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1547™

IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

Standards Coordinating Committee 21

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

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IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

Sponsor

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

Approved 12 June 2003

IEEE-SA Standards Board

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Abstract: This standard is the first in the 1547 series of interconnection standards and is a benchmark milestone demonstrating the open consensus process for standards development. Traditionally, utility electric power systems (EPS--grid or utility grid) were not designed to accommodate active generation and storage at the distribution level. As a result, there are major issues and obstacles to an orderly transition to using and integrating distributed power resources with the grid. The lack of uniform national interconnection standards and tests for interconnection operation and certification, as well as the lack of uniform national building, electrical, and safety codes, are understood. IEEE Std 1547 and its development demonstrate a model for ongoing success in establishing additional interconnection agreements, rules, and standards, on a national, regional, and state level. IEEE Std 1547 has the potential to be used in federal legislation and rule making and state public utilities commission (PUC) deliberations, and by over 3000 utilities in formulating technical requirements for interconnection agreements for distributed generators powering the electric grid.

This standard focuses on the technical specifications for, and testing of, the interconnection itself. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It 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 distributed resources (DR), including synchronous machines, induction machines, or power inverters/converters and will be sufficient for most installations. The criteria and requirements are applicable to all DR technologies, with aggregate capacity of 10 MVA or less at the point of common coupling, interconnected to electric power systems at typical primary and/or secondary distribution voltages. Installation of DR on radial primary and secondary distribution systems is the main emphasis of this document, although installation of DR on primary and secondary network distribution systems is considered. This standard is written considering that the DR is a 60 Hz source.
Keywords: certification; codes; commissioning, dc injection; design, field, installation, production tests; communications; diesel generators; distributed generation, power; resources; electric distribution systems; dispersed generation, storage; energy storage; faults; flicker; fuel cells; generators; grid; harmonics; IEEE; induction machines; inverters; interconnection requirements and specifications; islanding; microturbines; monitoring and control; paralleling; power converters, networks, quality; photovoltaic power systems; point of common coupling; public utility commissions; reclosing coordination; regulations; rule making, federal, national, regional, state; standards; synchronous machines; testing; utilities; wind energy systems

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Introduction

(This introduction is not part of IEEE Std 1547-2003, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems.)

IEEE Std 1547-2003 is the first of a series of standards being developed by Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage (SCC21) concerning distributed resources interconnection. The titles of the additional documents in that series follow.

— IEEE P1547.1™ Draft Standard For Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

— IEEE P1547.2™ Draft Application Guide for IEEE Std 1547-2003, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

— IEEE P1547.3™ Draft Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems

This first publication of IEEE Std 1547-2003 is an outgrowth of the changes in the environment for production and delivery of electricity and builds on prior IEEE recommended practices and guidelines developed by SCC21 [e.g., IEEE Std 929™-2000, IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems], and Standards Coordinating Committee 23 on Dispersed Storage and Generation (e.g., IEEE Std 1001™-1988, Guide for Interfacing Dispersed Storage and Generation Facilities with Electric Utility Systems).

Traditionally, utility electric power systems (EPS) were not designed to accommodate active generation and storage at the distribution level. The technologies and operational concepts to properly integrate distributed resources (DR) into the existing EPS continue to be further developed to fully realize 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 DR 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 DR technologies. This standard aims to be technology neutral, although cognizant that the technical attributes of DR and the types of EPSs do have a bearing on the interconnection requirements. The addition of DR to an EPS will change the system and its response in some manner. Although this standard establishes criteria and requirements for interconnection, this 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 requirements of this standard.

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 for addressing the business or tariff issues associated with interconnection.

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IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems

1. Overview

This standard provides interconnection technical specifications and requirements, and test specifications and requirements. Additionally, there is a bibliography included as Annex A that lists citations referred to in this standard for informative purposes, but that are not required to be used in conjunction with this standard.

1.1 Scope

This standard establishes criteria and requirements for interconnection of distributed resources (DR) with electric power systems (EPS).

1.2 Purpose

This standard provides a uniform standard for interconnection of distributed resources with electric power systems. It provides requirements relevant to the performance, operation, testing, safety 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.

The stated specifications and requirements, both technical and testing, are universally needed for interconnection of DR, including synchronous machines, induction machines, or power inverters/converters, and will be sufficient for most installations.[1]

[1]Additional technical requirements and/or tests may be necessary for some limited situations.

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1.3 Limitations

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

— This standard does not define the maximum DR capacity for a particular installation that may be interconnected to a single PCC or connected to a given feeder.
— This standard does not prescribe DR self-protection or all operating requirements for DR units.
— This standard does not address planning, designing, operating, or maintaining the Area EPS.
— This standard does not apply to automatic transfer schemes in which load is transferred between the DR 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.

2. References

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]

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

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

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

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

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

[2]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/).

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

[4]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/).

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

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3. Definitions and acronyms

For purposes of this standard, the following terms and definitions apply. IEEE 100™, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B4],[6] should be referenced for terms not defined in this clause.

3.1 Definitions

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

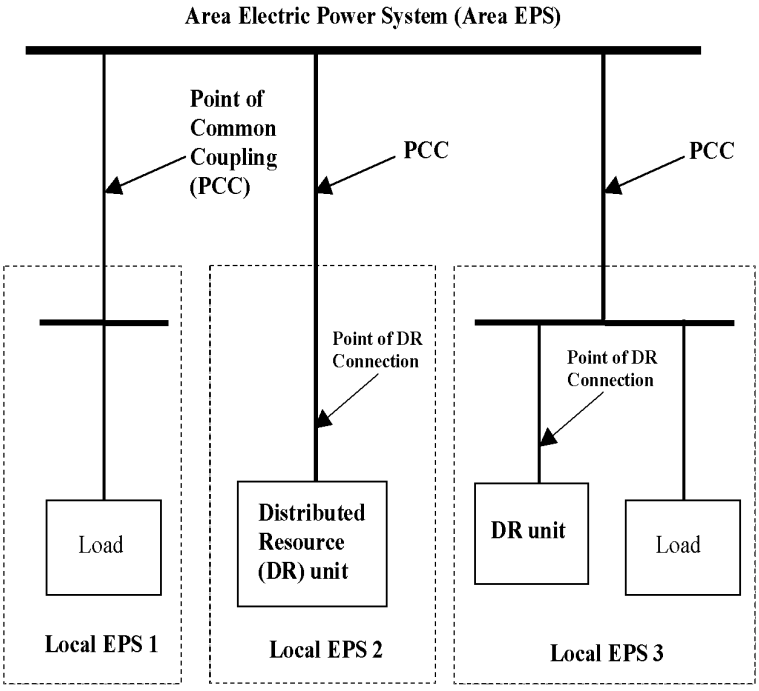
3.1.2 cease to energize: Cessation of energy outflow capability.

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.

3.1.5 distributed resources (DR): Sources of electric power that are not directly connected to a bulk power transmission system. DR includes both generators and energy storage technologies.

NOTE—See Figure 1 and Figure 2.



Note: Dashed lines are EPS boundaries. There can be any number of Local EPSs.

Figure 1—Relationship of interconnection terms

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

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

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

3.1.6.1 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 1.

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

NOTE—See Figure 1.

3.1.7 interconnection: The result of the process of adding a DR unit to an Area EPS.

NOTE—See Figure 2.

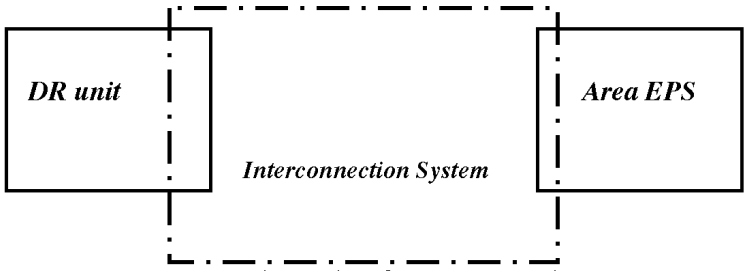


Figure 2—Schematic of interconnection

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

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

NOTE—See Figure 2.

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.

3.1.11.1 island, intentional: A planned island.

3.1.11.2 island, unintentional: An unplanned island.

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

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

NOTE—See Figure 1.

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3.1.14 point of distributed resources connection (point of DR connection): The point where a DR unit is electrically connected in an EPS.

NOTE—See Figure 1.

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

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 harmonics created by the DR unit operating into a linear balanced load divided by the greater of the test load current demand (I_L) or the rated current capacity of the DR unit (I_{rated}).

3.2 Acronyms

Area EPS	Area electric power system
DG	distributed generation
DR	distributed resources
EPS	electric power system
I	current
I_L	load current
I_{SC}	short circuit current
Local EPS	Local electric power system
PCC	point of common coupling
TDD	total demand distortion
TRD	total rated-current distortion

4. Interconnection technical specifications and requirements

The requirements in this clause shall be met at the PCC, although the devices used to meet these requirements can be located elsewhere. The requirements apply to interconnection of either a single DR unit based on that unit's rating or multiple DR units within a single Local EPS, 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.

The requirements in this clause are functional and do not specify any particular equipment or equipment type.

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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]

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.

4.1.2 Integration with Area EPS grounding

The grounding scheme of the DR interconnection shall not cause overvoltages that exceed the rating of the equipment connected to the Area EPS and shall not disrupt the coordination of the ground fault protection on the Area EPS.

4.1.3 Synchronization

The DR unit shall parallel with the Area EPS without causing a voltage fluctuation at the PCC greater than ±5% of the prevailing voltage level of the Area EPS at the PCC, and meet the flicker requirements of 4.3.2.

4.1.4 Distributed resources on distribution secondary grid and spot networks

4.1.4.1 Distribution secondary grid networks

This topic is under consideration for future revisions of this standard.

4.1.4.2 Distribution secondary spot networks[8]

Network protectors shall not be used to separate, switch, serve as breaker failure backup or in any manner isolate a network or network primary feeder to which DR is connected from the remainder of the Area EPS, unless the protectors are rated and tested per applicable standards for such an application.[9]

Any DR installation connected to a spot network shall not cause operation or prevent reclosing of any network protectors installed on the spot network. This coordination shall be accomplished without requiring any changes to prevailing network protector clearing time practices of the Area EPS.

Connection of the DR to the Area EPS is only permitted if the Area EPS network bus is already energized by more than 50% of the installed network protectors.

The DR output shall not cause any cycling of network protectors.

The network equipment loading and fault interrupting capacity shall not be exceeded with the addition of DR.

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

[8]When required by the authority who has jurisdiction over the DR interconnection, a study may be conducted to determine that all of the requirements of this subclause can be met when the aggregate DR installed on a spot network exceeds 5% of the spot network's maximum load.

[9]IEEE C37.108™-2002 [B8] and IEEE C57.12.44™-2000 [B9] provide guidance on the capabilities of network systems to accept distributed resources.

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DR installations on a spot network, using an automatic transfer scheme in which load is transferred between the DR and the EPS in a momentary make-before-break operation, shall meet all the requirements of this clause regardless of the duration of paralleling.

4.1.5 Inadvertent energization of the Area EPS

The DR shall not energize the Area EPS when the Area EPS is de-energized.

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.

4.1.7 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.

4.1.8 Interconnect integrity

4.1.8.1 Protection from electromagnetic interference

The interconnection system shall have the capability to withstand electromagnetic interference (EMI) environments in accordance with IEEE Std C37.90.2-1995. The influence of EMI shall not result in a change in state or misoperation of the interconnection system.

4.1.8.2 Surge withstand performance

The interconnection system shall have the capability to withstand voltage and current surges in accordance with the environments defined in IEEE Std C62.41.2-2002 or IEEE Std C37.90.1-2002 as applicable.

4.1.8.3 Paralleling device

The interconnection system paralleling-device shall be capable of withstanding 220% of the interconnection system rated voltage.

4.2 Response to Area EPS abnormal conditions[10]

Abnormal conditions can arise on the Area EPS that require a response from the connected DR. This response contributes to the safety of utility maintenance personnel and the general public, as well as the avoidance of damage to connected equipment, including the DR. All voltage and frequency parameters specified in these subclauses shall be met at the PCC, unless otherwise stated.

4.2.1 Area EPS faults

The DR unit shall cease to energize the Area EPS for faults on the Area EPS circuit to which it is connected.

[10]The isolation of a portion of the Area EPS, presenting the potential for an unintended DR island, is a special concern and is addressed in 4.4.1.
Setting adjustments may only be made as approved by the authority who has jurisdiction over the DR interconnection.

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4.2.2 Area EPS reclosing coordination

The DR shall cease to energize the Area EPS circuit to which it is connected prior to reclosure by the Area EPS.

4.2.3 Voltage

The protection functions of the interconnection system shall detect the effective (rms) or fundamental frequency value of each phase-to-phase voltage, except where the transformer connecting the Local EPS to the Area EPS is a grounded wye-wye configuration, or single-phase installation, the phase-to-neutral voltage shall be detected. When any voltage is in a range given in Table 1, the DR shall cease to energize the Area EPS within the clearing time as indicated. Clearing time is the time between the start of the abnormal condition and the DR ceasing to energize the Area EPS. For DR less than or equal to 30 kW in peak capacity, the voltage set points and clearing times shall be either fixed or field adjustable. For DR greater than 30 kW, the voltage set points shall be field adjustable.

The voltages shall be detected at either the PCC or the point of DR connection when any of the following conditions exist:

a) The aggregate capacity of DR systems connected to a single PCC is less than or equal to 30 kW,

b) The interconnection equipment is certified to pass a non-islanding test for the system to which it is to be connected,

c) The aggregate DR capacity is less than 50% of the total Local EPS minimum annual integrated electrical demand for a 15 minute time period, and export of real or reactive power by the DR to the Area EPS is not permitted.

Table 1—Interconnection system response to abnormal voltages

Voltage range (% of base voltage[a])	Clearing time(s)[b]
V< 50	0.16
50 ≤ V< 88	2.00
110 < V < 120	1.00
V ≥ 120	0.16

[a]Base voltages are the nominal system voltages stated in ANSI C84.1-1995, Table 1.
[b]DR ≤ 30 kW, maximum clearing times; DR > 30kW, default clearing times.

4.2.4 Frequency

When the system frequency is in a range given in Table 2, the DR shall cease to energize the Area EPS within the clearing time as indicated. Clearing time is the time between the start of the abnormal condition and the DR ceasing to energize the Area EPS. For DR less than or equal to 30 kW in peak capacity, the frequency set points and clearing times shall be either fixed or field adjustable. For DR greater than 30 kW, the frequency set points shall be field adjustable.

Adjustable under-frequency trip settings shall be coordinated with Area EPS operations.

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Table 2—Interconnection system response to abnormal frequencies

DR size	Frequency range (Hz)	Clearing time(s)[a]
≤ 30 kW	> 60.5	0.16
	< 59.3	0.16
> 30 kW	> 60.5	0.16
	< {59.8 – 57.0} (adjustable set point)	Adjustable 0.16 to 300
	< 57.0	0.16

[a]DR ≤ 30 kW, maximum clearing times; DR > 30 kW, default clearing times.

4.2.5 Loss of synchronism

Loss of synchronism protection is not required except as necessary to meet 4.3.2.

4.2.6 Reconnection to Area EPS

After an Area EPS disturbance, no DR reconnection shall take place until the Area EPS voltage is within Range B of ANSI C84.1-1995, Table 1, and frequency range of 59.3 Hz to 60.5 Hz.

The DR interconnection system shall include an adjustable delay (or a fixed delay of five minutes) that may delay reconnection for up to five minutes after the Area EPS steady-state voltage and frequency are restored to the ranges identified above.

4.3 Power quality

4.3.1 Limitation of dc injection

The DR and its interconnection system shall not inject dc current greater than 0.5% of the full rated output current at the point of DR connection.

4.3.2 Limitation of flicker induced by the DR

The DR shall not create objectionable flicker for other customers on the Area EPS.[11]

4.3.3 Harmonics

When the DR is serving balanced linear loads, harmonic current injection into the Area EPS at the PCC shall not exceed the limits stated below in Table 3. The harmonic current injections shall be exclusive of any harmonic currents due to harmonic voltage distortion present in the Area EPS without the DR connected.

[11]Flicker is considered objectionable when it either causes a modulation of the light level of lamps sufficient to be irritating to humans, or causes equipment misoperation. For guidance, refer to IEEE Std 519™-1992 [B5], IEEE P1453™ [B10], IEC/TR3 61000-3-7 [B1], IEC 61000-4-15 [B2], IEC 61400-21 [B3].

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Table 3—Maximum harmonic current distortion in percent of current (I)[a]

Individual harmonic order h (odd harmonics)[b]	h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	Total demand distortion (TDD)
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

[a] I = the greater of the Local EPS maximum load current integrated demand (15 or 30 minutes) without the DR unit, or the DR unit rated current capacity (transformed to the PCC when a transformer exists between the DR unit and the PCC).
[b]Even harmonics are limited to 25% of the odd harmonic limits above.

4.4 Islanding

4.4.1 Unintentional islanding

For an unintentional island in which the DR energizes a portion of the Area EPS through the PCC, the DR interconnection system shall detect the island and cease to energize the Area EPS within two seconds of the formation of an island.[12]

4.4.2 Intentional islanding

This topic is under consideration for future revisions of this standard.

5. Interconnection test specifications and requirements

This clause provides the test requirements to demonstrate that the interconnection system meets the requirements of Clause 4. The applicable tests from this clause are required for all interconnection systems. The results of these tests shall be formally documented.

The stated test 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.[13]

5.1 Design test

This design test shall be performed as applicable to the specific interconnection system technology. The test shall be performed on a representative sample, either in the factory, at a testing laboratory, or on equipment in the field.[14]

[12]Some examples by which this requirement may be met are:

1. The DR aggregate capacity is less than one-third of the minimum load of the Local EPS.
2. The DR is certified to pass an applicable non-islanding test.
3. The DR installation contains reverse or minimum power flow protection, sensed between the Point of DR Connection and the PCC, which will disconnect or isolate the DR if power flow from the Area EPS to the Local EPS reverses or falls below a set threshold.
4. The DR contains other non-islanding means, such as a) forced frequency or voltage shifting, b) transfer trip, or c) governor and excitation controls that maintain constant power and constant power factor.

[13]Additional tests may be necessary for some limited situations.

[14]The design test of 5.1 may be adopted as the testing basis for certification of interconnection systems.

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This test applies to a packaged interconnection system using embedded components or to an interconnection system that uses an assembly of discrete components.

The design test shall be conducted on the same sample in the sequence of Table 4.

Table 4—Sequence for conducting design test

Required order	Design test clause and title
1	5.1.1 Response to abnormal voltage and frequency
2	5.1.2 Synchronization
3	5.1.3 Interconnect integrity test
Suggested order	
4	5.1.1 Response to abnormal voltage and frequency
5	5.1.2 Synchronization
6	5.1.4 Unintentional islanding
7	5.1.5 Limitation of dc injection
8	5.1.6 Harmonics

5.1.1 Response to abnormal voltage and frequency

This test shall demonstrate that the DR ceases to energize the Area EPS when the voltage or frequency exceeds the limits as specified in 4.2.3 and 4.2.4. Interconnection systems provided with field adjustable set points shall also be tested at the minimum, midpoint, and maximum of the adjustable set point ranges. These tests shall be conducted using either the simulated utility or secondary injection method.

5.1.2 Synchronization

Test results conforming to requirements of A, B, or C below are accepted as indicating compliance with the requirements of 4.1.3. The appropriate conditions to be met for specific interconnection system technology follow.

A. Synchronous interconnection to an EPS, or an energized local EPS to an energized Area EPS

This test shall demonstrate that at the moment of the paralleling-device closure, all three parameters in Table 5 are within the stated ranges. This test shall also demonstrate that if any of the parameters are outside of the ranges stated in the table, the paralleling-device shall not close.

B. Induction interconnection

Self-excited induction generators shall be tested as per A in 5.1.2.

This test shall determine the maximum start-up (in-rush) current drawn by the unit.[15] The results shall be used, along with Area EPS impedance information for the proposed location, to estimate the starting voltage

[15]NEMA MG 1-1998 contains an acceptable method for determining inrush current.

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Table 5—Synchronization parameter limits for synchronous interconnection to an EPS, or an energized local EPS to an energized Area EPS

Aggregate rating of DR units (kVA)	Frequency difference (Δf, Hz)	Voltage difference (ΔV, %)	Phase angle difference (ΔΦ, °)
0 – 500	0.3	10	20
> 500 – 1 500	0.2	5	15
> 1 500 – 10 000	0.1	3	10

drop and verify that the unit shall not exceed the synchronization requirements in 4.1.3 and the flicker requirements in 4.3.2.

C. Inverter interconnection[16]

An inverter-based interconnection system that produces fundamental voltage before the paralleling device is closed shall be tested according to the procedure for synchronous interconnection as stated in A of 5.1.2.

All other inverter-based interconnection systems shall be tested to determine the maximum start-up current. The results shall be used, along with Area EPS impedance for the proposed location, to estimate the starting voltage magnitude change and verify that the unit shall meet the synchronization requirements in 4.1.3 and the flicker requirements in 4.3.2.

5.1.3 Interconnect integrity test

5.1.3.1 Protection from EMI

The interconnection system shall be tested in accordance with IEEE Std C37.90.2-1995 to confirm that the results are in compliance with 4.1.8.1. The influence of EMI shall not result in a change in state or mis-operation of the interconnection system.

5.1.3.2 Surge withstand performance

The interconnection system shall be tested for the requirement in 4.1.8.2 in all normal operating modes in accordance with IEEE Std C62.45-2002 for equipment rated less than 1000 V to confirm that the surge withstand capability is met by using the selected test level(s) from IEEE Std C62.41.2-2002. Interconnection system equipment rated greater than 1000 V shall be tested in accordance with manufacturer or system integrator designated applicable standards. For interconnection system equipment signal and control circuits, use IEEE Std C37.90.1-2002. The results of these tests shall indicate the unit did not fail, did not mis-operate, and did not provide misinformation.

5.1.3.3 Paralleling device

A dielectric test across the open-circuited paralleling device shall be conducted to confirm compliance with the requirements of 4.1.8.3.

5.1.4 Unintentional Islanding

A test or field verification shall be conducted to confirm that 4.4.1 is met regardless of the selected method of detecting isolation.[17]

[16]Some inverter-based interconnection systems may need to be tested to both requirements of C in 5.1.2.

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5.1.5 Limitation of dc injection

Inverter based DR shall be tested to confirm that the DR does not inject dc current greater than prescribed limits that are listed in 4.3.1.

5.1.6 Harmonics

The intent of the harmonics interconnection test is to assess that under a controlled set of conditions the DR unit meets the harmonic limits specified in 4.3.3.

The DR shall be operated in parallel with a predominantly inductive voltage source with a short circuit current capacity I_{SC} of not less than 20 times the DR rated output current at fundamental frequency. The voltage and frequency output of the voltage source shall correspond to the rated voltage and frequency of the DR. The unloaded voltage waveform produced by the Area EPS or simulated utility voltage source shall have a total harmonic distortion (THD) less than 2.5%.

The DR shall be operated at an output test load current, I_L, of 33%, 66%, and at a level as close to 100% of rated output current as practical. Use total rated-current distortion (TRD) in place of TDD. TRD is the total rms value of the sum of the current harmonics created by the DR unit operating into a linear balanced load divided by the greater of the test load current (I_L) demand or the rated current capacity of the DR unit (Irated). The individual harmonic distortion and TRD of the DR output current shall be measured for the first 40 harmonics. The harmonic current injections shall be exclusive of any harmonic currents due to harmonic voltage distortion present in the Area EPS without the DR connected. The test results shall not exceed the values in 4.3.3, Table 3.[18]

As an alternative, a synchronous generator DR shall be tested to meet the requirements of 4.3.3; either after installation or while powering a balanced resistive load and isolated from any other sources. The voltage harmonics while powering a resistive load at 100% of the machine kVA rating shall not exceed the levels in Table 6. Voltage harmonics shall be measured line to line for 3-phase/3 wire systems, and line to neutral for 3-phase/4-wire systems.

Table 6—Maximum harmonic voltage distortion in percent of rated voltage for synchronous machines

Individual harmonic order	h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	Total harmonic distortion
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

5.2 Production tests

Each interconnection system shall be subjected to requirements of 5.1.1 and 5.1.2. Interconnection systems with adjustable set points shall be tested at a single set of set points as specified by the manufacturer. This test may be conducted as a factory test or may be performed as part of a commissioning test (see 5.4).

[17] An example test is in UL 1741 [B14].

[18] These values or lower values may be required to meet the TDD of 5% at the PCC.

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5.3 Interconnection installation evaluation

5.3.1 Grounding integration with Area EPS

A system design verification shall be made to ensure that the requirements of 4.1.2 have been met.

5.3.2 Isolation device

A system design verification shall be made to ensure that the requirements of 4.1.7 have been met.

5.3.3 Monitoring provisions

A system design verification shall be made to ensure that the provisions for monitoring are in accordance with 4.1.6.

5.3.4 Area EPS faults

A system design verification shall be made to ensure that the requirements of 4.2.1 have been met.

5.3.5 Area EPS reclosing coordination

A system design verification shall be made to verify the interconnection system is coordinated with the Area EPS reclosing practices in accordance with 4.2.2.

5.4 Commissioning tests

All commissioning tests shall be performed based on written test procedures.[19] The following visual inspections shall be performed.

- A visual inspection shall be made to ensure that the grounding coordination requirement of 4.1.2 has been implemented.
- A visual inspection shall be made to confirm the presence of the isolation device if required by 4.1.7.

Initial commissioning tests shall be performed on the installed DR and interconnection system equipment prior to the initial parallel operation of the DR. The following tests are required:

- Operability test on the isolation device
- Unintentional-islanding functionality as specified in 5.4.1
- Cease to energize functionality as specified in 5.4.2
- Any tests of 5.1 that have not been previously performed on a representative sample and formally documented
- Any tests of 5.2 that have not been previously performed

The applicable tests of 5.1 shall be repeated when:

- Functional software or firmware changes have been made on the interconnection system
- Any hardware component of the interconnection system has been modified in the field, or, replaced or repaired with parts different from the tested configuration.

Sublauses 5.4.1 and 5.4.2, and the applicable tests of 5.2 shall be repeated if:

[19]Test procedures are commonly provided by equipment manufacturer(s) or system integrator(s) and approved by the equipment owner and Area EPS operator.

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— Protection settings have been changed after factory testing.
— Protection functions have been adjusted after the initial commissioning process.

5.4.1 Unintentional islanding functionality test

5.4.1.1 Reverse-power or minimum power test

A reverse-power or minimum power function, if used to meet the requirements of 4.4.1, shall be tested using injection techniques or by adjusting the DR output and local loads to verify that the reverse power or minimum power function is met.

5.4.1.2 Non-islanding functionality test

For non-islanding interconnection systems, 5.4.2 satisfies this requirement.

5.4.1.3 Other unintentional islanding functionality tests

If tests in 5.4.1.1 and 5.4.1.2 are not applicable to the interconnection system, the interconnection system shall be tested in accordance with procedures provided by the manufacturer or system integrator.

5.4.2 Cease to energize functionality test

Check the cease to energize functionality by operating a load interrupting device and verify the equipment ceases to energize its output terminals and does not restart/reconnect for the required time delay. The test shall be performed on each phase individually. This test verifies conformance to the cease to energize requirement of 4.1.4, 4.2.1, 4.2.2, 4.2.3, 4.2.4, and 4.4.1.

5.5 Periodic interconnection tests

All interconnection-related protective functions and associated batteries shall be periodically tested at intervals specified by the manufacturer, system integrator, or the authority who has jurisdiction over the DR interconnection. Periodic test reports or a log for inspection shall be maintained.

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Annex A

(informative)

Bibliography

The following citations are referred to in this standard for informative purposes and are not required to be used in conjunction with this standard.

[B1] IEC TR3 61000-3-7, Assessment of Emission Limits for Fluctuating Loads in MV and HV Power Systems.

[B2] IEC 61000-4-15, Flickermeter—Functional and Design Specifications.

[B3] IEC 61400-21, Wind Turbine Generator Systems—Part 21: Measurement and Assessment of Power Quality Characteristics of Grid Connected Wind Turbines—Ed. 1.0 (2001-12).

[B4] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition, New York, Institute of Electrical and Electronics Engineers, Inc.

[B5] IEEE Std 519-1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.[20]

[B6] IEEE Std 929™-2000, IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems.

[B7] IEEE Std 1001™-1988, IEEE Guide for Interfacing Dispersed Storage and Generation Facilities with Electric Utility Systems.

[B8] IEEE Std C37.108-1989 (R2002), IEEE Guide for the Protection of Network Transformers.

[B9] IEEE Std C57.12.44-2000, IEEE Standard Requirements for Secondary Network Protectors.

[B10] IEEE P1453, Draft Recommended Practice for Measurement and Limits of Voltage Flicker on AC Power Systems.

[B11] IEEE P1547.1™, Draft Standard For Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems.

[B12] IEEE P1547.2™, Draft Application Guide for IEEE Std 1547-2003, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems.

[B13] IEEE P1547.3™, Draft Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems.

[B14] UL 1741, Inverters, Converters, and Controllers for Use in Independent Power Systems.

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