

IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces



IEEE Standards Coordinating Committee 21

Sponsored by the
IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed
Generation, and Energy Storage

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3 Park Avenue
New York, NY 10016-5997
USA

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IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

Sponsor

Standards Coordinating Committee 21
Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

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Abstract: The technical specifications for, and testing of, the interconnection and interoperability between utility electric power systems (EPSs) and distributed energy resources (DERs) are the focus of this standard. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It also includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests. The stated requirements are universally needed for interconnection of DER, including synchronous machines, induction machines, or power inverters/converters and will be sufficient for most installations. The criteria and requirements are applicable to all DER technologies interconnected to EPSs at typical primary and/or secondary distribution voltages. Installation of DER on radial primary and secondary distribution systems is the main emphasis of this document, although installation of DERs on primary and secondary network distribution systems is considered. This standard is written considering that the DER is a 60 Hz source.

Keywords: certification, clearing time, codes, commissioning, communications, dc injection, design, diesel generators, dispersed generation, distributed generation, electric distribution systems, electric power systems, energy resources, energy storage, faults, field, flicker, frequency support, fuel cells, generators, grid, grid support, harmonics, IEEE 1547™, induction machines, installation, interconnection requirements and specifications, interoperability, inverters, islanding, microturbines, monitoring and control, networks, paralleling, performance, photovoltaic power systems, point of common coupling, power converters, production tests, quality, power, protection functions, public utility commissions, reclosing coordination, regulations, ride through, rule-making, standards, storage, synchronous machines, testing, trip setting, utilities, voltage regulation, wind energy systems

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Participants

At the time this standard was completed, the Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage had the following membership:

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Charles K. Vartanian, *Treasurer*

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Leo Casey
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Fei Gao
Frank Goodman
Bob Heile
Anderson Hoke

Victor Huang
Ben Kazimier
Joseph L. Koepfinger
Ben Kroposki
Debra Lew
Wenpeng Luan
David J. Narang
Adel Nasiri

Michael Ropp
Robert Saint
Chris Searles
Robby Simpson
Wayne Stec
Reigh Walling
Timothy Zgonena

At the time this standard was completed, the Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces Working Group (P1547 WG) of the Standard Coordinating Committee 21 (SCC21) on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage had the following membership:

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Thomas (Tom) Basso, *Past Chair*
John Berdner, Jens C. Boemer, Babak Enayati, Bob Fox, Mark Siira, *Vice Chairs*
Charles K. Vartanian, *Secretary*

Facilitators

Richard Bravo, Leo Casey, Frances Cleveland, Michael (Mike) Coddington, Dan Mungovan, Mohammad (Aminul) Huque, Marty Page, Jeannie M. Piekarz-Amber, Michael (Mike) Ropp, Chris Rowe, Brian Seal, Wayne Stec, Reigh Walling

Marcelo Algrain
Steven Allmond
Daniel Arjona
Dillon Ashton
Manuel Avendano
George Berntsen
David Blackledge
Jason Bobruk
Michael Brigandi
Edwin Briggs

Paul Brucke
Ken Brunkenhoefer
Jason Byerly
Sean Carr
James Carroll
Sudipta Chakraborty
Ke Chen
Nancy Connelly
Adam Cordova
Robert Cummings

James Daley
Patrick Dalton
Herbert Daugherty
Dick DeBlasio
Mamadou Diongt
Stanley Doe
Paul Dolloff
Anthony Eason
Jonathan Ehlmann
Zakia El Omari

Bryan Espiritu	Scott Karpel	James Reilly
Wesley Fassnacht	Ben Kazimier	Denisse Rivera
Roberto Favela	Gregory Kern	Roe Rodrigo
Terry Fix	John Kotula	John Ruddock
David Forrest	Paul Krell	Nachum Sadan
Masuda Fumio	Kandice Kubojiri	Roger Salas
Darrell Furlong	Jesse Leonard	Janette Sandberg
John Gajda	Eddy Lim	Joseph Schaefer
Halie Gashaw	Howard Liu	Karl Schoder
Ken Gebauer	Brian Lydic	Ulrich Schwabe
Sigifredo Gonzalez	Bruce Magruder	Rich Scroggins
Tilak Gopalarathnam	Fumio Masuda	Robert Sherman
Jason Gunawardena	Barry Mather	Ronald Shipman
Thomas Gwinn	Alex Mayer	Jaspreet Singh
Joshua Hambrick	Jonathan Meyer	Mark Smith
Keith Harley	Lyman Morikawa	Gary Smullin
Robert Harris	Naga Mosam	Jim Sprecher
Allen Heffner	John Moura	Clayton Stice
Paul Heitmann	Rohit Nair	Chase Sun
Anderson Hoke	Amir Najafzadeh	Monica Taba
Soonwook Hong	Eithar Nashawati	Sylvester Toe
Fred Horton	Jeffrey Newmiller	Phillip Undercuffler
Keith Houser	Catherine O'Brien	Rajiv Varma
James Hurtt	Justin Odom	Robert White
Ruben Inzunza	Vishal Patel	Stephen Yee
Hiroshi Iirie	Prasad Pmsvsv	Li Yu
Bob Jordan	Robert Preus	Mehran Zamani
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The following working group members participated in finalizing the development of the standard with working group inputs, and in facilitating the development of those inputs development process:

Marcelo Algrain	Robert Harris	Brian Seal
John Berdner	Anderson Hoke	Ronald Shipman
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The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Mahamadou Abdou Tankari	Abdallah Barakat	Wallace Binder
William Ackerman	John Baranowski	Richard Bingham
Kennedy Aganah	Thomas Barnes	Thomas Blackburn
Mark Ahlstrom	Paul Barnhart	William Bloethe
Ali Al Awazi	Jeffrey Barsch	Jens Boemer
Mihaela Albu	Frank Basciano	Shelly Born
Saleman Alibhay	Michael Basler	Ward Bower
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Jay Anderson	David Beach	Matthew Braet
Daniel Arjona	John Berdner	Richard Bravo
Curtis Ashton	George Berntsen	Edwin Briggs
Carlos Avalos	Martin Best	Adam Bromley
Mark Baldassari	Murty Bhavaraju	David Brown

Paul Brucke
Gustavo Brunello
Ken Brunkenhoefer
Demetrio Jr Bucaneg
Clayton Burns
Jeffrey Burnworth
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Nancy Chilton
Michael Chirico
James Cleary
Frances Cleveland
Michael Coddington
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Larry Conrad
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Adam Cordova
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Dieter Dohnal
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Herbert Dreyer
David Dunne
Anthony Eason
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Aaron Ellis
Zakia El Omari
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Introduction

This introduction is not part of IEEE Std 1547™-2018, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.

IEEE Std 1547 was the first of a series of standards developed by Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage (SCC21) concerning distributed resources interconnection. IEEE Std 1547 was amended in 2014 (IEEE Std 1547a™-2014) in response to a widely expressed need to make changes to subclauses related to voltage regulation, voltage response to Area EPS abnormal conditions, and frequency response to Area EPS abnormal conditions in IEEE Std 1547-2003. The additional documents in that series are as follows:

- IEEE Std 1547.1™ [B17] provides conformance test procedures for equipment interconnecting distributed energy resources (DER) with electric power systems (EPS).¹
- IEEE Std 1547.2™ [B18] is an application guide for IEEE Std 1547.
- IEEE Std 1547.3™ [B19] provides guidance for monitoring, information exchange, and control of DER interconnected with EPS.
- IEEE Std 1547.4™ [B20] provides guidance for design, operation, and integration of distributed resource island systems with EPS.
- IEEE Std 1547.6™ [B21] is a recommended practice for interconnecting DER with electric distribution secondary networks.
- IEEE Std 1547.7™ [B22] provides guidance for conducting distribution impact studies for DER interconnection.

The first publication of IEEE Std 1547 was an outgrowth of the changes in the environment for production and delivery of electricity and built on prior IEEE recommended practices and guidelines developed by SCC21 (which included IEEE Std 929™-2000 [B14] and IEEE Std 1001™-1988 [B15]).

Traditionally, utility EPSs were not designed to accommodate active generation and storage at the distribution level. The technologies and operational concepts to effectively integrate DERs into existing EPSs continue to be further developed to realize additional benefits and to avoid negative impacts on system reliability and safety.

There is a critical need to have a single document of consensus standard technical requirements for DER interconnection rather than having to conform to numerous local practices and guidelines. This standard addresses that critical need by providing uniform criteria and requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection.

The intent of this standard is to define the technical requirements in a manner that can be universally adopted. The universality relates not only to the technical aspects, but also to the adoption of this standard as being pertinent across a number of industries and institutions, e.g., hardware manufacturers, utilities, energy service companies, codes and standards organizations, regulators and legislators, and other interested entities.

This standard focuses on the technical specifications for, and testing of, the interconnection itself, and not on the types of the DER technologies. This standard aims to be technology-neutral, although acknowledges that the technical attributes of DER and the types and characteristics of EPSs do have a bearing on the interconnection requirements. The addition of a DER to an EPS will change the system and its response in some manner. Although this standard establishes criteria and requirements for interconnection, this

¹ The numbers in brackets correspond to the numbers of the bibliography in [Annex A](#).

standard is not a design handbook nor is it an application guideline. This standard provides the minimum functional technical requirements that are universally needed to help assure a technically sound interconnection. Any additional local requirements should not be implemented to the detriment of the functional technical objectives of this standard.

This standard recognizes that distributed energy resources need to be integrated into the Area EPS in coordination with the Area EPS operator. The functions specified in this standard may need to be supplemented in coordination with the Area EPS operator for specific situations.

It is beyond the scope of this standard to address the methods used for performing EPS impact studies, mitigating limitations of the Area EPS, or addressing the business or tariff issues associated with interconnection.

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IEEE Standard for ~~Interconnecting~~ Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

1. Overview

1.1 General

This standard provides interconnection and interoperability technical ~~specifications and requirements~~, and test specifications and requirements for distributed energy resources (DERs). Additionally, ~~there is a bibliography~~ several annexes are included ~~as Annex A that lists citations referred to~~ in this standard that provide additional material for informative purposes, but ~~that~~ are not required to be used in conjunction with this standard.

1.2 Scope

This standard establishes criteria and requirements for interconnection of distributed energy resources (~~DER~~) with electric power systems (EPSs) and associated interfaces. The stated technical specifications and requirements, ~~both technical and testing~~, are universally needed for interconnection and interoperability of ~~DER, including synchronous machines, induction machines, or power inverters/converters~~, distributed energy resources (DERs)² and will be sufficient for most installations.^{†3} The specified performance requirements apply at the time of interconnection and as long as the DER remains in service.

²For example, synchronous machines, induction machines, or static power inverters/converters.

^{†3}Additional technical requirements ~~and/or tests~~ may be necessary for ~~some limited~~ higher DER penetration situations.

1.3 Purpose

This ~~standard document~~ provides a uniform standard for the interconnection and interoperability of distributed energy resources with electric power systems. It provides requirements relevant to the interconnection and interoperability performance, operation, and testing, and, to safety, maintenance and security considerations, ~~and maintenance of the interconnection.~~

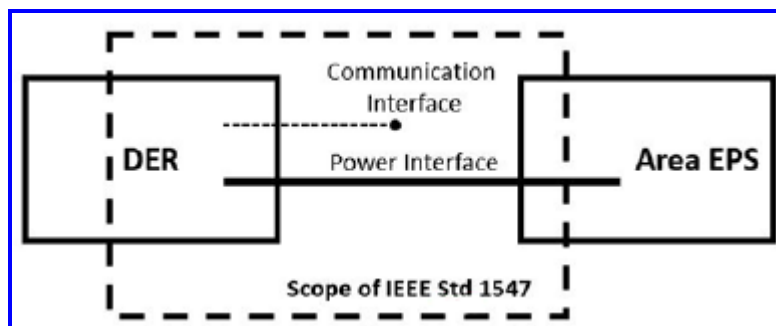
~~The requirements shall be met at the point of common coupling (PCC), although the devices used to meet these requirements can be located elsewhere. This standard applies to interconnection based on the aggregate rating of all the DR units that are within the Local EPS. The functions of the interconnection system hardware and software that affect the Area EPS are required to meet this standard regardless of their location on the EPS.~~

1.4 General remarks and limitations

The criteria and requirements in this document are applicable to all distributed energy resource technologies, ~~with aggregate capacity of 10 MVA or less at the PCC,~~ interconnected to EPSs at typical primary ~~and/or~~ secondary distribution ~~voltages~~ voltage levels. Installation of ~~DR~~ DER on radial primary and secondary distribution systems is the main emphasis of this standard, although installation of ~~DR~~ DER on primary and secondary network distribution systems is considered. This standard ~~is~~ has been written ~~considering that the DR is~~ assuming a 60 Hz ~~source~~ nominal system frequency.⁴

Figure 1 illustrates the scope of this standard. The criteria and requirements in this document may influence the design and capabilities of the power interface, the local DER communication interface and all those parts of a DER that are related to meeting the requirements of this standard. In Clause 4 to Clause 11, the term “DER” refers to all those parts of a DER that are related to meeting the interconnection and interoperability requirements of this standard.

⁴If the standard is used with other nominal frequency values, all frequency values in the standard should be adjusted appropriately. This may require proportional adjustment of the frequency values in coordination with the regional reliability coordinator.



(New)

Figure 1 — Scope of this standard

The following list describes what remains outside the scope of this standard:

- This standard as a whole is not intended for, and is in part inappropriate for, application to energy resources connected to transmission or networked sub-transmission systems.^{5, 6}
- This standard does not define the maximum ~~DR~~ DER capacity for a particular installation that may be interconnected to a single point of common coupling (PCC) or connected to a given feeder.
- Outside of the specific interconnection and interoperability requirements in the following clauses, this standard does not prescribe ~~DR~~ DER self-protection or ~~all~~ any DER operating requirements ~~for DR units,~~ as long as these do not preclude the DER from meeting the requirements of this standard.⁷

⁵Investigations of events that inadvertently tripped bulk power system connected resources in North America suggest that one root cause may have been misapplication of previous versions of this standard; refer to NERC [B28] for more details.

⁶The performance of energy resources connected to transmission or networked sub-transmission systems may be specified by the responsible transmission planner in coordination with the regional reliability coordinator.

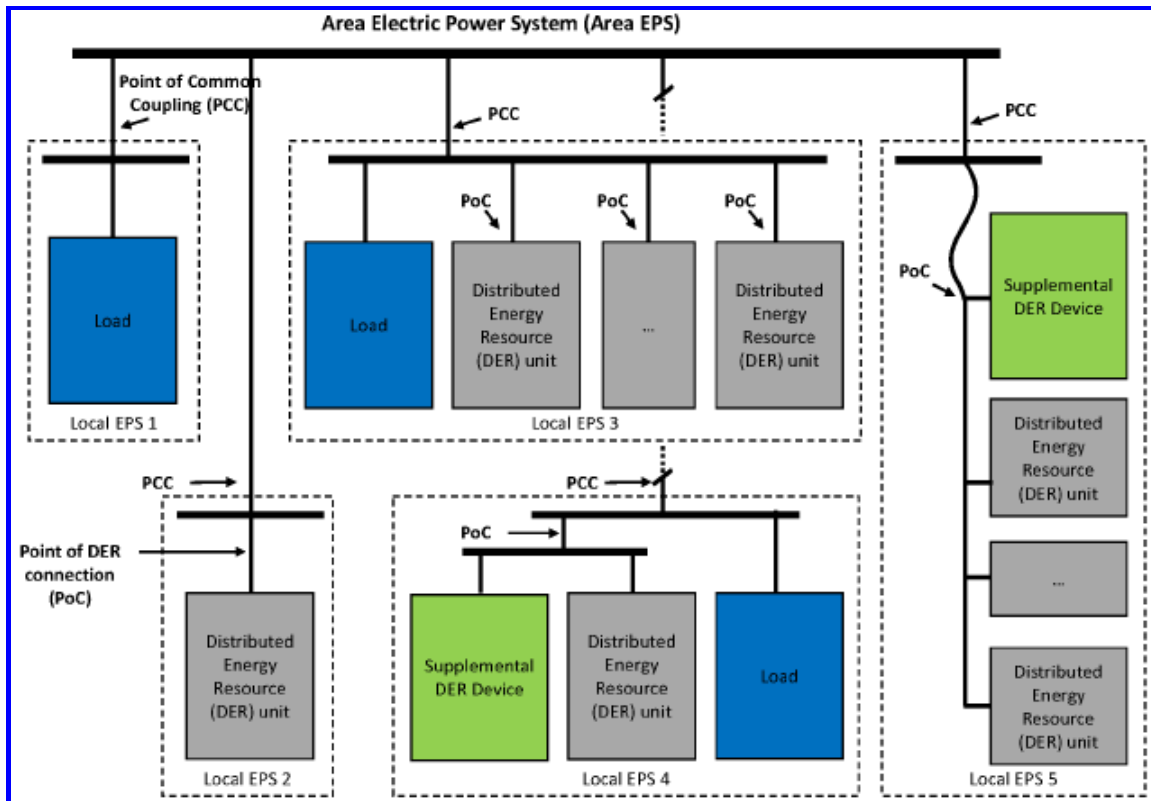
⁷Requirements specified in 6.4.2 and 6.5.2 do provide constraints that must be respected in the application of DER self-protection.

- This standard does not address planning, designing, operating, or maintaining the Area EPS with DER.
- This standard does not apply to automatic transfer schemes in which load is transferred between the ~~DR~~ DER and the EPS in a momentary make-before-break operation provided the duration of paralleling the sources is less than 100 ms, except as noted in ~~4.1.4~~ Clause 9.
- As defined in 4.13, 5.3.1, 6.4.2.1, 6.5.2.1, and 10.1, emergency and standby DER⁸ are exempt from certain requirements of this standard.
- This standard does not give any guidance regarding how the Area EPS operator may specify functional parameter settings other than the default setting within the specified ranges of allowable settings, e.g., to coordinate with the existing Area EPS protection and control devices.
- This standard does not determine the communication network specifics nor the utilization of the DER provisions for a local DER interface capable of communicating (*local DER communication interface*) to support the information exchange requirements specified in this standard.
- The lower and upper values of the *ranges of allowable settings* for voltage and frequency trip settings specified in this standard for DER are not intended to limit the capabilities and settings of other equipment on the Area EPS.⁹
- For DER interconnections that include individual synchronous generator units rated 10 MVA and greater, and where the requirements of this standard conflict with the requirements of IEEE Std C50.12 or IEEE Std C50.13, the requirements of IEEE Std C50.12 or IEEE Std C50.13, as relevant to the type of synchronous generator used, shall prevail.

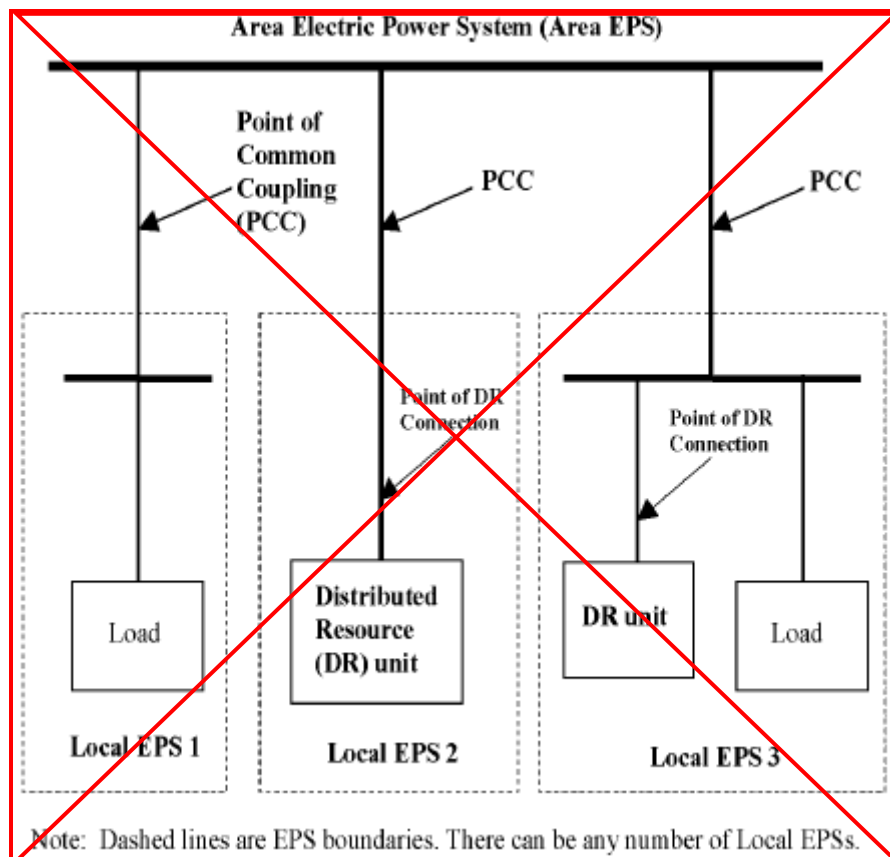
⁸As defined by authority having jurisdiction.

⁹Refer to footnotes 80 and 99 on recommendations for utility practices to use trip settings on Area EPS equipment that conflict with this standard to occasionally and selectively accommodate worker safety practices or to safeguard distribution infrastructure while in an abnormal configuration.

This standard applies to interconnection based on the aggregate nameplate rating of all the DER units that are within the Local EPS. Supplemental DER devices other than DER units may be used to achieve compliance with the requirements of this standard at the applicable reference point per Clause 4. These devices are not required to be co-located with the DER units, but shall be within the Local EPS. The requirements of this standard shall be met regardless of the location of the DER and supplemental DER devices within the Local EPS. These relationships are shown in Figure 2.



(New)



(Deleted)

NOTE 1—The example of Local EPS 1 includes only load. Any requirements for this Local EPS are outside the scope of this standard.

NOTE 2—The example of Local EPS 2 includes only DER. Depending on the DER rating, requirements of this standard apply either at the PCC or the PoC. The DER unit in this example is able to meet requirements at its terminals without any supplemental DER device; the PoC coincides with the DER unit's terminals.

NOTE 3—The example of Local EPS 3 includes both DER units and load. Depending on the aggregate DER units' rating and the percent of average load demand, requirements of this standard apply either at the PCC or the PoC. The two (or more) DER units are able to meet requirements at its terminals without any supplemental DER device; the PoC coincides with the DER units' terminals; there are two (or more) PoCs.

NOTE 4—The example of Local EPS 4 includes a DER unit, a supplemental DER device, and load. Depending on the DER unit's rating and the percent of average load demand, requirements of this standard apply either at the PCC or the PoC. The DER unit is not able to meet requirements at its terminals without any supplemental DER device; the PoC is the point where the requirements of this standard are met by the DER unit in conjunction with the supplemental DER device exclusive of any load, if present, in the respective part of the Local EPS.

NOTE 5—The example of Local EPS 5 includes two (or more) DER units and a supplemental DER device but no load. Depending on the aggregate DER units' rating, requirements of this standard apply either at the PCC or the PoC. As indicated by the curved line, the PCC and PoC may be located well apart from each other. The two (or more) DER units are not able to meet requirements at their terminals without any supplemental DER device; the PoC is the point where the requirements of this standard are met by two (or more) DER units in conjunction with the supplemental DER device exclusive of any load, if present, in the respective part of the Local EPS.

Figure 2 — Relationship of interconnection terms

The stated technical specifications and requirements are universally needed for interconnection and interoperability of DER¹⁰ and will be sufficient for most installations.¹¹ The applicability of certain specifications and requirements are dependent on application considerations. For these, the requirements are provided in terms of a limited number of technology-neutral performance categories, for which it is the responsibility of the *authority governing interconnection requirements* (AGIR) to determine applicability. The rationale used as the basis for the performance categories is as follows:

For categories related to reactive power capability and voltage regulation performance requirements (Clause 5):

¹⁰For example, synchronous machines, induction machines, or static power inverters/converters.

¹¹Additional technical requirements may be necessary for some limited situations.

- Category A covers minimum performance capabilities needed for Area EPS voltage regulation and are reasonably attainable by all DER technologies as of the publication of this standard. This level of performance is deemed adequate for applications where the DER penetration in the distribution system is lower,¹² and where the overall DER power output is not subject to frequent large variations.
- Category B covers all requirements within Category A and specifies supplemental capabilities needed to adequately integrate DERs in local Area EPSs where the aggregated DER penetration is higher or where the overall DER power output is subject to frequent large variations.

For categories related to response to Area EPS abnormal conditions (Clause 6):

- Abnormal operating performance Category I is based on essential bulk power system (BPS) stability/reliability needs and reasonably attainable by all DER technologies that are in common usage today.
- Abnormal operating performance Category II covers all BPS stability/reliability needs and is coordinated with existing reliability standards¹³ to avoid tripping for a wider range of disturbances of concern to BPS stability.¹⁴

¹²This clause intentionally uses qualitative DER penetration levels qualifiers. The impact of DER on frequency and voltage performance of the interconnections and the regional power systems differs significantly and it remains in the responsibility of an AGIR to quantify impactful DER penetration levels. Refer to Annex B for more rationale on category assignments.

¹³In North America, the limitations for transmission-connected resources as specified in NERC PRC-024-2 [B27] may be used for reference.

¹⁴Includes 1LG stuck breaker transmission faults as well as normally and delayed cleared faults at the lower-level transmission and sub-transmission levels where fault durations can be longer (primarily due to the use of zone impedance relaying), e.g., sub-transmission 3LG with normal fault clearing or simultaneous 1LG faults on different phases of two sub-transmission circuits on the same structure with normal fault clearing. (NERC [B26], [B28], [B29], [B30].)

- Abnormal operating performance Category III is based on both BPS stability/reliability and distribution system reliability/power quality needs and is coordinated with existing interconnection requirements for very high DER penetration.¹⁵

All performance categories specify minimum equipment capability requirements and may also specify designated limiting requirements for ranges of allowable settings of control or trip parameter values. For categories related to reactive power capability and voltage regulation performance requirements (Clause 5), Category B is inherently capable of meeting the requirements for Category A. For categories related to response to Area EPS abnormal conditions (Clause 6), categories with higher number values are inherently capable of meeting the voltage and frequency ride-through requirements of lower number value categories; however, this may not hold for voltage and frequency trip requirements because their ranges of allowable settings may be mutually exclusive. If a DER listed for a higher level abnormal operating performance category was used in a lower-level category application, the correct range of allowable settings for magnitude and duration values of trip settings shall be ensured, for example by the use of software profiles designated for each abnormal operating performance category.

Additional guidelines on criteria for assignment of DER performance categories are given in Annex B.¹⁶

Where applicable, the stated technical specifications and requirements are given in generator sign convention, which is opposite to load sign convention. In generator sign convention, a DER current lagging voltage provides/injects reactive power to the system (over-excited operation of DER, positive reactive power), and this tends to increase the applicable voltage under normal system conditions; a DER current leading voltage consumes/absorbs reactive power from the system (under-excited operation of DER, negative reactive power), and this tends to decrease of the applicable voltage under normal system conditions.

¹⁵For example, CA Rule 21 [B4].

¹⁶As proposed in the IEEE P1547 response to FERC NOPR RM16-8 submitted by the IEEE Standards Association in May 2016 [B6], the criteria for assignment of DER performance categories outlined in the informative Annex B may be used as a reference point to partly specify "Good Utility Practice" for specific ride through requirements as required from small generating facilities per FERC Order 828 [B7].

1.5 Conventions for word usage and notes to text, tables and figures

In this document, the word *shall* is used to indicate a mandatory requirement. The word *should* is used to indicate a recommendation. The word *may* is used to indicate a permissible action. The word *can* is used for statements of possibility and capability.

Notes to text, tables, and figures are for information only and do not contain requirements needed to implement the standard.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they shall be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

~~The following standards shall be used in conjunction with this standard. When the stated version of the following standards is superseded by an approved revision, then that revision shall apply.~~

~~The applicability of the following standards is determined by the specific requirements stated in this standard, such as requiring certain sections.~~

ANSI C84.1-~~1995~~, Electric Power Systems and Equipment—Voltage Ratings (60 Hz).^{2 17}

IEC/TR 61000-3-7, Electromagnetic compatibility (EMC)—Part 3-7: Limits—Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems.¹⁸

^{2 17} ~~ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA~~ (<http://www.ansi.org/>).

¹⁸ IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

[IEC 61000-4-3, Electromagnetic compatibility \(EMC\)—Part 4-3: Testing and measurement techniques— Radiated, radio-frequency, electromagnetic field immunity test.](#)

[IEC 61000-4-5, Electromagnetic compatibility \(EMC\)—Part 4-5: Testing and measurement techniques— Surge immunity test.](#)

~~[B5]~~ IEEE Std 519-~~1992~~TM, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.^{19, 20}

[IEEE Std 1453TM, IEEE Recommended Practice for the Analysis of Fluctuating Installations on Power Systems.](#)

[IEEE Std 1815TM, IEEE Standard for Electric Power Systems Communications-Distributed Network Protocol \(DNP3\).](#)

[IEEE Std 2030.5TM, IEEE Adoption of Smart Energy Profile 2.0 Application Protocol Standard.](#)

IEEE Std C37.90.1TM-~~2002~~, IEEE Standard Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus.^{3,4}

IEEE Std C37.90.2TM-~~1995~~, IEEE Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers.

[IEEE Std C50.12TM, IEEE Standard for Salient-Pole 50 Hz and 60 Hz Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications Rated 5 MVA and Above.](#)

[IEEE Std C50.13TM, IEEE Standard for Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above.](#)

³ ¹⁹ The IEEE standards or products referred to in Clause 2 are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

⁴ ²⁰ IEEE publications are available from The Institute of Electrical and Electronics Engineers, ~~445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA~~ (<http://standards.ieee.org/>).

IEEE Std C62.41.2TM-2002, IEEE Recommended Practice on Characterization of Surges in Low Voltage (1000 V and less) AC Power Circuits.

IEEE Std C62.45TM-2002, IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits.

[IEEE Std C62.92.1TM, IEEE Guide for the Application of Neutral Grounding in Electric Utility Systems— Part I: Introduction.](#)

~~NEMA MG-1 1998, Motors and Generators, Revision 2.~~⁵

3. Definitions and acronyms

For [the](#) purposes of this ~~standard~~ [document](#), the following terms and definitions apply. ~~IEEE 100TM,~~
The ~~Authoritative Dictionary of IEEE Standards Terms, Seventh Edition [B4],~~⁶ [Dictionary Online](#) should
be ~~referenced~~ [consulted](#) for terms not defined in this ~~clause~~ [document](#).²¹

[NOTE—Defined terms and acronyms are italicized throughout the standard.](#)²²

3.1 Definitions

[abnormal operating performance category:](#) The grouping for a set of requirements that specify technical capabilities and settings for a DER under abnormal operating conditions, i.e., outside the *continuous operation region*.

[applicable voltage:](#) Electrical quantities that determine the performance of a Local EPS or DER specified with regard to the *reference point of applicability*, individual phase-to-neutral, phase-to-ground, or phase-to-phase combination and time resolution.

²¹[IEEE Standards Dictionary Online](#) subscription is available at <http://dictionary.ieee.org>.

²²[Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.](#)

⁵~~NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).~~

⁶~~The numbers in brackets correspond to those of the bibliography in Annex A.~~

NOTE—Applicable voltages are used as a synonym for applicable frequency, which can be derived from the applicable voltages.

~~3.1.3 design test: Test of one or more devices made to a certain design to show that the design meets certain specifications.~~

~~3.1.4 distributed generation (DG): Electric generation facilities connected to an Area EPS through a PCC; a subset of DR.~~

~~3.1.6.1~~ area electric power system, ~~area~~ (Area EPS): An EPS that serves Local EPSs.

NOTE—Typically, an *Area EPS* has primary access to public rights-of-way, priority crossing of property boundaries, etc., and is subject to regulatory oversight. See Figure 4 2.

~~3.1.1~~ area electric power system operator (Area EPS operator): The entity responsible for designing, building, operating, and maintaining the *Area EPS*.

authority governing interconnection requirements (AGIR): A cognizant and responsible entity that defines, codifies, communicates, administers, and enforces the policies and procedures for allowing electrical interconnection of DER to the *Area EPS*. This may be a regulatory agency, public utility commission, municipality, cooperative board of directors, etc. The degree of AGIR involvement will vary in scope of application and level of enforcement across jurisdictional boundaries. This authority may be delegated by the cognizant and responsible entity to the *Area EPS operator* or *bulk power system operator*.

NOTE—Decisions made by an authority governing interconnection requirements should consider various stakeholder interests, including but not limited to Load Customers, *Area EPS operators*, *DER operators*, and *bulk power system operator*.

authority having jurisdiction: Authority having the rights to inspection and approval of the design and construction of Local EPS premise electrical systems.

available active power: Active power that a DER can deliver to the *Area EPS* subject to the availability of the DER's primary source of energy.

NOTE—Examples are solar irradiance in the case of a photovoltaic DER and wind speed in case of a wind turbine generator.

bulk power system (BPS): Any electric generation resources, transmission lines, interconnections with neighboring systems, and associated equipment.

3.1.2 cease to energize: Cessation of ~~energy outflow capability~~ active power delivery under steady-state and transient conditions and limitation of reactive power exchange.

NOTE 1—This may lead to momentary cessation or trip.

NOTE 2—This does not necessarily imply, nor exclude disconnection, isolation, or a trip.

NOTE 3—Limited reactive power exchange may continue as specified, e.g., through filter banks.

NOTE 4—Energy storage systems are allowed to continue charging but are allowed to cease from actively charging when the maximum state of charge (maximum stored energy) has been achieved.

NOTE 5—Refer to 4.5 for additional details.

clearing time: The time between the start of an abnormal condition and the DER ceasing to energize the *Area EPS*. It is the sum of the detection time, any adjustable time delay, the operating time plus arcing time for any interposing devices (if used), and the operating time plus arcing time for the interrupting device (used to interconnect the DER with the *Area EPS*).

continuous operation: Exchange of current between the DER and an EPS within prescribed behavior while connected to the *Area EPS* and while the *applicable voltage* and the system frequency is within specified parameters.

continuous operation region: The performance operating region corresponding to *continuous operation*.

3.1.5-distributed resources energy resource (DER): ~~Sources~~ A source of electric power that ~~are~~ is not directly connected to a bulk power ~~transmission~~-system. ~~DER~~ DER includes both generators and energy storage technologies capable of exporting active power to an EPS. An interconnection system or a supplemental DER device that is necessary for compliance with this standard is part of a DER.²³

NOTE 1—Controllable loads used for demand response are not included in the definition of DER.

NOTE 2—See ~~Figure 1 and~~ Figure 2.

distributed energy resource operator (DER operator): The entity responsible for operating and maintaining the distributed energy resource.

distributed energy resource (DER) unit: An individual DER device inside a group of DER that collectively form a system.

distributed energy resource managing entity (DER Managing Entity): An entity that monitors and manages the DER through the *local DER communication interface*. The DER managing entity could be for example a utility, an aggregator, a building energy management system, or other.

disturbance period: The range of time during which the *applicable voltage* or the system frequency is outside the *continuous operation* region.

3.1.6-electric power system (EPS): Facilities that deliver electric power to a load.

NOTE—This may include generation units. See Figure ~~1~~ 2.

energize: Active power outflow of the DER to an EPS under any conditions (e.g., steady state and transient).

enter service: Begin operation of the DER with an energized Area EPS.

flicker: The subjective impression of fluctuating luminance caused by voltage fluctuations.

²³Equivalent to “distributed resources (DR)” as defined and used in IEEE Std 1547-2003.

NOTE—Above a certain threshold, flicker becomes annoying. The annoyance grows very rapidly

with the amplitude of the fluctuation. At certain repetition rates even very small amplitudes can be annoying (IEEE Std 1453).

3.1.11.1 island, intentional island: A planned electrical island that is capable of being energized by one or more Local EPSs. These (1) have DER(s) and load, (2) have the ability to disconnect from and to parallel with the Area EPS, (3) include one or more Local EPS(s), and (4) are intentionally planned.

NOTE—An intentional island may be an intentional Area EPS island or an intentional Local EPS island (also: “facility island”).

intentional Area EPS island: An intentional island that includes portions of the Area EPS.

intentional Local EPS island: An intentional island that is totally within the bounds of a Local EPS.

3.1.7 interconnection: The result of the process of adding ~~a DR unit~~ DER to an Area EPS, whether directly or via intermediate Local EPS facilities.

~~NOTE—See Figure 2.~~

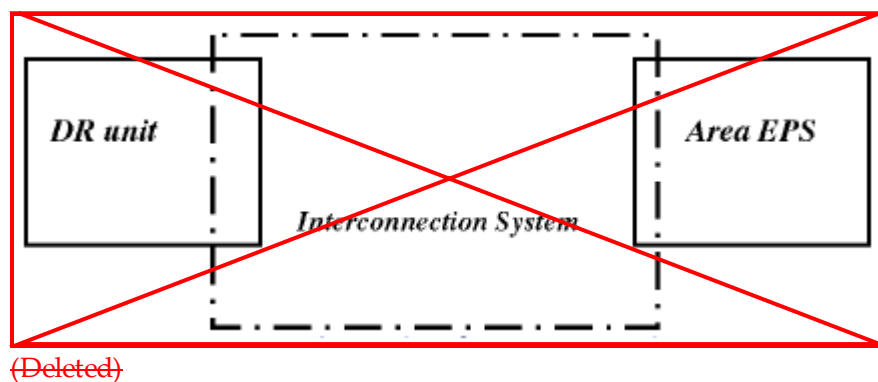


Figure 2—Schematic of interconnection

3.1.8 interconnection equipment: Individual or multiple devices used in an interconnection system.

3.1.9 interconnection system: The collection of all interconnection and interoperability equipment and functions, taken as a group, used to interconnect a ~~DER unit(s)~~ DER to an Area EPS.²⁴

~~NOTE—See Figure 2.~~

interface: An electrical or logical connection from one entity to another that supports one or more energy or data flows implemented with one or more power or data links.

interoperability: The capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively. (IEEE Std 2030® [B23])

3.1.10 inverter: A machine, device, or system that changes direct-current power to alternating-current power.

3.1.11 island: A condition in which a portion of an Area EPS is energized solely by one or more Local EPSs through the associated PCCs while that portion of the Area EPS is electrically separated from the rest of the Area EPS on all phases to which the DER is connected. When an island exists, the DER energizing the island may be said to be “islanding”.

load: Devices and processes in a local EPS that use electrical energy for utilization, exclusive of devices or processes that store energy but can return some or all of the energy to the local EPS or Area EPS in the future.

local DER communication interface: A local interface capable of communicating to support the information exchange requirements specified in this standard for all applicable functions that are supported in the DER.

~~**3.1.12 non-islanding:** Intended to prevent the continued existence of an island.~~

²⁴This term was frequently used in IEEE Std 1547-2003. Given the scope of the present standard, which may have implications to the design of the entirety of the DER, this standard uses the term “DER” in most places.

3.1.6.2 local electric power system, ~~local~~ (Local EPS): An EPS contained entirely within a single premises or group of premises.

NOTE—See Figure 1 2.

mandatory operation: Required continuance of active current and reactive current exchange of DER with Area EPS as prescribed, notwithstanding disturbances of the Area EPS voltage or frequency having magnitude and duration severity within defined limits.

mandatory operation region: The performance operating region corresponding to *mandatory operation*.

medium voltage: A class of nominal system voltages equal to or greater than 1 kV and less than or equal to 35 kV.

NOTE—IEEE standards are not unanimous in establishing the range for “medium voltage”.

momentary cessation: Temporarily *cease to energize* an EPS, while connected to the Area EPS, in response to a disturbance of the *applicable voltages* or the system frequency, with the capability of immediate Restore Output of operation when the *applicable voltages* and the system frequency return to within defined ranges.

momentary cessation operation region: The performance operating region corresponding to momentary cessation.

manufacturer stated measurement accuracy: Accuracy declared by the manufacturer, at which a DER measures the *applicable voltage*, current, power, frequency, or time.

nameplate ratings: Nominal voltage (V), current (A), maximum active power (kW), apparent power (kVA), and reactive power (kvar) at which a DER is capable of sustained operation.

NOTE—For Local EPS with multiple DER units, the aggregate DER nameplate rating is equal to the sum of all DERs nameplate rating in the Local EPS, not including aggregate capacity limiting mechanisms such as coincidence factors, plant controller limits, etc., that may be applicable for specific cases.

normal operating performance category: The grouping for a set of requirements that specify technical capabilities and settings for DER under normal operating conditions, i.e., inside the *continuous operation region*.

open loop response time: The duration from a step change in control signal input (reference value or system quantity) until the output changes by 90% of its final change, before any overshoot.

NOTE 1—The control loop considered in this definition refers to the DER control system in conjunction with the Area EPS. The “open loop” response time is equal to the DER control response time when the DER is interconnected with a stiff grid (ideal voltage source).

NOTE 2—The open loop response time is equal to 2.3 times the time constant of a first-order (i.e., single lag) system.

operating mode: Mode of DER operation that determines the performance during normal or abnormal conditions.

performance operating region: A region bounded by point pairs consisting of magnitude (voltage or frequency) and cumulative time duration which are used to define the operational performance requirements of the DER.

permissive operation: Operating mode where the DER performs ride-through either in *mandatory operation* or in *momentary cessation*, in response to a disturbance of the *applicable voltages* or the *system frequency*.

permissive operation region: The performance operating region corresponding to permissive operation.

permit service: A setting that indicates whether a DER is allowed to enter or remain in service.

per unit (p.u.) / percent of (%): Quantity expressed as a fraction of a defined base unit quantity. For active power (active current), the base quantity is the rated active power (rated active current). For apparent power (current), the base quantity is the rated apparent power (rated current). For system frequency, the base quantity is the nominal frequency (i.e., 60.0 Hz in North America). Quantities expressed in per unit can be converted to quantities expressed in percent of a base quantity by multiplication with 100.

3.1.13 point of common coupling (PCC): The point ~~where a Local EPS is connected to an~~ of connection between the Area EPS and the Local EPS.

NOTE 1—See Figure ~~4~~ 2.

NOTE 2—Equivalent, in most cases, to “service point” as specified in the National Electrical Code® (NEC®) [B31] and the National Electrical Safety Code® (NESC®) [B1].

3.1.14 point of distributed energy resources connection (point of ~~DR~~ DER connection—PoC): The point where a ~~DR~~ DER unit is electrically connected in ~~an~~ a Local EPS and meets the requirements of this standard exclusive of any load present in the respective part of the Local EPS.

NOTE 1—See Figure ~~4~~ 2.

NOTE 2—For (a) DER unit(s) that are not self-sufficient to meet the requirements without (a) supplemental DER device(s), the point of DER connection is the point where the requirements of this standard are met by DER (a) device(s) in conjunction with (a) supplemental DER device(s) exclusive of any load present in the respective part of the Local EPS.

post-disturbance period: The period starting upon the return of all *applicable voltages* or the system frequency to the respective ranges of the *mandatory operation region* or *continuous operation region*.

pre-disturbance period: The time immediately before a *disturbance period*.

protective function(s): The behavior whose purpose is to maintain safe operations and/or maintain safe conditions.

range of allowable settings: The range within which settings may be adjusted to values other than the specified default settings.

reference point of applicability (RPA): The location where the interconnection and interoperability performance requirements specified in this standard apply.

regional reliability coordinator: The functional entity that maintains the real-time operating reliability of the bulk electric power within a reliability coordinator area.

restore output: Return operation of the DER to the state prior to the abnormal excursion of voltage or frequency that resulted in a ride-through operation of the DER.

return to service: Enter service following recovery from a trip.

ride-through: Ability to withstand voltage or frequency disturbances inside defined limits and to continue operating as specified.

~~3.1.15~~ **simulated utility**: An assembly of variable frequency and variable voltage test equipment used to simulate ~~a normal utility source~~ an Area EPS.

step response: The output as a function of time t when the input is a step.

supplemental DER device: Any equipment that is used to obtain compliance with some or all of the interconnection requirements of this standard.

NOTE—Examples include capacitor banks, STATCOMs, harmonic filters that are not part of a DER unit, protection devices, plant controllers, etc.

~~3.1.16 total demand distortion (TDD)~~: The total root-sum-square harmonic current distortion, in percent of the maximum demand load current (15 or 30 minute demand).

~~3.1.17~~ **total rated-current distortion (TRD)**: The total root-sum-square of the current distortion components (including harmonics and inter-harmonics) created by the ~~DR~~ DER unit ~~operating into~~ expressed as a ~~linear balanced load divided by the greater~~ percentage of the ~~test load current demand (I_L) or the~~ DER rated current capacity ~~of the DR unit (I_{rated})~~.

trip: Inhibition of immediate return to service, which may involve disconnection.

NOTE—Trip executes or is subsequent to cessation of energization.

type test: A test of one or more devices manufactured to a certain design to demonstrate, or provide information that can be used to verify, that the design meets the requirements specified in this standard.

~~3.1.11.2 island~~, **unintentional island:** An unplanned island.

zero-sequence continuity: Circuit topology providing continuity between two defined points in the zero sequence network representation.

NOTE—A transformer that has a delta or ungrounded-wye winding in the topological path between the defined points produces discontinuity of the zero-sequence network.

3.2 Acronyms

<u>AGC</u>	<u>automatic generation control</u>
<u>AHI</u>	<u>authority having jurisdiction</u>
<u>AGIR</u>	<u>authority governing interconnection requirements</u>
Area EPS	area electric power system
<u>Area EPS operator</u>	<u>area electric power system operator</u>
<u>BPS</u>	<u>bulk power system</u>
<u>DER</u>	<u>distributed energy resources</u>
<u>DER operator</u>	<u>distributed energy resources operator</u>
<u>EMS</u>	<u>energy management system</u>
<u>EMI</u>	<u>electromagnetic interference</u>

~~DG~~	~~distributed generation~~
~~DR~~	~~distributed resources~~
EPS	electric power system
ESS	energy storage system
FIDVR	fault-induced delayed voltage recovery
~~I~~	~~current~~
~~I_L~~	~~load current~~
~~I_{SC}~~	~~short-circuit current~~
Local EPS	local electric power system
NP	network protector
NRTL	nationally recognized testing laboratory
PCC	point of common coupling
PoC	point of DER connection
PV	photovoltaic
RMS	root mean square
ROCOF	rate of change of frequency
RPA	reference point of applicability
~~TDD~~	~~total demand distortion~~
TRD	total rated-current distortion

4. General interconnection technical specifications and performance requirements

4.1 Introduction

The reference point of applicability (RPA) is the location where the interconnection and interoperability performance requirements specified in this standard shall be met. The electrical quantities referred to in this standard are those at the RPA, unless stated otherwise in this standard.

~~The requirements in this clause shall be met at the PCC, although the devices used to meet these requirements can be located elsewhere.~~ The performance requirements of this standard apply to interconnection of either a single ~~DR~~ DER unit based on that unit's rating or multiple ~~DR~~ DER units within a single Local EPS ("DER system"), based on the aggregate rating of all the ~~DR~~ DER units that are within the Local EPS. The capabilities and functions of the ~~interconnection system~~ DER hardware and software that affect the *Area EPS* are required to meet this standard regardless of their location on the EPS. The performance requirements in this ~~clause~~ standard are functional and do not specify any particular equipment or equipment type.

The technical specifications and performance requirements specified here are universally needed for interconnection and interoperability of DER²⁵ and will be sufficient for most installations.²⁶ The applicability of certain specifications and requirements are dependent on application considerations. For these, the requirements are provided in terms of a limited number of technology-neutral performance categories, for which it is the responsibility of the authority governing interconnection requirements (AGIR) to determine applicability. Guidelines on criteria for assignment of DER performance categories are given in Annex B.

²⁵ ~~For example, The stated technical specifications and requirements are universally needed for interconnection of DR, including synchronous machines, induction machines, or static power inverters/converters, and will be sufficient for most installations.~~⁷

⁷ ²⁶ Additional technical requirements may be necessary for some limited situations.

DER shall be designed and installed such that it meets the performance and test and verification requirements described in Clause 4 to Clause 11 of this standard. Unless specified otherwise, the term “DER” means “DER system”. In specific cases, “DER unit” is explicitly stated.

4.2 Reference points of applicability (RPA)

The characteristics of the Local EPS and DER shall determine the *reference point of applicability (RPA)*. Except as otherwise stated in this standard, the RPA for all performance requirements of this standard shall be the *point of common coupling (PCC)*.

Alternatively, for Local EPSs where zero sequence continuity²⁷ between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection (PoC)*, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC:

- a) Aggregate DER nameplate rating of equal to or less than 500 kVA, or
- b) Annual average load demand²⁸ of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.

²⁷ When the zero sequence continuity is broken, for example by a delta-wye transformer between the PCC and the PoC, the voltages at the PoC may not be representative of the voltages at the PCC under abnormal voltage conditions. Examples of issues created by this condition include the following:

— Difficulty of ‘sensing’ single-phase-to-ground faults or failure to detect ground-fault overvoltages. Note that 7.4.1 specifies requirements for ground-fault overvoltage;

— Detecting abnormal voltage conditions when a DER back-feeds into the grid during a balanced open-phase condition;

— Ability of detecting Area EPS open-phase by the DER is diminished.

²⁸ As calculated by Area EPS operator.

For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to Area EPS abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the Area EPS operator and the DER operator, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.^{29, 30}

Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.³¹

For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand²⁸ is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and performance requirements specified in 5.2 for reactive power capability and in Clause 7 for power quality may be evaluated excluding the influence of the Local EPS load.

Figure H.1 illustrates a decision tree to determine the RPA for Local EPS where zero sequence continuity is maintained. Figure H.2 illustrates a decision tree to determine the RPA for Local EPS where zero sequence continuity is not maintained.

²⁹ The intent of meeting the response to Area EPS abnormal voltage conditions requirements of 6.4 at the PCC is to appropriately detect ground faults and ground-fault overvoltage at the PCC.

³⁰ For DER that are permitted to use the PoC as the RPA, the location selected as the RPA may be different for each of the various functional requirements defined in Clause 5.

³¹ Examples are undervoltage and overcurrent relays within the local EPS between the RPA and PCC that are set such that they may trip the DER during the voltage disturbance ride-through operation for short-circuit faults other than ones on the Area EPS circuit section to which the DER is connected. This does not preclude selectively tripping DER for faults on the Area EPS as specified in 6.2.1.

4.3 Applicable voltages

The *applicable voltages*³² determine the performance of a Local EPS or DER and are the electrical quantities specified with regard to the reference point of applicability, individual phase-to-neutral, phase-to-ground, or phase-to-phase combination and time resolution.

For DER with a PCC located at the medium-voltage level, the *applicable voltages* shall be determined by the configuration and nominal voltage of the Area EPS at the PCC. For DER with a PCC located at the low-voltage³³ level, the *applicable voltages* shall be determined by the configuration of the low-voltage winding of the Area EPS transformer(s) between the medium-voltage system and the low-voltage system. The *applicable voltages* that shall be detected are shown in Table 1 and Table 2. For multi-phase systems, the requirements for *applicable voltages* shall apply to all phases.

Table 1—Applicable voltages when PCC is located at medium voltage

Area EPS at PCC	Applicable voltages
Three-Phase, Four-Wire	Phase-to-phase and phase-to-neutral
Three-Phase, Three-Wire, Grounded	Phase-to-phase and phase-to-ground
Three-Phase, Three-Wire, Ungrounded	Phase-to-phase
Single-Phase, Two-Wire	Phase-to-2nd wire (the 2nd wire may be either a neutral or a 2nd phase)

(New)

Table 2—Applicable voltages when PCC is located at low voltage

Low-voltage winding configuration of Area EPS transformer(s) ^a	Applicable voltages
Grounded Wye, Tee, or Zig-Zag ^b	Phase-to-phase and phase-to-neutral, or Phase-to-phase and phase-to-ground
Ungrounded Wye, Tee, or Zig-Zag	Phase-to-phase or phase-to-neutral
Delta ^c	Phase-to-phase
Single-Phase 120/240 V (split-phase or Edison connection)	Line-to-neutral—for 120 V DER units Line-to-line—for 240 V DER units ^d

(New)

^aA three-phase transformer or a bank of single-phase transformers may be used for three-phase systems.

³² *Applicable voltages* are used in synonym for *applicable frequency*, which can be derived from the *applicable voltages*.

³³ 1000 V and less per IEEE Std C62.41.2 and IEEE Std C62.45.

^bFor 120/208 V two-phase services, line-to-line voltages shall be sufficient.

^cIncluding delta with mid tap connection (grounded or ungrounded).

^dSensing line-to-neutral on both legs of a 120/240 V split-phase or Edison connection effectively senses the line-to-line and is therefore compliant with this requirement. Sensing line-to-ground may also be used; however, the ground connection should only be used for voltage sensing purposes.

The applicable frequency is the fundamental-frequency component. The *applicable voltages* shall be quantified as the effective (RMS) values over the preceding fundamental frequency period, unless otherwise specified in this standard.

For voltage-reactive power³⁴ (volt-var) mode requirements in 5.3.3 and voltage-active (real) power³⁵ mode requirements in 5.4.2 where DER do not respond to individual phase voltages, the *applicable voltages* are quantified as the average of the three-phase effective (RMS) values or alternatively positive sequence component of voltages over one fundamental frequency period.

For voltage trip and ride-through requirements in 6.4, the following shall apply:

- For low-voltage ride-through and undervoltage trip, the relevant voltage at any given time shall be the least magnitude of the individual *applicable voltages* relative to the corresponding nominal voltage.
- For high-voltage ride-through and overvoltage trip, the relevant voltage at any given time shall be the greatest magnitude of the *applicable voltages* relative to the corresponding nominal voltage.

For rate of change of frequency (ROCOF) ride-through requirements in 6.5.2.5, the ROCOF shall be the average rate of change of frequency over an averaging window of at least 0.1 s.

³⁴ Voltage-reactive power mode may also be commonly referred to as “volt-var” mode.

³⁵ Voltage-active power mode may also be commonly referred to as “volt-watt” mode.

4.4 Measurement accuracy

The DER³⁶ shall meet the minimum steady-state³⁷ and transient³⁸ measurement and calculation³⁹ accuracy requirements for voltage, frequency, active power, reactive power, and time as specified in Table 3. Actual measurement and calculation accuracy of a DER shall be stated for each of the values above.

Table 3 — Minimum measurement and calculation accuracy requirements for manufacturers^a

Time frame	Steady-state measurements			Transient measurements		
Parameter	Minimum measurement accuracy	Measurement window	Range	Minimum measurement accuracy	Measurement window	Range
Voltage, RMS	($\pm 1\% V_{nom}$)	10 cycles	0.5 p.u. to 1.2 p.u.	($\pm 2\% V_{nom}$)	5 cycles	0.5 p.u. to 1.2 p.u.
Frequency ^b	10 mHz	60 cycles	50 Hz to 66 Hz	100 mHz	5 cycles	50 Hz to 66 Hz
Active Power	($\pm 5\% S_{rated}$)	10 cycles	0.2 p.u. $< P < 1.0$ p.u.	Not required	N/A	N/A
Reactive Power	($\pm 5\% S_{rated}$)	10 cycles	0.2 p.u. $< Q < 1.0$ p.u.	Not required	N/A	N/A
Time	1% of measured duration	N/A	5 s to 600 s	2 cycles	N/A	100 ms < 5 s

(New)

^aMeasurement accuracy requirements specified in this table are applicable for voltage THD $< 2.5\%$ and individual voltage harmonics $< 1.5\%$.

³⁶ The DER includes any equipment required to meet the interconnection performance and interoperability requirements of the standard, including protective relays and measurement transducers.

³⁷ Steady-state measurements may be used for providing monitoring information through a local DER communication interface at the reference point of applicability as specified in Table 29 in 10.5.

³⁸ Transient measurements can be used by protective relays for achieving the mandatory voltage and frequency-tripping requirements as specified in 6.4.1 and 6.5.1.

³⁹ Only the fundamental parameters can actually be measured, e.g., time, voltage, and current. Other quantities are calculated based on the fundamental parameters measured, e.g., frequency, active power, and reactive power.

^bAccuracy requirements for frequency are applicable only when the fundamental voltage is greater than 30% of the nominal voltage.

4.5 Cease to energize performance requirement

In the *cease to energize* state, the DER shall not deliver active power during steady-state or transient conditions. The requirements for *cease to energize* shall apply to the point of DER connection (PoC).

For Local EPS with aggregate DER rating less than 500 kVA, the reactive power exchange in the *cease to energize* state shall be less than 10% of nameplate DER rating and shall exclusively result from passive devices. For Local EPS with aggregate DER rating 500 kVA and greater, the reactive power exchange in the *cease to energize* state shall be less than 3% of nameplate DER rating and shall exclusively result from passive devices.⁴⁰

If requested by the Area EPS operator, the DER operator shall provide the reactive susceptance that remains connected to the Area EPS in the *cease to energize* state.

Import of active power and reactive power exchange in the *cease to energize* state is permitted only for continuation of supply to DER housekeeping and auxiliary loads.

Alternatively, the requirements for *cease to energize* may be met by disconnecting⁴¹ the local EPS, or the portion of the local EPS to which the DER is connected from the Area EPS. The DER may continue to deliver power to the portion of the Local EPS that is disconnected from the Area EPS.⁴²

⁴⁰ In cases where the Area EPS is isolated, the passive reactive power devices of the DER will rapidly discharge by Area EPS loads and transformer magnetization and cease to exchange reactive power with the isolated Area EPS.

⁴¹ For example, via a separate disconnection device.

⁴² This may allow DER units to continue to energize the isolated Local EPS and supply local loads when disconnected from the Area EPS.

4.6 Control capability requirements

The DER shall be capable of responding to external inputs⁴³ as specified in this subclause.

4.6.1 Capability to disable permit service

The DER shall be capable of disabling the permit service setting and shall *cease to energize* the Area EPS and trip in no more than 2 s.⁴⁴

4.6.2 Capability to limit active power

The DER shall be capable of limiting active power as a percentage of the nameplate active power rating. The DER shall limit its active power output to not greater than the active power limit set point in no more than 30 s or in the time it takes for the primary energy source to reduce its active power output to achieve the requirements of the active power limit set point, whichever is greater.⁴⁵ In cases where the DER is supplying loads in the Local EPS, the active power limit set point may be implemented as a maximum active power export to the Area EPS. Under mutual agreement between the *Area EPS operator* and the *DER operator*, the DER may be required to reduce active power below the level needed to support Local EPS loads.

4.6.3 Execution of mode or parameter changes

Transition between modes shall commence in no more than 30 s after the mode setting change is received at the local DER communication interface. Changes of control functional modes shall be executed such that the DER output is transitioned smoothly over a time period between 5 s and 300 s.

⁴³ The external input may come through a manual DER control panel or through the *local DER communication interface* specified in Clause 10.

⁴⁴ This function is not intended to necessarily meet all requirements for protection, such as direct transfer trip. The objective of this requirement is related to bulk system operation.

⁴⁵ Linear ramping and step-wise ramping with small step sizes may be desirable.

Ramping of DER output is not required for control parameter setting changes. For all control and protective function parameter settings, the time following the input to the *local DER communication interface* and preceding the point in time when the invoked action begins shall be no greater than 30 s.

4.7 Prioritization of DER responses

Requirements set forth in Clause 5 and Clause 6 shall be prioritized as follows:⁴⁶

- a) The response to disabling permit service setting specified in 4.6.1 shall take precedence over any requirements within Clause 5 and Clause 6.
- b) DER tripping requirements specified in 6.2, 6.4.1, and 6.5.1 shall take precedence over any other requirements within Clause 5 and Clause 6, subject to the following:
 - 1) Where the prescribed trip duration settings for the respective voltage or frequency magnitude are set at least 160 ms or 1% of the prescribed tripping time, whichever is greater, beyond the prescribed ride-through duration, the DER shall comply with the ride-through requirements specified in 6.4.2 and 6.5.2 prior to tripping.
 - 2) In all other cases, the ride-through requirements shall apply until 160 ms or 1% of the prescribed tripping time, whichever is greater, prior to the prescribed tripping time.
- c) DER ride-through requirements specified in 6.4.2 and 6.5.2 shall take precedence over all other requirements within Clause 5 and Clause 6, with the exception of tripping requirements listed in item b) above. Ride-through may be terminated by the detection of an *unintentional island* specified in 8.1. However, false detection of an *unintentional island* that does not actually exist shall not justify non-compliance with ride-through requirements. Conversely, ride-through requirements specified in Clause 6 shall not inhibit the islanding detection performance specified in 8.1 where a valid unintentional islanding condition exists.

⁴⁶ Based on the actual settings of the control modes, a mode with lower priority may still take effect prior to a mode with higher priority.

- d) The voltage-active power mode requirements specified in 5.4.2 and frequency-droop (frequency-power) response requirements specified in 6.5.2.7 shall take precedence over all other requirements within Clause 5 and Clause 6, with the exception of tripping and ride-through requirements listed in item b) and item c) above. If both voltage-active power and frequency-droop modes are active, the lesser of the power value shall take precedence.
- e) The response to active power limit signal specified in 4.6.2 shall take precedence over all other requirements within Clause 5 and Clause 6, with the exception of tripping and ride-through requirements listed in item b) and item c) above, and voltage-active power mode requirements and frequency-droop response requirements listed in item d).
- f) The voltage regulation functions specified in 5.3 shall take precedence over any remaining requirements within Clause 5 and Clause 6.

4.1 General requirements

4.1.1 Voltage regulation

~~The DR shall not actively regulate the voltage at the PCC. The DR shall not cause the Area EPS service voltage at other Local EPSs to go outside the requirements of ANSI C84.1-1995, Range A.~~

4.1.6 Monitoring provisions

~~Each DR unit of 250 kVA or more or DR aggregate of 250 kVA or more at a single PCC shall have provisions for monitoring its connection status, real power output, reactive power output, and voltage at the point of DR connection.~~

4.8 Isolation device

When required by the Area EPS operating practices, a readily accessible, lockable, visible-break isolation device shall be located between the Area EPS and the ~~DR-unit~~ DER.⁴⁷

⁴⁷ The isolation device should be clearly marked to include signage per The National Electrical Code® [B31], as applicable.