications and provides the associated methods of test for the verification of their endurance, properties and electrical performance in such applications. The test methods are essentially battery chemistry neutral, i.e. applicable to all secondary battery types. On-grid applications are characterized by the fact that batteries are connected, via power conversion devices, to a regional or nation- or continent-wide electricity grid and act as instantaneous energy sources and sinks to stabilize the grids performance when randomly major amounts of electrical energy from renewable energy sources are fed into it. Related power conversion and interface equipment is not covered by this part of IEC 61427.

<https://webstore.iec.ch/en/publication/93655>

IEC 62485 series

Safety requirements for secondary batteries and battery installations

Safety requirements for secondary batteries and battery installations

- Part 1: General safety information
- Part 2: Stationary batteries



- Part 3: Traction batteries
- Part 4: Valve-regulated lead-acid batteries for use in portable appliances
- Part 5: Safe operation of stationary lithium ion batteries
- Part 6: Safe operation of lithium-ion batteries in traction applications

<https://webstore.iec.ch/en/publication/22134>

IEC 63056

Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries for use in electrical energy storage systems

IEC 63056:2020 specifies requirements and tests for the product safety of secondary lithium cells and batteries used in electrical energy storage systems (Figure 2) with a maximum DC voltage of 1 500 V (nominal).

Basic safety requirements for the secondary lithium cells and batteries used in industrial applications are included in IEC 62619. This document provides additional or specific requirements for electrical energy storage systems.

Since this document covers batteries for various electrical energy storage systems, it includes those requirements which are common and minimum to the electrical energy storage systems.

Examples of appliances that are within the scope of this document are:

- telecommunications,
- central emergency lighting and alarm systems,
- stationary engine starting,
- photovoltaic systems,
- home (residential) energy storage systems (HESS), and
- large energy storage: on-grid/off-grid.

This document applies to cells and batteries for uninterruptible power supplies (UPS).

This document does not apply to portable systems 500 Wh or below, which are covered by IEC 61960-3.

<https://webstore.iec.ch/en/publication/29224>

IEC 62933 series

Electrical energy storage (EES) systems



Electrical energy storage (EES) systems

- Part 1: Vocabulary
- Part 2-1: Unit parameters and testing methods - General specification
- Part 2-2: Unit parameters and testing methods - Application and performance testing
- Part 2-200: Unit parameters and testing methods - Case study of electrical energy storage (EES) systems located in EV charging station with PV
- Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification
- Part 3-2: Planning and performance assessment of electrical energy storage systems - Additional requirements for power intensive and renewable energy sources integration related applications
- Part 3-3: Planning and performance assessment of electrical energy storage systems - Additional requirements for energy intensive and backup power applications
- Part 4-1: Guidance on environmental issues - General specification
- Part 5-1: Safety considerations for grid-integrated EES systems - General specification
- Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems
- Part 5-3: Safety requirements for grid-integrated EES systems – Performing unplanned modification of electrochemical based system

<https://webstore.iec.ch/en/publication/64642>

2.5.4 Fuel Cell

IEC 62282-3-300

Fuel cell technologies - Part 3-300: Stationary fuel cell power systems - Installation

IEC 62282-3-300 provides minimum safety requirements for the installation of indoor and outdoor stationary fuel cell power systems in compliance with IEC 62282-3-100 and applies to the installation of the following systems:

- intended for electrical connection to mains directly or with a readily accessible, manually operable switch or circuit-breaker;
- intended for a stand-alone power distribution system;
- intended to provide AC or DC power;
- with or without the ability to recover useful heat.

<https://webstore.iec.ch/en/publication/6756>



2.5.5 Information Technology

IEC TS 63236-1

Direct current (DC) appliance couplers for information and communication technology (ICT) equipment installed in data centres and telecom central offices - Part 1: 2,6 kW system

IEC TS 63236-1:2021(E) applies to DC appliance couplers for class I equipment with two active contacts plus an earthing contact, a rated power of 2,6 kW and a rated voltage range from 294 V to 400 V DC. They are intended to power DC information and communication technology equipment only, as specified in IEC 62368-1.

<https://webstore.iec.ch/en/publication/63765>

2.5.6 Railway

EN 50124-1 and -2

Railway applications insulation coordination

Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment; - Part 2: Overvoltages and related protection; German version EN 50124-2:2017

<https://www.din.de/en/getting-involved/standards-committees/dke/publications/wdc-beuth:din21:278538152>

<https://www.din.de/en/getting-involved/standards-committees/dke/publications/wdc-beuth:din21:278537972>

IEC 61992-1

Railway applications Fixed Installations DC Switchgear

IEC 61992 series specifies requirements for d.c. switchgear and controlgear and is intended to be used in fixed electrical installations with nominal voltage not exceeding 3 000 V d.c., which supply electrical power to vehicles for public guided transport, i.e. railway vehicles, tramway vehicles, underground vehicles and trolley-buses. Part 1 specifies general requirements.

<https://webstore.iec.ch/en/publication/6242>

IEC 60850



Supply voltage of traction systems

This International Standard specifies the main characteristics of the supply voltages of traction systems, such as traction fixed installations, including auxiliary devices fed by the contact line, and rolling stock, for use in the following applications

<https://webstore.iec.ch/en/publication/3685>

EN 50122

Railway applications - Fixed installations - Electrical safety, earthing and the return circuit

This document specifies requirements for the protective provisions relating to electrical safety in fixed installations associated with AC and/or DC traction systems and to any installations that can be endangered by the electric traction power supply system. This also includes requirements applicable to vehicles on electrified lines. It also applies to all aspects of fixed installations which are necessary to ensure electrical safety during maintenance work within electric traction power supply systems. This document specifies requirements for protective provisions against the effects of stray currents, which result from the operation of DC electric traction power supply systems.

As several decades' experience has not shown evident corrosion effects from AC electric traction power supply systems, this document only deals with stray currents flowing from a DC electric traction power supply system.

This document applies to all metallic fixed installations which form part of the traction system, and also to any other metallic components located in any position in the earth, which can carry stray currents resulting from the operation of the railway system.

This document applies to all new DC lines and to all major revisions to existing DC lines. The principles can also be applied to existing electrified transportation systems where it is necessary to consider the effects of stray currents

<https://webstore.iec.ch/en/publication/59671>

2.5.7 Ship

IEEE 1709-2018

IEEE Recommended Practice for 1 kV to 35 kV Medium-Voltage DC Power Systems on Ships
Guidelines to specify, procure, design, manufacture and develop manuals, safety procedures, practices and procedures for effective maintenance of medium-voltage direct current (MVDC) electrical power systems are discussed in this recommended practice. Recommendations are



made for analytical methods, preferred interconnection interfaces and performance characteristics for reliable integration of MVDC electrical components into the ship MVDC electrical power systems.

<https://ieeexplore.ieee.org/document/8569023>



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