



IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces

Developed by the

IEEE Standards Coordinating Committee 21
on

Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage



IEEE Std 1547.1™-2020

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IEEE SA Standards Board

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Abstract: The type, production, commissioning, and periodic tests, and evaluations that shall be performed to confirm that the interconnection and interoperation functions of equipment and systems interconnecting distributed energy resources with the electric power system conform to IEEE Std 1547 are specified in this standard.

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™, IEEE 1547.1™, 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, power quality, production tests, 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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Introduction

This introduction is not part of IEEE Std 1547.1-2020, IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces.

IEEE Std 1547.1 is one of a series of standards developed by Standards Coordinating Committee 21 (SCC21) concerning distributed energy resource (DER) interconnection. IEEE Std 1547.1 and the root standard, IEEE Std 1547, were amended in 2014 and 2015 (IEEE Std 1547a™ and IEEE Std 1547.1a™, respectively) in response to a widely expressed need to make changes to subclauses related to voltage regulation and response to *area EPS* abnormal conditions in IEEE Std 1547-2003 and IEEE Std 1547-2005. A new revision of IEEE Std 1547 was published in 2018 to accommodate additional requirements needed for higher levels of DER. The titles of the additional documents in the series are as follows:

- IEEE Std 1547, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.
- IEEE P1547.2™, Draft Application Guide for IEEE Std 1547, Interconnecting Distributed Resources with Electric Power Systems [B9].
- IEEE Std 1547.3™, IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems [B21].
- IEEE P1547.4™, IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems [B22].
- IEEE Std 1547.6™, IEEE Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks [B24].
- IEEE Std 1547.7™, IEEE Guide for Conducting Distribution Impact Studies for Distributed Resource Interconnection [B25].
- IEEE P1547.9™, Draft Guide to Using IEEE Standard 1547 for Interconnection of Energy Storage Distributed Energy Resources with Electric Power Systems [B10].

The root standard, IEEE Std 1547, defines a set of uniform requirements for the interconnection of DER to the distribution segment of the *electric power system* (EPS). 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.

IEEE Std 1547 includes requirements relevant to the operation of the interconnection. It generally defines limitations and set points for various parameters that must be satisfied prior to the connection of a DER to the EPS, at the instant of connection, and for the separation of such resources from the EPS for abnormal conditions.

IEEE Std 1547.1 provides conformance test and evaluation procedures to establish and verify compliance with the requirements of IEEE Std 1547. When applied, the IEEE 1547.1 test and evaluation procedures provide a means for manufacturers, utilities, or independent *testing agencies* to confirm the suitability of any given DER for interconnection with the EPS. Such certification can lead to the ready acceptance of confirmed equipment as suitable for use in the intended service by the parties concerned. While this standard defines test and evaluation procedures, it does not specify measurement techniques. Suitable measurement techniques can be found in various technical publications including, but not limited to, IEEE Std 120™ [B17].

It is beyond the scope of IEEE Std 1547.1 to specify the design and performance criteria for DER or components. It is left to the parties concerned to determine that the equipment manufacturer's specifications and confirmed performance satisfy the technical needs of the EPS distribution circuit to which the DER is to be connected and the EPS in general. Similarly, this standard does not address the local electrical power system technical needs nor load requirements for the facility or premises where the *point of DER connection* is made.

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IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces

1. Overview

1.1 General

This standard provides tests and procedures for verifying conformance of distributed energy resources (DERs ~~interconnection systems (ICSs)~~) to IEEE Std 1547™.¹ It is recognized that a DER ~~an ICS~~ can be a single device providing all required functions or an assembly of components, each having limited functions and capabilities. Components having limited functions and capabilities shall be tested for those functions in accordance with this standard. Conformance may be established through a combination of type ~~(referred to as “design” tests in IEEE Std 1547)~~, production, and *commissioning tests* as well as DER design evaluations and DER installation evaluations. Additionally, conformance to IEEE Std 1547 may require ~~requires interconnection installation evaluation and~~ periodic tests.

This standard also includes Annex A, which describes normative test signals and ramp functions used in conducting some tests. Information on where to find the test results reporting template (a separate document) is provided in Annex B. Additionally, Annex C through Annex J provide informative content ~~a bibliography is included as Annex B; it lists documents~~ that may be helpful ~~are referred to~~ in implementing this standard ~~for informative purposes~~, but that is ~~are~~ not required to implement the procedures defined in this standard.

1.2 Scope

This standard specifies the type, production, ~~and~~ commissioning, and periodic tests and evaluations that shall be performed to confirm ~~demonstrate~~ that the interconnection and interoperation functions of and equipment and systems interconnecting of the ~~distributed energy resources (DERs) with the electric power system (EPS) DER~~ conform to IEEE Std 1547, as revised, corrected, or amended.

¹Information on normative references can be found in Clause 2.

1.3 Purpose

Distributed energy resources (DERs) shall ~~Interconnection equipment that connects DR to an electric power system (EPS) must~~ meet the requirements specified in IEEE Std 1547. Standardized test and evaluation procedures are necessary to establish and verify compliance with those requirements. These ~~test~~ procedures shall ~~must~~ provide ~~both~~ repeatable results, ~~independent of test location~~, and flexibility to accommodate a ~~the~~ variety of DER ~~DR~~ technologies and functions.

1.4 Limitations

This standard does not cover testing for product safety.

Although this standard does not define a certification process, these tests may be used as part of such a process.²

1.5 Compliance review

The tests and procedures in this standard are intended to provide reasonable test coverage for DER components and systems in meeting the requirements of IEEE Std 1547, but it cannot anticipate and cover all aspects of IEEE Std 1547. There are likely to be scenarios that this standard does not anticipate. The requirements of IEEE Std 1547 apply to systems operating in the field and over their operating lifetime. Type tests and commissioning tests, for example, may not be able to predict exact performance of systems in the field.

²For example, in the U.S. it is typical for inverter-based DERs to be approved under Underwriter's Laboratories Standard 1741 (UL 1741), which directly references IEEE Std 1547 and calls for application of the test procedures in IEEE Std 1547.1. In this example, type tests in IEEE Std 1547.1 are typically conducted by a Nationally Recognized Testing Laboratory (NRTL), and the DER unit is approved for compliance with UL 1741, indicating it has passed the IEEE Std 1547.1 type tests.

2. Normative references

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

[DNP3 Application Note AN2018-001, DNP3 Profile for Communications with Distributed Energy Resources.](#)

[IEC 61000-3-6, Electromagnetic compatibility \(EMC\)—Part 3-6: Limits—Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems.](#)³

[IEC/IEEE 62271-37-013, International Standard for High-voltage switchgear and control gear—Part 37—013: Alternating-current generator circuit-breakers.](#)

[IEEE C37.04™-2018, IEEE Standard for Ratings and](#)

[Requirements for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V.](#) ⁴,
⁵

[IEEE Std C37.09™-2018, IEEE Standard Test Procedures for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V.](#)

[IEEE Std C37.60™, IEEE/IEC International Standard—High-voltage switchgear and controlgear—Part 111: Automatic circuit reclosers and fault interrupters for alternating current systems up to 38 kV.](#)

³[IEC publications are available from the International Electrotechnical Commission \(www.iec.ch\).](#)

⁴ ³IEEE publications are available from The Institute of Electrical and Electronics Engineers, ~~445 Hoes Lane, Piscataway, NJ 08854, USA~~ (http://standards.ieee.org/).

⁵ ⁴The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.

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

~~ANSI C37.06, American National Standard for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis—Preferred Ratings and Related Required Capabilities.²~~

~~ANSI C84.1, American National Standard for Electric Power Systems and Equipment—Voltage Ratings (60 Hz).~~

~~IEEE C37.09TM, IEEE Standard Test Procedure for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis.^{3,4}~~

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

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

[IEEE Std C37.111TM/IEC 60255-24, IEEE/IEC Measuring relays and protection equipment—Part 24: Common format for transient data exchange \(COMTRADE\) for power systems.](#)

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

IEEE Std C62.45TM, 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 Electrical Utility Systems—Part I: Introduction.](#)

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/>).~~

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

[IEEE C62.92.6™, IEEE Guide for Application of Neutral Grounding in Electrical Utility Systems, Part VI—Systems Supplied by Current-Regulated Sources.](#)

[IEEE Std 112™, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.](#)

[IEEE Std 115™, IEEE Guide for Test Procedures for Synchronous Machines—Part I—Acceptance and Performance Testing and Part II—Test Procedures and Parameter Determination for Dynamic Analysis.](#)

[IEEE Std 421.5™, IEEE Recommended Practice for Excitation System Models for Power System Stability Studies.](#)

[IEEE Std 1159.3™, IEEE Recommended Practice for Power Quality Data Interchange Format \(PQDIF\).](#)

IEEE Std 1547™, IEEE Standard for [Interconnection and Interoperability of](#) ~~Interconnecting~~ Distributed [Energy](#) Resources with [Associated](#) Electric Power Systems [Interfaces.](#) ~~NEMA MG-1, Motors and Generators.~~⁵

[IEEE Std 1815™-2012, IEEE Standard for Electric Power Systems Communications-Distributed Network Protocol \(DNP3\).](#)

[IEEE Std 2030.5™-2018, IEEE Standard for Smart Energy Profile Application Protocol.](#)

[SunSpec DER Information Model Specification, published on July 15 of 2019, available at
https://sunspec.org.](#)

3. Definitions, [abbreviations](#), and acronyms

[3.1 Definitions](#)

For ~~purposes of~~ this [document](#) ~~standard~~, the following terms and definitions apply. See [IEEE Std 1547](#) for additional relevant definitions. The [IEEE Standards](#) ~~Authoritative~~ Dictionary [Online](#)⁶ ~~of IEEE Standards Terms [B5]~~ should be [consulted](#) ~~referenced~~ for terms not defined in this [subclause or in IEEE Std 1547](#) ~~clause~~.

⁶[IEEE Standards Dictionary Online is available at
http://dictionary.ieee.org.](#)

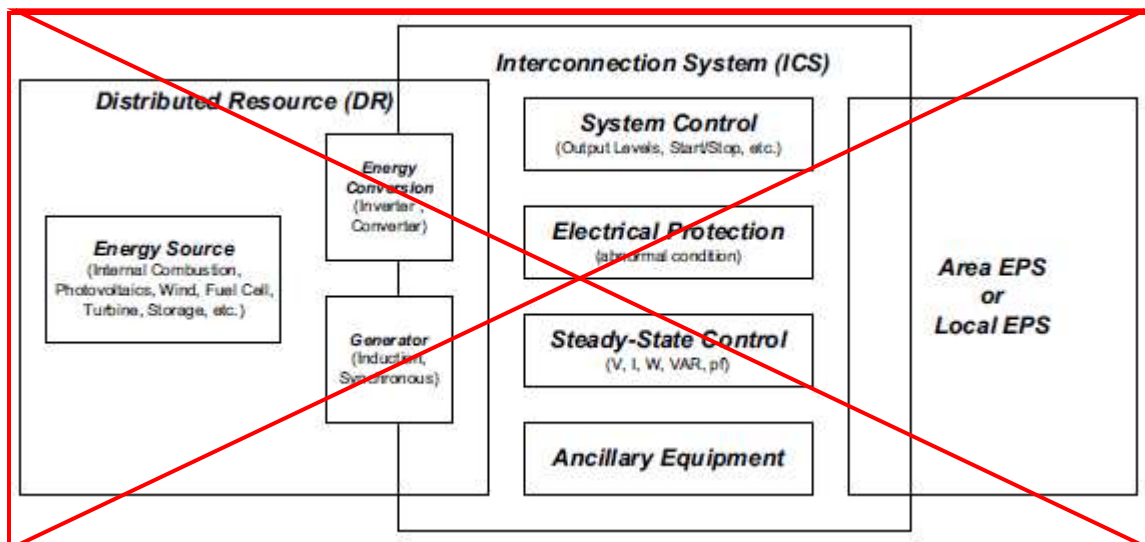
Because this standard is integrally linked with IEEE Std 1547, many terms are used in both documents. Some definitions from IEEE Std 1547-2018 that are frequently used here are repeated verbatim for the convenience of readers. Those definitions are marked with an asterisk (*).

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.

ac test source ~~simulated area electric power system (EPS)~~: An assembly of voltage and frequency test equipment replicating a utility power source for the purposes of DER testing. Where appropriate, the actual area EPS may be used as the ac test source. ~~Where appropriate, the actual area EPS can be used as the simulated area EPS.~~

~~3.1 ICS boundaries~~

~~An ICS consists of system controls, electrical protection, and steady state control and may include energy conversion and/or generator. The DR may include all or part of the ICS. Figure 1 shows the boundary between the ICS, the EPS, and the energy source.~~



~~(Deleted)~~

~~Figure 1—Boundaries between the ICS, the EPS, and the DR~~

3.2 Definitions

area electric power system (area EPS)*: An EPS that serves *local EPSs*.

NOTE—~~that~~, Typically, an *area EPS* has primary access to public rights-of-way, priority crossing of property boundaries, etc., and is subject to regulatory oversight.⁷

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 regional reliability coordinator (as defined in IEEE Std 1547-2018).

NOTE—Decisions made by AGIR should consider various stakeholder interests, including but not limited to load customers, *area EPS operators*, *DER operators*, and regional reliability coordinator.

clearing time*: The time between the start of the abnormal condition and the ~~DER distributed resources' (DR's)~~ ceasing to energize the ~~area electric power system (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 DR~~ with the *area EPS*).

commissioning test: A test conducted when the equipment is installed to verify correct operation.

DER evaluation: *Design evaluation or installation evaluation.*

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

⁷Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard.

DER unit: A fully compliant DER that does not require *supplemental DER devices* to meet the requirements of IEEE Std1547.

DER system: A system that consists of *DER unit(s)* and *supplemental DER device(s)* that is type tested as a system and installed in accordance with the DER manufacturer's instructions and that, as a whole, is fully compliant with IEEE Std 1547.

DER composite: A system that consists of partially compliant DER components and *supplemental DER device(s)*, and requires detailed design evaluation, *installation evaluation*, and *commissioning tests* to determine full compliance to IEEE Std 1547 requirements.

design evaluation: An evaluation (desk study) during the design and interconnection review process to verify that the fully compliant *DER system* or composite of the individual partially compliant DERs forming a system as designed meets the interconnection and interoperability requirements of IEEE Std 1547. This evaluation is usually done off-site before equipment is delivered and installed.

~~3.2.4 design test: See: type test.~~

detection time: The minimum length of time from the inception of ~~an~~ the abnormal condition to the change in state of the device or function dedicated to controlling the *interrupting device*. Syn: **processing time**.

~~3.2.6 distributed generation (DG): Electric generation facilities connected to an area electric power system (EPS) through a point of common coupling (PCC); a subset of distributed resources (DR).~~

distributed energy resource (DER)* ~~resources (DR):~~ A source ~~Sources~~ of electric power that ~~is~~ are not directly connected to a bulk power ~~transmission~~ system, as defined in IEEE Std 1547-2018. DER ~~DR~~ 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.

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

electric power system (EPS)*: Facilities that deliver electric power to a load. ~~Note that EPS may include generation units.~~ See also: **area electric power system (area EPS)**; **local electric power system (local EPS EPS)**.

NOTE— This may include generation units.

installation evaluation: An evaluation at the time of DER commissioning to verify that the fully compliant DER system or composite of the individual partially compliant DER units forming a system as delivered and installed meets the interconnection and interoperability requirements of IEEE Std 1547.

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”).

interconnection system* (ICS): The collection of all interconnection and interoperability equipment and functions, taken as a group, used to interconnect a DER ~~distributed resources (DR) unit~~ to an *area electric power system (EPS)*.

interrupting device: A device capable of being opened ~~and reclosed~~ whose purpose is to disconnect loads or interrupt load current or fault current ~~faults~~ and restore service ~~or disconnect loads~~.

NOTE— These devices can be manual, automatic, or motor-operated. Examples include circuit breakers, motor-operated switches, and electronic switches.

~~3.2.11 inverter: A machine, device, or system that changes dc power to ac power.~~

island*: A condition in which a portion of an *area electric power system (area EPS)* is energized solely by one or more *local EPSs* through the associated ~~points of common coupling (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.”

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

minimum required accuracy (MRA): The minimum required steady-state measurement and calculation accuracy of a DER for a given parameter, as defined in Table 3 in IEEE Std 1547-2018.

multiphase: Describes a system or device with two or more phases derived from separate transformers or a three-phase transformer. The nominal phase angle between phases is 120 degrees or 240 degrees.

NOTE—120/240V three-wire systems (i.e., split-phase systems) are not considered *multiphase* since they are derived from a single transformer from a single phase of the distribution system.

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.

~~3.2.14 nominal:~~ ~~The value or range of a parameter being within expected norms or being the normal operating level of that parameter.~~

paralleling device: A device (e.g., circuit breaker) operating under the control of a synchronizing function to electrically connect two energized power sources together.

plant controller: A control system that manages and commands other devices in the *DER system* or *DER composite*, including the *DER units* and any *supplemental DER devices*, as well as collects measurement and status information of the aggregated *DER units* and other *supplemental DER devices*. The *plant controller* may function as the DER's interoperability interface. The *plant controller* may also perform any of the IEEE 1547 control functions as designed by the *DER operator*.

NOTE—Also referred to as system controller or master controller.

point of common coupling (PCC)*: The point of connection between the ~~where a local electric power system (EPS) is connected to an~~ *area EPS* and the local EPS.

point of distributed energy resources ~~(DR)~~-connection (point of DER connection–PoC)*: The point where a DER ~~DR~~ *unit* is electrically connected in a local ~~an electric power system (EPS)~~ and meets the requirements of IEEE Std 1547 exclusive of any load present in the respective part of the local EPS.

production test: A test conducted by the manufacturer on every unit of equipment prior to shipment.

reference point of applicability (RPA)*: The location where the interconnection and interoperability performance requirements specified in IEEE Std 1547 apply.

signal injection test methods: Test methods where signals are injected into the sense terminals of the equipment under test (EUT). These methods include both primary injection test methods and secondary injection test methods.

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.

testing agency: The test and verification authority responsible for performing type tests and overseeing production testing programs to verify conformance of the DER to the standard.

NOTE—In the U.S., the testing agency may be required to be a Nationally Recognized Testing Laboratory.

~~3.2.21 simulated utility: See: simulated area electric power system (EPS).~~

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

~~3.2.23 trip time: The interval that begins at the leading zero crossing of the first half cycle of the voltage waveform in which the measured parameter (e.g., frequency, voltage, power) exceeds the trip limit and ends when the equipment under test (EUT) responds as required.~~

type test*: ~~A Test~~ of one or more devices manufactured ~~made~~ 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 ~~certain specifications. Syn: design test.~~

3.2 Abbreviations and acronyms

AGIR authority governing interconnection requirements

CSV comma-separated value

CT current transformer

DER distributed energy resource

DRTS digital real-time simulator

~~d.p.f.~~ ~~displacement power factor~~

~~DR~~ ~~distributed resources~~

EMI electromagnetic interference

EPS electric power system

EUT equipment under test

GFOV ground fault overvoltage

HIL hardware-in-the-loop

HVRT high-voltage ride-through

I/O input/output

<u>IA</u>	<u>interface algorithm</u>
<u>ID</u>	<u>identifier</u>
<u>kV</u>	<u>kilovolt</u>
<u>kVA</u>	<u>kilovolt ampere</u>
<u>kvar</u>	<u>kilovolt ampere reactive</u>
<u>kW</u>	<u>kilowatt</u>
<u>LROV</u>	<u>load rejection overvoltage</u>
<u>LVRT</u>	<u>low-voltage ride-through</u>
<u>MRA</u>	<u>minimum required accuracy (per Table 3 of IEEE Std 1547-2018)</u>
<u>MVA</u>	<u>megavolt ampere</u>
<u>NRTL</u>	<u>Nationally Recognized Testing Laboratory</u>
~~ICS~~	~~interconnection system~~
PCC	point of common coupling
p.f.	power factor
<u>PDF</u>	<u>portable document format</u>
<u>PHIL</u>	<u>power hardware-in-the-loop</u>
<u>PoC</u>	<u>point of [distributed energy resource (DER)] connection</u>
<u>p.u.</u>	<u>per unit</u>
PUT	parameter under test
<u>OPR</u>	<u>owner's project requirements</u>

<u>QF</u>	<u>quality factor</u>
RLC	resistance, inductance, and capacitance
rms	root mean square
<u>ROCOF</u>	<u>rate of change of frequency</u>
<u>RPA</u>	<u>reference point of applicability</u>
<u>RVC</u>	<u>rapid voltage changes</u>
THD	total harmonic distortion
<u>TLS</u>	<u>transport layer security</u>
TRD	total rated-current distortion
<u>UI</u>	<u>unintentional islanding</u>
<u>var</u>	<u>volt-ampere reactive</u>
VT	voltage transformer <u>or transducer, synonymous with potential transformer or transducer</u>

4. General requirements

[4.1 General](#)

Implementation of these test procedures shall be conducted in accordance with appropriate safety procedures, sequences, and precautions.

[This standard identifies procedures for performing the tests and verifications to verify compliance to the interconnection and interoperability requirements stated in IEEE Std 1547. As described in Clause 11 of IEEE Std 1547-2018, the requirements are evaluated in different phases of the DER implementation as follows:](#)

- One or more samples of the DER type shall first pass applicable *type tests* (Clause 5) and interoperability tests (Clause 6); criteria that cannot reasonably be verified through *type tests* shall be verified through other means such as *DER evaluations* and *commissioning tests*. The *type testing agency*⁸ shall report the results as described in 4.5, including any *partial compliance conditions*.
- Each *DER unit* or *supplemental DER device* shall pass all required *production tests* applicable to that device (Clause 7).
- The *type testing agency's* results report and manufacturer's instructions shall be used for any *system design evaluations* to determine what additional tests may be required once installed, per Clause 8. The *design evaluation* shall seek to provide that all requirements of IEEE Std 1547 that have not been met through type testing will be met by means determined appropriate in the *design evaluation* (simulations, calculations, etc.) and/or through *installation evaluations* and/or *commissioning tests*.
- *Installation evaluations* and *commissioning tests* shall be performed on-site by qualified personnel as required by the *design evaluation* results, manufacturer's instructions, and *interconnection requirements*, per Clause 8.
- Periodic tests and verifications shall be performed on-site by qualified personnel as mutually agreed upon by the *area EPS operator* and the *DER operator* per Clause 9.

NOTE—The requirements for *design evaluations*, *installation evaluations*, and *commissioning tests* vary depending on the *reference point of applicability* (RPA) for the DER and whether the DER installation includes *supplemental DER devices* that were not part of type testing. The procedures provided in Clause 8 for *design evaluations*, *installation evaluations*, and *commissioning tests*, and the content in Clause 9 related to periodic tests are intentionally less prescriptive than the *type* and *production tests* to allow for the wide variations among DER installations and *area EPS operator* procedures.

⁸In the U.S., the *type testing agency* may be required to be a Nationally Recognized Testing Laboratory (NRTL), which may provide certification that the DER has passed the *type tests* in this document.

It shall be permitted to combine multiple tests into one test upon mutual agreement between the testing agency and the DER manufacturer provided that the combined test fulfills all requirements of the individual tests. All requirements in this document, including those in 4.7, shall be met by any combined tests.

4.2 Test result accuracy

The test results shall verify that the equipment under test (EUT) meets the requirements of IEEE Std 1547 within the tolerances defined in this subclause ~~manufacturer's specified accuracy~~.

Unless otherwise specified in the type tests, the DER performance shall be within 150% of the minimum required measurement accuracy (MRA), as specified in Table 3 of IEEE Std 1547-2018 for steady-state conditions.^{9, 10} For control functions where the DER regulates an output parameter, Y , in response to a measured input parameter, X ,¹¹ the output parameter measured by the test lab, Y_{meas} , shall meet Equation (1):

$$Y_{\text{min}} \leq Y_{\text{meas}} \leq Y_{\text{max}} \quad (1)$$

where

$$Y_{\text{min}} \text{ is } Y(X_{\text{meas}} + 1.5 \times \text{MRA}(X)) - 1.5 \times \text{MRA}(Y)^{12}$$

⁹DER control performance for a given parameter cannot be required to have greater accuracy than the DER can measure. Thus the DER cannot be required to control an output parameter within 100% of MRA of the expected value, where MRA is specified in Table 3 of IEEE Std 1547-2018. The "150% of MRA" criteria used in Equation (1) allows for both DER measurement uncertainty (MRA) and control uncertainty.

¹⁰DER should also meet the transient measurement requirements in Table 3 of IEEE Std 1547-2018, but those requirements are not used to calculate type test criteria.

¹¹These control functions include voltage-reactive power, voltage-active power, active power-reactive power, and frequency droop, as specified in IEEE Std 1547-2018.

¹²This equation leverages the fact that for all reasonable implementations of the functions to which this equation applies, the equation is monotone decreasing.

$Y_{\max}$ is $Y(X_{\text{meas}} - 1.5 \times MRA(X)) + 1.5 \times MRA(Y)$ ¹³

$Y(X)$ is a mathematical function defining the target DER output parameter (active or reactive power) in terms of the input (voltage, frequency, or active power)

X_{meas} is the input parameter as measured by the test lab

$MRA(a)$ is the DER's minimum required steady-state measurement accuracy of a per Table 3 in IEEE Std 1547-2018, where a is an input or output parameter under test (voltage, reactive power, active power, or frequency)

An example of the application of Equation (1) is provided in Annex C.

Other methods of verifying the DER meets the criteria for a *type test* shall be permitted if specified in the relevant *type test* subclause.

4.3 Testing environment

The EUT manufacturer shall specify the range of environmental conditions for the EUT. Therefore, tests shall be conducted in an environment that is within the manufacturer's specified environmental operating conditions.

~~4.3 Measurement accuracy and calibration of the testing equipment~~

~~Measurement equipment used to confirm performance of an EUT shall have calibration traceability.
The accuracy of the measuring equipment shall be suitable for the test being conducted.~~

4.4 Product information

The setting of limits and the structure of this standard are based on the understanding that the DER installer and user are responsible for following the installation recommendations of the DER manufacturer.

¹³This equation leverages the fact that for all reasonable implementations of the functions to which this equation applies, the equation is monotone decreasing.

The manufacturer shall supply the EUT tester with documentation necessary for the correct installation into a typical system or process in the intended environment, which may include installation instructions, user instructions, application notes, EUT manuals, and/or other documents.

A functional description and a definition of specification limits for the acceptance criteria shall be provided by the manufacturer and noted in the test report.

Any external devices or equipment or special connection requirements ~~necessary to conduct the tests~~ shall be clearly stated (including rationale) in the EUT manufacturer's instructions ~~user documentation~~. Special requirements can include the amount of network impedance, volt-ampere ~~voltampere~~ burden of the EUT, the use of shielded or special cables, maximum cable length, and the use of filters, ~~and the correct bonding to functional earth (grounding)~~. If different devices or connection requirements apply in different environments, this shall also be stated. A list of auxiliary equipment (e.g., options or enhancements) that can be added to the EUT and that can impact the result of EUT tests shall be made available. This information shall also be documented ~~covered~~ in the test report to clarify the as-tested arrangement(s). Accuracy and tolerances of device parameters shall be stated by the EUT manufacturers.

Where the EUT is a DER system as defined in 3.1, the manufacturer's instructions shall include at least the following information:

- Required components of the DER system
- Optional components of the DER system
- Maximum allowable impedance or voltage rise between the PCC and the PoC(s) of individual components of the DER system
- Allowed electrical topologies of the DER system (radial, daisy-chain, etc.)
- Requirements on any transformers within the DER system
- DER system communication components, if any
- Requirements on instrumentation transducers, if any

- Requirements on use of shielded or special cables, if any

When type-testing a *DER system* and evaluating its documentation, the test agency shall consider the impacts of the following on conformance of the *DER system* to the test criteria under the range of allowable *DER system* configurations:

- Voltage rise or drop between the PCC and the PoC(s) of individual components of the *DER system*
- Reactive power losses within the *DER system*
- Communication latency within the *DER system*

4.5 Test reports

4.5.1 Overview

The test results shall be documented in a summary test report described in 4.5.3 through 4.5.6. ~~The report shall clearly and unambiguously present all relevant information of the tests (e.g., load conditions, conductor type or routing, functional description, acceptance criteria).~~

~~Within~~ The testing agency or evaluator shall also create a detailed test report, retained by the manufacturer and testing agency. If the test setup or testing equipment used during testing deviates from common testing agency methods, the report shall include sufficient information to rerun the test and reproduce the results. Within the detailed test report, test procedures, as performed, shall be documented ~~detailed~~; and engineering considerations, including test modifications and exemptions, shall be described ~~justified~~. ~~When used in conjunction with this standard, the test report shall include sufficient critical operating information to rerun the test and reproduce the results.~~

~~Each test method shall be specified; and engineering considerations, including range of operating conditions, shall be justified.~~

4.5.2 Purpose

The new requirements contained in IEEE Std 1547-2018 significantly expand the functional capabilities and complexity of DER to reflect the greater DER impact at higher penetration levels. Also, at high DER penetration levels, the DERs may need to be designed and operated in manners similar to that of the conventional units they replace in order to maintain the existing service levels. Hence, the number of parameters and settings that must be verified in association with the expanded functionality has also increased substantially. IEEE Std 1547-2018 also includes requirements for coordination with other utility protective equipment, and that coordination requires a more detailed knowledge of the performance capabilities of the DER and the existing grid. As the levels of DER use increase, it becomes increasingly critical for *area EPS operators* and others to understand the performance capabilities and limitations of the DER and to use that information during *DER evaluations* conducted in association with interconnection studies. The large volume of data and increased criticality of such data have made it imperative that performance data be summarized to identify the capabilities that were evaluated and also be presented in a standardized format. Standardized formats for testing results summaries facilitate exchanges of information between parties, reduce potential for errors during data exchanges, allow for automated *DER evaluations*, and provide traceability of test results back to the *testing agencies*. The requirements for the reporting of testing results are contained in this subclause (4.5).

4.5.3 Results reporting

The requirements contained in 4.5 shall apply to reporting of the results collected during the following types of testing:

- Type testing of representative samples of *DER units* and *DER systems* conducted or supervised by the *testing agency*.
- Production testing of *DER units* and *DER systems* conducted at time of manufacture, where the manufacturing process and production testing is periodically inspected by a *testing agency*.

- Commissioning testing conducted at time of DER installation or at other times during the DER evaluation process as specified by the area EPS operator or relevant authority governing interconnection requirements (AGIR).
- Installation evaluations or testing conducted to verify the as-built configuration. Installation testing does not require any specific reporting. Installation evaluations may be recorded in any mutually agreeable format that meets the requirements of Clause 8.
- Periodic testing results do not require reporting in a standardized format and may be recorded in any mutually agreeable format that meets the requirements of Clause 9.

The testing agency shall produce a summary report summarizing the results of the type testing that shall be retained by the EUT manufacturer. The type test summary report shall include the EUT nameplate information described in Table 28 of IEEE Std 1547-2018 and shall identify all evaluated functions, including any associated ranges of adjustment within the range of allowable settings,¹⁴ used to demonstrate compliance with Clause 4 and Clause 5 of this standard. The summary of the type testing results shall be presented in the file formats defined in 4.5.3 through 4.5.6.

Production testing results shall be provided by the manufacturer upon request. The file shall include model and serial numbers of the EUTs plus any additional information, recorded at time of manufacture, using the production testing process approved and monitored by an applicable testing agency.

Where commissioning testing is conducted, a test report summarizing the results of commissioning testing and any recommended corrective actions shall be documented and provided to the area EPS operator. The scope of the testing and reporting shall be in accordance with the requirements of Clause 8 or as mutually agreed between the area EPS operator and the DER system owner or operator. The commissioning summary test report shall be issued by an individual or entity qualified to perform or supervise such tests or field evaluations. The commissioning test summary report shall be provided in a secured portable document format (PDF) file or any other format mutually agreeable between the area EPS operator and the DER system owner or operator.

¹⁴Where not prohibited by IEEE Std 1547-2018, settings beyond the ranges of allowable settings may also be tested, for example to demonstrate additional capability.

Where the *DER evaluation* or commissioning process requires settings to be applied, the report documenting the applied settings may be issued by the installer, manufacturer, or other qualified entities. The verification of applied settings report shall be provided in a secured PDF or comma-separated value (CSV) file, or any other format, mutually agreeable between the *area EPS operator* and the *DER system* owner or operator. The data structure and naming convention requirements as outlined in 4.5.5 shall be used in summary reports of settings as applied in the field.

4.5.4 Data formats

Testing results summaries shall be reported using both a secured PDF file for written results and a CSV file, including a 256-bit Secure Hash Algorithm (SHA-256 hash) checksum value, for tabular results. The PDF summary file shall be issued by the *testing agency*, or other applicable testing body, and shall include reference to the associated tabular CSV format filename(s), SHA-256 hash checksum value(s). A template of the tabular CSV file is referenced in Annex B. The PDF summary file shall also include reference to any other files needed to demonstrate compliance with this standard, such as oscillographic data recorded in accordance with the requirements of subclause 11.4.2 of IEEE Std 1547-2018. The reference to other files shall include the file name and the checksum associated with each file.

Where oscillographic data is required to document results of testing, the data shall be supplied in either COMTRADE (IEEE Std C37.111) or PQDIF (IEEE Std 1159.3) format, and shall meet the requirements for sampling rate, accuracy and any pre- or post-event capturing specified for each test.

4.5.5 Naming convention and data structure

The naming conventions used to identify specific nameplate data in the CSV file shall utilize the Data Structure and Naming Convention shown in 4.5.5.1 and 4.5.5.2 and in the template referenced in Annex B. These Naming Convention and Data Structure formats shall be used for each record in the CSV file.

4.5.5.1 Naming convention

The naming convention is as follows:

Parameter Name-Data Context-Data Type-Optional Modifier(s), Value, Units, <CR><LF>

Parameter names are composed of the parameter base identifier, optional context qualifiers, optional type qualifiers, and additional optional modifiers. Parameter names can be composed of uppercase alpha characters, numbers, underscores, and hyphen. Underscores are used for readability within single concept portions of the name. Hyphens are used to separate data context, data type, and modifier sections of the name.

Parameter values can be one or more numbers or text strings. If a parameter value contains more than one element, the elements are separated by hyphens. Hyphens should not be used in parameter value text strings.

4.5.5.2 Data structure

Data structure is as follows:

- *Parameter Name:* as specified in Table 28 of IEEE Std 1547-2018 or naming template in Annex B
- *Data Context:*
 - TR¹⁵ – Technical Range – May be used by EUT manufacturer to indicate the technical capabilities of the DER unit which may be beyond the evaluated ranges, or
 - ER – Evaluated Range – Indicates performance evaluated by the testing entity, or

¹⁵The Data Source designators TR, SS, SR, and Other are out of scope of IEEE Std 1547.1 but are included here to illustrate ways in which the template might be used for standardized information exchange of data commonly used in interconnection processes.

- SR – Specified Range – May be used by *area EPS operator* to indicate specified range different from the ranges of allowable settings of IEEE Std 1547-2018.¹⁶
 - SS – Specified Settings – May be used to indicate the settings specified by the *area EPS operator* or AGIR, or
 - AS – Applied Setting – Indicates the setting applied in the DER. Typically reported at time of commissioning, or following subsequent parameter changes; or
 - Other – Undefined, but allowed for future use.
 - **Data Type:**
 - MIN – Minimum value in a range of adjustment or evaluated range, or
 - MAX – Maximum value in a range of adjustment or evaluated range, or
 - **Optional Modifier(s):** Undefined, but allowed for future use.
 - **Value:**
 - The value of the parameter resulting from the type testing, or
 - The text string associated with the parameter.
 - **Units:**
 - The abbreviation for the scientific unit associated with the value, as shown in Table 1.
- NOTE—Where multiple values or strings are supported, separate with underscores.
- <CR><LF>: Carriage return and line feed. End of record identifier.

¹⁶ Ranges different from the ranges of allowable settings of IEEE Std 1547-2018 should not be specified unless exceptional cases require so. These cases should be reported to the sponsor of this standard for consideration in future revisions of IEEE Std 1547-2018.

Table 1—Abbreviations of unit values

Abbreviation	Value	Abbreviation	Value
V, V p.u.	Volt (dc), V p.u. (ac)	kVA	Apparent power
A	Amps (ac or dc)	P p.u.	Per unit active power
Hz	Frequency	var p.u.	Per unit reactive power
s	Time in seconds	PF	Power factor (injecting or absorbing)
Text	Text string	S	Reactive susceptance (formerly Mho)
Ohms	Resistance (<i>R</i>) or Reactance (<i>X</i>)		
Per unit values are based on the corresponding nameplate values of the EUT			

(New)

NOTE—The requirements in this clause are scope constrained to the reporting of results occurring during type testing of *DER units*. During the development of this standard, numerous other stakeholders have expressed interest in creating a standardized format for exchange of DER parameters for other purposes. Some examples of possible uses would be as follows: specification of utility requirements documents, local modifications of source requirements, modeling of DER performance for distribution as well as transmission planning and protection, etc. While such use is out of scope of this standard, the data structure and Naming Conventions specified previously allow for such uses via the Data Source and Optional Modifiers fields. Data Source identifiers might identify a specific utility or regional authority. The optional modifiers identifier might identify sub requirement based on location, time of use, multiple tariff requirements, etc. While these uses are out-of-scope, the standard acknowledges the value of standardized data exchange formats and provides flexibility in data structure/naming conventions to support those uses.

4.5.6 Traceability

The Type Testing Summary Report shall identify the name and address of the *testing agency*. The report shall include references to any certificates of compliance or report numbers associated with *DER evaluation*. The report shall include the issuance date of the report and the name of the individual responsible for issuance of the report.

4.6 Testing equipment requirements

4.6.1 AC test ~~Simulated area EPS (utility)~~ source requirements

Where testing allows or requires the use of an ac test ~~a simulated area EPS~~ source, the following requirements shall be met unless stated otherwise in a specific test procedure:

- The ac test ~~simulated area EPS~~ source shall be capable of confirming the EUT manufacturer's stated performance.
- The voltage harmonics of the ac test ~~simulated area EPS~~ source, as measured with the EUT connected and operating in steady state at rated power, shall be less than 3.0 ~~2.5~~% total harmonic distortion (THD).
- ~~The individual voltage harmonics of the simulated utility shall be less than 50% of the limits in Table 3 of IEEE Std 1547.~~
- During the tests, the steady-state ac test ~~voltage of the simulated area EPS~~ source voltage shall not vary by more than $\pm 1\%$ of ~~the~~ nominal (0.01 p.u. on the nominal voltage base) from the set voltage.
- During the tests, the steady-state ac test source frequency shall not vary by more than 0.1 Hz unless required by the test.
- The ac test source used for each test shall have sufficient resolution of voltage and frequency control to produce the test profiles designated in the respective tests.
- The ac test source used for each test shall be capable of changing voltage and frequency at a rate that is sufficient to meet the requirements of the respective tests.¹⁷
- The ac test source used for each test shall be capable of producing the voltage or frequency profile required by that test. The testing agency shall confirm through evaluation of the voltage and frequency profile measured at the EUT's voltage sense points that the applied voltage and frequency meet the requirements of the test.

¹⁷See annexes and type tests for additional information on test voltage and frequency profiles.

- ~~— For voltage trip magnitude tests, the voltage change resolution of~~
- ~~— the simulated utility source shall be within $0.5a$ of the nominal voltage, where a is the manufacture's stated accuracy.~~
- ~~— For frequency trip magnitude tests, the frequency change resolution of the simulated utility source shall be within $0.5a$ of the nominal frequency, where a is the manufacture's stated accuracy.~~
- The number of phase and neutral connections provided by the ac test source ~~simulated-area EPS~~ shall be compatible with the EUT. A *multiphase ac test source* ~~simulated-area EPS~~ that provides a neutral connection shall produce phase-to-neutral voltages that are balanced within $\pm 3\%$ of nominal and phase displacement to within $\pm 3^\circ$. For *multiphase ac test sources* ~~simulated-area EPSs~~ without a neutral connection, the phase-to-phase voltage balance shall be $\pm 3\%$ of nominal in magnitude. For three-phase ac test sources, the negative sequence voltage of the ac test source shall be less than 1.5%.
- The ac test source may include a load bank, for example to sink power when a source that cannot sink power is used, unless otherwise specified in a test.

Where signal injection test methods are used, the injected voltage signal shall meet the requirements of this subclause, scaled to the level of the injected signal. The test report shall state which tests used signal injection and briefly state the rational justification for its use.

For the purposes of production and commissioning tests, it might not be feasible to meet all of the above requirements on the ac test source. In the case of production tests, the manufacturer and testing agency shall establish acceptable requirements. In the case of commissioning tests, the area EPS operator and the DER operator or their designated representatives shall establish acceptable requirements.

For tests and EUTs that are within the scope of IEEE Std 4, in the case of any conflicting requirements, those of IEEE Std 1547.1 shall apply.

4.6.2 Simulated DER input source requirements

If the testing agency and the DER manufacturer agree that the following two conditions are true, it shall be permitted to use substitute hardware to emulate the prime mover or DER input energy source:

- The emulation system adequately captures the dynamics of the real prime mover or input energy source for all time scales relevant to the test for which it is to be used.¹⁸
- Vulnerabilities including DER auxiliary systems that may affect the DER's ability to perform the test are properly captured. Auxiliary systems (for example, control power supplies, pumps, etc.) may be of particular concern in ride-through tests.
- ~~— For voltage trip timing tests, the simulated utility source shall be capable of a step change from V_1 to $V_1 + 0.5(V_2 - V_1)$ within the greater of one cycle of the voltage waveform or 1% of the trip time setting of the EUT.⁶~~
- ~~— For frequency trip timing tests, the simulated utility source shall be capable of a step change from f_1 to $f_1 + 0.5(f_2 - f_1)$ within the greater of one cycle of the voltage waveform or 1% of the trip time setting of the EUT.⁷~~

4.6.3 Measurement system requirements

Test system measurements ~~Each measurement~~ shall have an uncertainty of no more than 0.5 times the minimum required DER measurement accuracy for steady-state measurements in Table 3 of IEEE Std 1547-2018 ~~of the EUT.~~

¹⁸This statement is not intended to require that photovoltaic inverters be tested with real PV arrays or solar array simulators or that battery inverters be tested with real batteries or dynamic battery emulators; a dc voltage source may be sufficient. Input source requirements may depend on the specific test being performed.

⁶~~See Annex A for additional information.~~

⁷~~See Footnote 6.~~

The required frequency measurement uncertainty may be achieved by post-processing sampled waveform data.¹⁹

Measurement equipment shall be capable of confirming the DER meets the test criteria for each test. Measurement equipment used to confirm ~~manufacturer's stated~~ performance of an EUT shall have valid (non-expired) and traceable calibration.²⁰

The sampling rate of the measurement system used for each test shall be at least two times the frequency of the measured signal (including any harmonics and transients of interest for the test). Filtering shall not limit the ability of the measurement system to accurately capture the measured signal.

For tests and EUTs that are within the scope of IEEE Std 4, in the case of any conflicting requirements, those of IEEE Std 1547.1 shall apply.

Where not specified otherwise in this standard, applicable voltages shall be quantified as the effective (rms) values over the preceding fundamental frequency period, per IEEE Std 1547.

4.7 Requirements on *type test* order and selection of DER sample(s)

During type testing, certain groups of tests shown in Table 2 shall be run using the same EUT sample and with certain restriction on test order as defined in the following list and in Table 2. The intent of this requirement is to evaluate any impacts of one test on another test in the same group.

- Tests listed within a single cell of Table 2 may be run in any order, but shall be run before tests in the cell immediately to the right, if any.

¹⁹At the time of drafting of the standard, typical measurement equipment often did not meet the frequency measurement uncertainty requirement. While it is preferable that measurement equipment (or its specifications) be updated to meet the uncertainty requirement, post-processing of sampled data is allowed to avoid creating a requirement that cannot be met by typical equipment.

²⁰For example, in the U.S. and some other locations, ISO 17025 is used to provide guidance on calibration criteria.

— Tests not listed in Table 2 may be run in any order, on any sample.

Running all *type tests* on a single sample while accounting for the test order requirements in Table 2 is one way to meet this requirement.

Table 2—Test groups to be run on a single sample

Group	Subgroup 1	Subgroup 2
1	5.3 Temperature stability ^a 5.8 Interconnection integrity ^a	5.4.2 Test for overvoltage trip 5.4.3 Test for undervoltage trip 5.5.1 Test for overfrequency trip 5.5.2 Test for underfrequency trip
2	5.4.4 Low-voltage ride-through tests 5.4.7 High-voltage ride-through tests 5.5.3 Test for low-frequency ride-through 5.5.4 Test for high-frequency ride-through 5.5.5 Test for rate of change of frequency (ROCOF)	5.10 Unintentional islanding

(New)

^a Temperature stability and interconnection integrity tests may be run on different EUT samples provided that at least 30% of voltage trip tests and at least 30% of frequency trip tests are run on each sample.²¹

All samples used in type testing shall have identical hardware, software, and firmware. The *testing agency* shall record and report all EUT serial numbers; hardware model numbers; control board assembly versions; software version numbers; firmware version numbers; and other identifiers that distinguish hardware, software, and firmware for the tested samples. Aside from serial numbers, all other distinguishing identifiers shall be verified as identical by the *testing agency*.

In the case of a test failure resulting in a modification to the DER, the test agency shall decide whether to re-run some or all previous tests based on the nature of the modification. This may apply to tests in the same group within Table 2, tests in a different group, and/or tests not listed in Table 2.

²¹The intent of this requirement is to require that a significant portion of trip tests are run on a sample that has undergone temperature stability testing and a significant portion are run on a sample that has undergone interconnection integrity testing without requiring that a single sample undergo both interconnection integrity and temperature testing. A sample used for temperature testing may be modified to insert temperature sensors, which could compromise its ability to withstand interconnection integrity tests in some cases.

4.8 Intentional island-capable DERs and devices

For DERs and devices designed to be capable of operating in an intentional island, the tests shall cover the extended ranges specified by the manufacturer for intentional island operation. The values of any extended ranges shall comply with 8.2.7 of IEEE Std 1547-2018. The manufacturer shall specify which of the DER categories listed in 8.2.8 of IEEE Std 1547-2018 for intentional islands the device or DER falls into; the device or DER may fall into more than one intentional island category. The test report shall state the ranges of settings tested.

During transition to and from intentional island operation, the area EPS island shall comply with 8.2.4 through 8.2.6 of IEEE Std 1547-2018.

5. Type tests

5.1 General

Type tests are performed or overseen by a testing agency on one or more ~~on a~~ representative unit(s) and may be conducted in the factory, at a testing laboratory, or on equipment in the field. ~~Unless otherwise specified,~~ Equipment under test shall be installed per the manufacturer's specification and operated under the conditions specified for each test (or nominal operating conditions if not specified).

As stated in IEEE Std 1547-2018, type test results from a DER within a product family of the same design, including hardware and software (with electrical components proportionally scaled according to the DER voltage and current ratings), shall be allowed as representative of other DERs within the same product family with power ratings between 50% to 200% of the tested DER.

Exception: Each member of a product family shall be tested according to 5.17 and 5.18 unless the DER manufacturer and the testing agency mutually agree that one member of the family is representative of the entire family for the purposes of maximum sustained fault current, in which case the tests in 5.17 and 5.18 may be performed on only one representative member of the family.

Where it is not feasible for technical reasons to evaluate the EUT ~~cannot be evaluated~~ using one or more of the test regimens specified in this standard, alternative test regimens agreed to by the manufacturer and the *testing agency* and accomplishing the same measurements with the same accuracy may be used. When used, the details of such alternative test regimens shall be recorded in the test report along with an explanation of why the alternative test regimen was used.

Signal injection test methods may be used only when it is explicitly stated that they are allowed in a given subclause. Injected voltage signals shall meet the requirements of 4.6.1, scaled appropriately to ~~conduct tests in 5.1, 5.2, 5.3, 5.4, 5.8, and 5.10.~~

Several test procedures require the EUT to be operated at different discrete power levels (e.g., 33%, 66%, and 100% of rated power). Adjustments may be made to the EUT to achieve the discrete power levels, provided that these adjustments do not otherwise affect the performance of the EUT for the parameter under test (PUT), unless otherwise specified. Alternatively, to accomplish testing at discrete power levels, the input source may be power limited to result in the desired EUT output power levels unless otherwise specified.

IEEE Std 1547 allows for type testing to be performed on complete systems, multifunction relays, discrete devices, or any combination. If type testing is performed on anything other than a fully integrated system, some of the component times in Figure A.1 may not be available. In these cases, production and/or *commissioning tests* shall be conducted to fully demonstrate the ability of the complete system to comply with the timing required by IEEE Std 1547. As an alternative, the test report may show that the sum of individual component timings meets the requirement; ~~may be shown~~ in such cases, the individual component timings shall be documented in the report as well. Other requirements also apply when type testing is performed on an EUT that is not a fully integrated system, as described in Clause 11 of IEEE Std1547-2018 and in Clause 8 of this standard test report.

When the EUT manufacturer requires a transformer installed between the EUT and RPA, several type tests require that the transformer be included during testing as part of the equipment under test. When the EUT manufacturer instructions allow more than one transformer configuration, the relevant tests shall be repeated with each configuration. In such cases, the transformer used in type testing may have any convenient turns ratio. The impedance (resistance and reactance) and winding configuration(s) of the transformer used for type testing shall be as listed in the EUT manufacturer's specifications.

5.2 Priority of responses

The tests needed to demonstrate compliance with the requirements of 4.7 (Priority of Responses) in IEEE Std 1547-2018 were duly considered and are included in, and are part of, the tests in 5.4, 5.5, 5.10, 5.13, and 5.16 of this standard.

~~For the purposes of this standard, multiphase ICSs include single-phase three-wire ICSs.~~

5.3 Temperature stability

5.3.1 Purpose

This test verifies that the EUT maintains measurement accuracy of parameters as required in Table 3 of IEEE Std 1547-2018 over its specified ~~temperature range. EUT functions shall be tested to confirm that they operate within the manufacturer's stated accuracy over the stated~~ operating temperature range. Because of the wide variation in DER equipment, it is not possible to specify a single test procedure that works for all DERs. Therefore, a functional test procedure to verify the EUT's measurement accuracy ~~exercise each EUT input and output function~~ shall be agreed to by the manufacturer and the *testing agency*. The functional test procedure shall confirm EUT operation within the minimum required measurement ~~manufacturer's stated~~ accuracy for magnitude and time. ~~It is the intent of this test to confirm the manufacturer's specified accuracy over the specified operating temperature range for measurements and timing references used to provide compliance with IEEE Std 1547.~~

~~The test consists of two sections. The operational test verifies that the EUT functions per manufacturer's specification over its operating temperature range. The storage test verifies that the EUT can be stored without damage over the manufacturer's specified storage temperature range.~~

5.3.2 General

Where protective, monitoring, measurement, and control functions can be conveniently separated from the ~~ICS, the~~ remainder of the DER without impacting the function of the EUT, the remainder of the DER ICS may be omitted from this test.²² However, the manufacturer shall provide the *testing agency* with substantive information to verify that the complete DER performs ~~ICS will perform~~ acceptably over the manufacturer's stated ~~claimed~~ operating temperature range. If only a portion of the DER is tested, the maximum and minimum temperature tests shall be run at the temperature that portion would experience when the DER is operating at the maximum and minimum operating temperatures, respectively.

The measurement accuracy verifications may be conducted with the EUT operating at any convenient power level.

5.3.3 Procedures ~~Procedure~~

5.3.3.1 Operational temperature test procedure

The test shall seek to verify ~~To ensure~~ that the equipment has reached the desired temperature by allowing the equipment, ~~it should be allowed~~ to stabilize at the specified chamber temperature. Stabilized temperature is reached after a minimum of 2.5 h ~~hr~~ and when three successive temperature readings taken at 30 minute ~~min~~ intervals are at or above maximum temperature for high temperature tests, or at or below minimum temperature for low temperature tests ~~within 1°C~~. For the minimum operating temperature point, the equipment shall remain deenergized ~~deenergized~~ until the stable temperature has been achieved in the test chamber. The test procedure is as follows:-

²²This does not remove the requirement that the measurement accuracy of voltage, frequency, active power, and reactive power be verified at maximum and minimum operating temperatures.

- a) Select test temperatures per the EUT specification. The EUT ~~shall~~ should be tested at the minimum, ~~nominal (or average of maximum and minimum if not specified),~~ and maximum operating temperatures. ~~If nonlinear response is observed, additional test temperatures should be selected between the minimum and maximum temperatures.~~
- b) The measurement ~~trip and reset~~ parameters to be validated ~~measured~~ over the temperature range include voltage, active ~~current,~~ power, reactive power, and ~~phase angle,~~ frequency. In addition, a clearing, and time test shall be conducted at the high end of function as appropriate for the temperature range, and an Enter Service EUT. The objective is to confirm each subsection of the EUT. The selection of parameters or functions to be evaluated for this test shall be conducted at the low end of the operating temperature range to verify that measurement made so that all hardware components (including those that execute software functions) likely to be affected by temperature are evaluated. Where hardware components are common to more than one function, only one of the common functions need be evaluated to confirm accuracy of time is acceptable over the specified temperature range.
- c) Perform the tests and record the data. ~~Perform a minimum set of tests that will verify that the EUT protective functions will operate properly over the operating temperature range as specified by the manufacturer.~~
- d) At each temperature point selected in step a), repeat each test selected in step b) for a total of five times.

5.1.2.2 Storage temperature test procedure

~~Select test temperatures per the EUT specification. The EUT should be conditioned at the minimum and maximum storage temperatures. Where the EUT's operating and storage temperatures are the same, this test is not required.~~

~~Select the test method. Storage temperature performance can be established in one of two ways:~~

- ~~— The first method is to review the storage temperature specifications of the individual components of the EUT. If all the components meet the requirements, the EUT meets the requirements.~~