

TECHNICAL SPECIFICATION

**Distributed energy resources connection with the grid -
Part 2: Additional requirements for PV generation systems**

CONTENTS

FOREWORD	4
INTRODUCTION	6
1 Scope	8
2 Normative references	8
3 Terms and definitions	9
4 Requirements for PV systems	10
4.1 General	10
4.2 Reference points of requirements	11
4.3 Elements and configuration	11
4.3.1 Elements in PV systems	11
4.3.2 Configuration of PV systems	12
4.4 Basic operation	15
4.5 Protection and fault ride through function	16
4.6 Power control and grid support function	17
4.7 Electromagnetic compatibility for low frequency conducted disturbances	19
4.8 Information exchange for remote monitoring, control, and configuration	20
4.8.1 Remote monitoring	20
4.8.2 Remote control	22
4.8.3 Remote configuration	24
Annex A (normative) Application of point of requirements for the connection of PV systems with electric power networks	30
A.1 Reference points	30
A.2 Relation between compatibility, immunity, emission and planning levels	31
A.2.1 General	31
A.2.2 Use of planning levels for each operation of PV systems	34
Annex B (normative) Electromagnetic environment classes and compatibility levels specified in the IEC 61000 series	37
B.1 Overview	37
B.2 Electromagnetic environment classes	37
B.3 Compatibility levels for each electromagnetic phenomenon	38
B.4 Compatibility levels specified in IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12	40
Annex C (normative) Sign conventions for measurements of voltage, current and power	41
C.1 General	41
C.2 Reference polarity and direction	41
C.2.1 Reference polarity of voltage	41
C.2.2 Reference direction of current	41
C.2.3 Sign conventions for measurements of voltage, current and power	42
C.3 Reference frame of active and reactive power	42
C.4 Physical meanings of the power flows of generators in regional standards	46
Bibliography	49
Figure 1 – Overview of IEC documents relevant to the grid connection of PV systems	7
Figure 2 – Possible elements in PV systems	11
Figure 3 – Example of a grid-tied PV system consisting of a single generating unit	12

Figure 4 – Example of grid-tied PV systems consisting of multiple generating units	13
Figure 5 – Example of remote information exchange in a PV system.....	14
Figure 6 – Example of the producer reference frame.....	16
Figure A.1 – Three reference points where requirements are applied	31
Figure A.2 – Example of the location of PCC in the public low-voltage network	32
Figure A.3 – Illustration of EMC concepts	33
Figure A.4 – Relation between compatibility, immunity, emission and planning levels	34
Figure A.5 – Autonomous operation of PV systems	35
Figure A.6 – Wide and remote area operation of DER and loads with an energy management system	36
Figure C.1 –Reference polarity of voltage	41
Figure C.2 – Reference polarity of current	41
Figure C.3 – Reference polarity and direction for the measurements for DER	42
Figure C.4 – Reference polarity and direction for the measurements for Load	42
Figure C.5 – Rotating vector voltage and current for load.....	43
Figure C.6 – Rotating vector voltage and current for DER	43
Figure C.7 – Complex power for load	44
Figure C.8 – Complex power for DER	45
Figure C.9 – Power quadrants for load	45
Figure C.10 – Power quadrants for DER	46
 Table 1 – List of requirements for PV systems and relevant clauses in IEC TS 62786-1.....	 10
Table 2 – Types of PV system with possible elements	12
Table 3 – Example of some parts comprising PV systems, excluding the PCE	14
Table 4 – Requirements and relevant IEC documents on each function	17
Table 5 – Existing standards for immunity requirements.....	20
Table 6 – Nameplate data	21
Table 7 – Basic information (those data are not in the nameplate)	21
Table 8 – Status of the PV system	21
Table 9 – Measured values of the PV system.....	22
Table 10 – Minimum required parameters for Connect/Disconnect	23
Table 11 – Minimum required parameters for Constant power factor control	23
Table 12 – Minimum required parameters for Maximum active power control	23
Table 13 – Minimum required parameters for Active power control.....	24
Table 14 – Minimum required parameters for Reactive power control.....	24
Table 15 – Minimum required parameters for Protection and ride-through relevant to voltage.....	25
Table 16 – Minimum required parameters for Protection and ride-through relevant to frequency.....	25
Table 17 – Minimum required parameters for Voltage – Var control	26
Table 18 – Minimum required parameters for Frequency – Watt control	27
Table 19 – Minimum required parameters for Voltage – Watt control.....	28
Table 20 – Minimum required parameters for dynamic-reactive current control	29
Table B.1 – Classes of electromagnetic environments defined in IEC 61000-2-4.....	38

Table B.2 – Total harmonic distortion	38
Table B.3 – Power supply voltage amplitude variations	38
Table B.4 – Power supply voltage unbalance	38
Table B.5 – Power supply voltage frequency variations	39
Table B.6 – Individual harmonic voltage	39
Table B.7 – Compatibility levels specified in IEC 61000-2-2, IEC 61000-2-4 and IEC 61000-2-12	40
Table C.1 – Physical meanings of the power flows of loads	46
Table C.2 – Physical meanings of the power flows of generators	46
Table C.3 – Physical meanings of the power flows of generators in Japan	47
Table C.4 – Physical meanings of the power flows of generators in IEEE 1547.1	47
Table C.5 – Physical meanings of the power flows of generators in EN 50549-10	47
Table C.6 – Physical meanings of the power flows of generators in AS/NZS 4777.2	48

INTERNATIONAL ELECTROTECHNICAL COMMISSION

Distributed energy resources connection with the grid - Part 2: Additional requirements for PV generation systems

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 62786-2 has been prepared by IEC technical committee 8: System aspects of electrical energy supply. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
8/1756/DTS	8/1790/RVDTS

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 Technical Specification 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 in the IEC 62786 series, published under the general title *Distributed energy resources connection with the grid*, can be found on the IEC website.

This document is to be read in conjunction with IEC TS 62786-1:2023

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.

INTRODUCTION

The use of solar photovoltaic energy systems or photovoltaic generating systems (PV systems) has been expanding rapidly around the world as one of distributed energy resources (DER). While the growing adoption of PV systems has benefits such as CO₂ reduction, the intermittent power supply characteristic of PV systems raises concerns about the power imbalance in the power network as well as about the instability of electric power networks showing up as voltage fluctuations and frequency deviations.

However, not only can PV systems convert the solar power to electricity, which is fed into the electric power networks, but PV systems can also provide operational functions which support the stability, reliability, and efficiency of electric power networks. Moreover, PV systems can also operate autonomously and are able to respond rapidly to the local conditions of the electrical power network as well as effectively participate in the management of electrical power networks by exchanging information with system operators and other DER.

In 2017, IEC TS 62786 Ed.1, which specified the general requirements for connecting DER to the electrical power network networks, was published. During the development of IEC TS 62786 Ed. 1, it has been recognised that standardization should address the requirements for the specific types of DER. That was because TC82 proposed in 2016 to develop a standard on grid connection requirements for solar photovoltaic energy systems on the basis of IEC TS 62786 and to publish it as a sub-part of IEC TS 62786. Consequently, JWG10 was established under TC8 in 2018, and JWG10 held a kick-off meeting with TC82 and TC120 in March 2018 and agreed to start the development of the TS 62786 series.

In October 2018, JWG10 proposed a new standardization policy for the TS 62786 series so that the TS 62786 series would have a hierarchical structure. The top layer is Part 1 of the TS 62786 series, which specifies general technical requirements for DER relevant to grid connection such as power control and grid protection functions. Additionally, TS 62786-1 specifies new requirements regarding interoperability to implement information exchange for remote monitoring, control and configuration. In October 2021, TC8 CAG agreed on the hierarchical structure of the TS 62786 series, and it was agreed that each technical committee can define testing provisions for evaluating the performance of its own product by referring to the TS 62786 series.

As shown in Figure 1, consolidating other IEC documents which specify requirements relevant to grid connection, Part 2 of TS 62786 supplements TS 62786-1. Moreover, Part 2 adds detailed required specifications for PV systems to provide the bridge between requirements for PV systems and power conversion equipment which constitutes these systems.

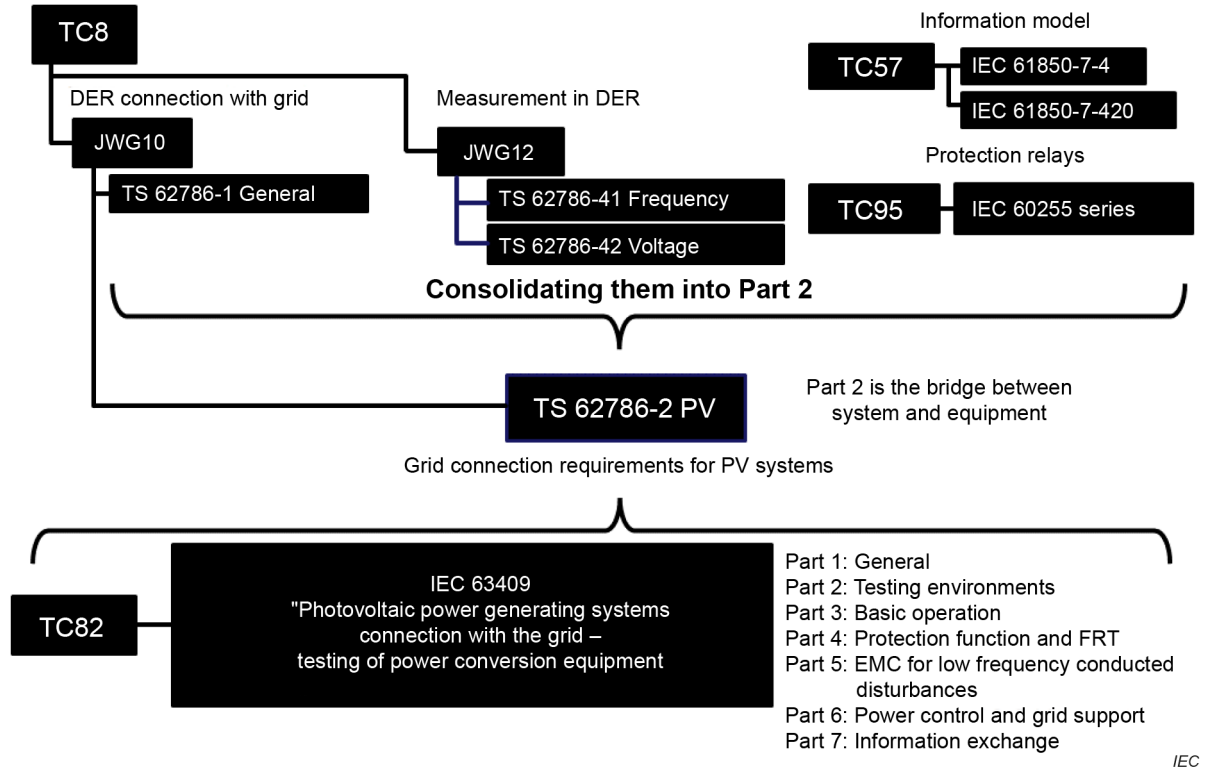


Figure 1 – Overview of IEC documents relevant to the grid connection of PV systems

1 Scope

This part of the IEC TS 62786 series supplements IEC TS 62786-1, and specifies requirements for the connection of the solar photovoltaic energy system or photovoltaic generating system (PV system) with an electric power network, or the network. This document covers all sizes of PV systems connected to low voltage or medium voltage power networks and gives typical requirements for various sizes of PV systems.

In this document, requirements for grid-connected PV systems are applied to those categorized as grid tied, grid tied with storage and grid tied with storage and back up. Mini-grid and Micro-grid are out of scope. Those types of PV systems with possible elements are described in 4.3.

This document specifies the following technical requirements for the PV system:

- reference points of requirements,
- elements and configuration,
- basic operation,
- protection and fault ride through function,
- power control and grid support function,
- electromagnetic compatibility for low frequency conducted disturbances,
- information exchange for remote monitoring, control, and configuration.

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 60050-901:2013, *International Electrotechnical Vocabulary (IEV) – Part 901: Standardization*

IEC 60255-127, *Measuring relays and protection equipment – Part 127: Functional requirements for over/under voltage protection*

IEC 60255-181, *Measuring relays and protection equipment – Part 181: Functional requirements for frequency protection*

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 61000-2-4:2024, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in power distribution systems in industrial locations for low-frequency conducted disturbances*

IEC 61000-2-12, *Electromagnetic compatibility (EMC) – Part 2-12: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems*

IEC 61000-4-27, *Electromagnetic compatibility (EMC) – Part 4-27: Testing and measurement techniques – Unbalance, immunity test for equipment with input current not exceeding 16 A per phase*

Bibliography

IEC 60375, *Conventions concerning electric circuits*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

IEC 61000-4-13, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity test*

IEC 61000-4-19, *Electromagnetic compatibility (EMC) – Part 4-19: Testing and measurement techniques – Test for immunity to conducted, differential mode disturbances and signalling in the frequency range 2 kHz to 150 kHz at a.c. power ports*

IEC 61000-4-28, *Electromagnetic compatibility (EMC) – Part 4-28: Testing and measurement techniques – Variation of power frequency, immunity test for equipment with input current not exceeding 16 A per phase*

IEC 61000-4-34, *Electromagnetic compatibility (EMC) – Part 4-34: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with mains current more than 16 A per phase*

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 61724-1, *Photovoltaic system performance – Part 1: Monitoring*

IEC 61850-7-4, *Communication networks and systems for power utility automation – Part 7-4: Basic communication structure – Compatible logical node classes and data object classes*

IEC 61850-7-420, *Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources and distribution automation logical nodes*

IEC TR 61850-90-7:2023, *Communication networks and systems for power utility automation – Part 90-7: Object models for power converters in distributed energy resources (DER) systems*

IEC 62053-23, *Electricity metering equipment – Particular requirements – Part 23: Static meters for reactive energy (classes 2 and 3)*

IEC TS 62786-3, *Distributed energy resources connection with the grid – Part 3 Additional requirements for Stationary Battery Energy Storage System*

IEC TS 62786-41, *Distributed energy resources connection with the grid – Part 41: Requirements for frequency measurement used to control distributed energy resources (DER) and loads*

EN 50549-10:2022, *Requirements for generating plants to be connected in parallel with distribution networks – Part 10: Tests for conformity assessment of generating units*

IEEE 1547.1-2020, *IEEE Standard Conformance Test Procedures For Equipment Interconnecting Distributed Energy Resources With Electric Power Systems And Associated Interfaces*

AS/NZS 4777.2:2020, *Grid connection of energy systems via inverters, Part 2: Inverter requirements*