

IEEE 1547 Standards for Grid Integration of Distributed Energy Resources (DER)

Overview and Current Activity

IEEE PES Seattle Chapter Meeting
June 11, 2015

Presentation Outline

1547™-2003

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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- What is IEEE 1547?
- How 1547 is Used
- How 1547 is Evolving
- Getting Involved

IEEE 1547 Scope and Purpose

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.

IEEE 1547 Key Provisions

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

4.1.1 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.

IEEE SCC21 1547 Series of Standards

IEEE Std 1547™(2003 and 2014 Amendment 1) Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std P1547™(full revision) Draft Standard for Interconnection and **Interoperability** of Distributed **Energy** Resources with **Associated** Electric Power Systems **Interfaces**

IEEE Std 1547.1™(2005 and 2015 Amendment 1) Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

IEEE Std P1547.1 (full revision) Draft Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed **Energy** Resources with Electric Power Systems **and Associated Interfaces**

IEEE Std 1547.2™(2008) Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std 1547.3™(2007) Guide for Monitoring Information Exchange, and Control of Distributed Resources with Electric Power Systems

IEEE Std 1547.4™(2011) Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

IEEE Std 1547.6™(2011) Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks

IEEE Std 1547.7™ (2013) Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection

IEEE Std P1547.8™ Draft Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Std 1547-2003

IEEE Standards Classification

- **Standards**: documents specifying mandatory requirements (**shall**)
- **Recommended Practice**: documents in which procedures and positions preferred by the IEEE are presented (**should**)
- **Guide**: documents that furnish information -- e.g., provide alternative approaches for good practice, suggestions stated but no clear-cut recommendations are made (**may**)

EPACT 2005 cites & requires IEEE standards 1547 and best practices consideration for DER interconnection

Most states have adopted or referenced IEEE 1547

IEEE 1547 developed by national team of 444 professionals



IEEE 1547 Interconnection Standards Use in USA

IEEE 1547 **Interconnection System and Test Requirements**

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding
- etc.

IEEE 1547.1 **Interconnection System Testing**

- O/U Voltage and Frequency
- Synchronization
- EMI
- Surge Withstand
- DC injection
- Harmonics
- Islanding
- Reconnection

UL 1741* **Interconnection Equipment**

- 1547.1 Tests
- Construction
- Protection against risks of injury to persons
- Rating, Marking
- Specific DR Tests for various technologies

NEC **

Article 690 PV Systems;

Article 705: interconnection systems (shall be suitable per intended use per UL1741)

PJM Interconnection, Inc. ***Small Generator Interconnection Standards*** **FERC approved**

*(0-to<10MW and 10-to-20 MW;
incorporate 1547 and 1547.1)*

* UL 1741 supplements and is to be used in conjunction with 1547 and 1547.1

** Articles: 480 Storage Batteries ;
692 Fuel Cell Systems;
694 Wind Electric Systems
(NEC info. based on NEC 2011)

IEEE 1547 Closer to Home

FUEL CELL, SOLAR, WIND, BIOGAS, COMBINED HEAT AND POWER, OR HYDROPOWER ELECTRIC GENERATING FACILITIES OF 100 KILOWATTS OR LESS

Application and Agreement for Interconnection, Net Metering, and Production Metering

This Application and Agreement is considered complete when it provides all applicable and correct information required below. Additional information to evaluate the Application and Agreement may be required. Capitalized terms used in this Application and Agreement have the meanings set forth in this schedule unless the usage clearly indicates otherwise.

A non-refundable application fee will be charged against the Customer's electric bill upon receipt of this Application and Agreement from Customer. If no account currently exists, the application fee must accompany this Application and Agreement:

| | |
|--|----------|
| UL 1741 Inverter-based Generating Facilities of 0 kW to 100 kW | \$ 0.00 |
| Generating Facilities of 0 kW to 25 kW (without UL 1741 rated inverters) | \$100.00 |
| Generating Facilities of 25 kW to 100 kW (without UL 1741 rated inverters) | \$500.00 |

Additional fees may apply if the Interconnection Customer needs to apply for a different Tier (as described in Schedule 152) or if studies are required. Additional charges for taxes may apply.

Copied from PSE Electric Tariff Schedule 150, Attachment B

https://www.pse.com/aboutpse/Rates/Documents/elec_sch_150_attach_b.pdf

IEEE Std 1547a – Amendment 1, May 2014

(Amendment 1: revisions to 4.1.1, 4.2.3, and 4.2.4)

4.1.1 Voltage Regulation

... DER allowed to change its output of active and reactive power.

4.2.3 (*Response to abnormal grid ...*) Voltage

**.... DER allowed to “ride through” abnormalities of grid voltage;
... grid and DER operators can mutually agree to other voltage trip
and clearing time settings**

4.2.4 (*Response to abnormal grid ...*) Frequency

**... DER allowed to provide modulated power output as a function
of frequency**

**... ... grid and DER operators can mutually agree to other
frequency trip and clearing time settings**

IEEE Std 1547.1a -- Amendment 1 [2015] to 1547.1

New type tests: ...e.g., modulated power output allowed as a function of frequency conditions ...

5.3 Response to abnormal frequency conditions

Insert new subclauses (into IEEE Std 1547.,1)

5.3.3 Real power reduction test where the EUT responds to over frequency

The manufacturer shall specify the response characteristics of the EUT real power reduction in response to over-frequency events

5.3.4 Real power increase test where the EUT responds to under frequency

The manufacturer shall specify the response characteristics of the EUT real power increase in response to under-frequency events.

IEEE Std 1547.1a -- Amendment 1 [2015] to 1547.1

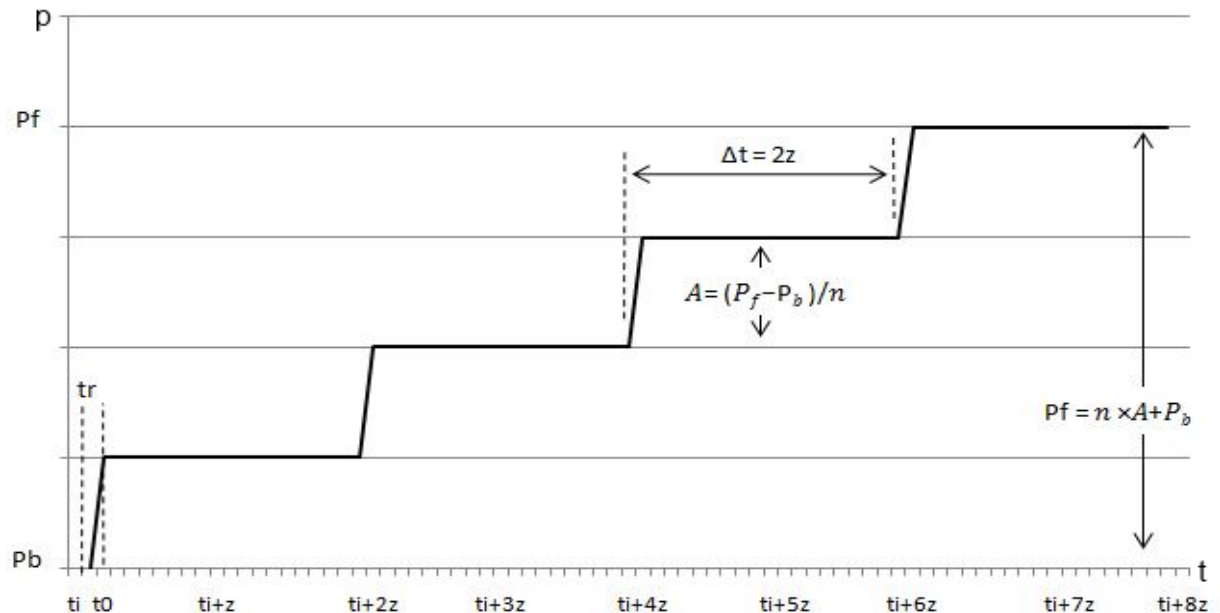
New type test ...**5.13 Voltage regulation** ... four categories of voltage regulation testing ... each applicable to: static power inverters/converters, induction machines, and synchronous machines.

- Where the EUT responds to variations in voltage the manufacturer shall specify the response characteristics.
- Where the EUT responds to communicated settings the manufacturer shall specify the protocol, means of communications and the response characteristics.
- Where the EUT responds to a time schedule the manufacturer shall specify the response characteristics.
- Where the reactive power output of the EUT changes with respect to real power output, the manufacturer shall specify the response characteristics.

IEEE Std 1547.1a New Annex A.5

A. 5 Power variation test
(step-wise ramp function) –
general

Figure A.6 -- Graphical
representation of power
variation test using step-wise
ramp function with $n = 4$



P1547 Revision: Draft *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.*

- *Build from existing Std 1547 document structure*
- *Incorporate revisions based on existing 1547 series*
- *Address additional criteria and requirements based on approaches of Std 2030 and P2030.2, including interoperability, and, associated interfaces*

Scope: This standard establishes criteria and requirements for interconnection of distributed **energy** resources (DER) with electric power systems (EPS), **and associated interfaces.**

Note: Interfaces defined in IEEE 2030: “a logical interconnection from one entity to another that supports one or more data flows implemented with one or more data links.

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

P1547 example works in progress (WIP): not approved!

Draft P1547 WIP voltage regulation considerations underway

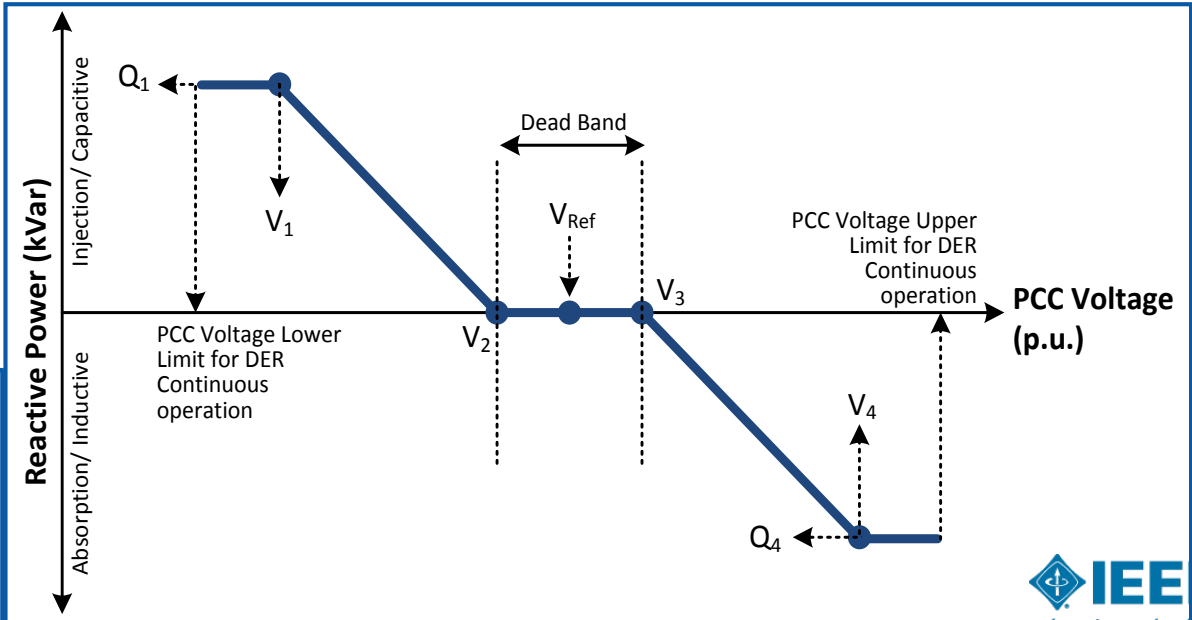
4.1.1 Reactive Power Capability of the DER

... capable of injecting and absorbing minimum reactive power ...

4.1.2 Voltage and Reactive Power Control

... capabilities of modes of reactive power control functions:
Power factor; Volt-Var; Active-power power-factor; Reactive power

P1547/Draft 1
Figure - Volt-Var Mode
(not approved)

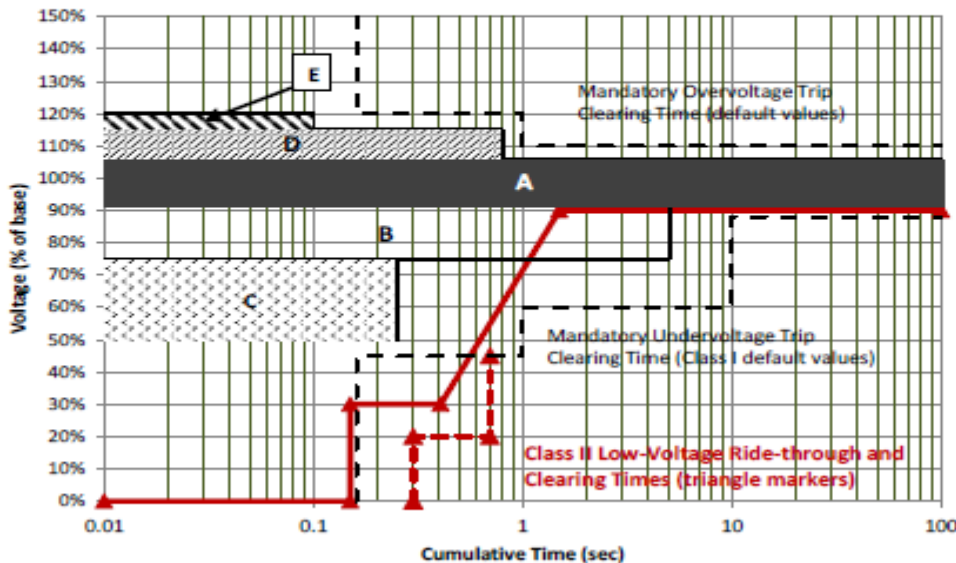


P1547 example works in progress (WIP): not approved!

P1547 Clause 4.2 { "Response to grid abnormal conditions" }

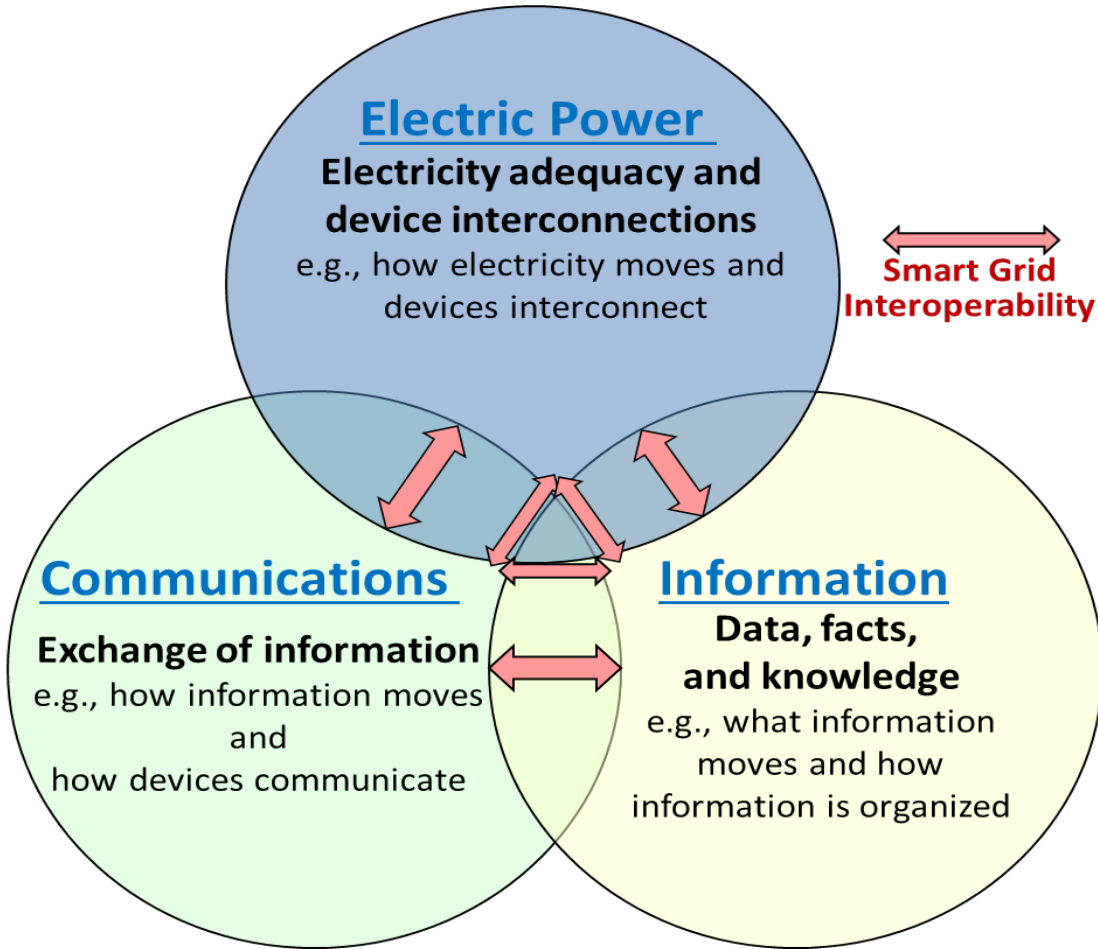
- Rationale & Performance of Class I & II interconnection – e.g., differentiate requirements in a technology neutral way
- Needed definitions
- High-level trip & ride-through concept

V. Example figures (& tables) (1/3) Atlanta proposal (November 2014)



Example high-level trip & ride-through concept

Smart Grid Interoperability: *Power, Communications and Information Technologies*



Interoperability: the capability of two or more networks, systems, devices, applications, or components to **externally exchange & readily use information securely & effectively.**
(IEEE Std 2030)

Smart Grid: the integration of power, communications, & information technologies for an improved electric power infrastructure serving loads while providing for an ongoing **evolution of end-use applications.** (Std 2030)

Some Key 1547 Standards Development

Issues -- Issues not normally addressed in technical standards, but do inform the revision process

- Federal/State Implementation and Impacts (rules, regulations)
- Fully Commercialized/Certified Products, After Sale Support, Warranties
- Liability (DER vs. grid operators)
- Functionality of Interconnection Package (always more to add)
- Lower Interconnection/interoperability System Cost
- Cost of EPS Re-Fit (how and who pays)
- Operation (which standard and who is in control)
- Reliability (operational issues – durability vs. availability)
- Misunderstanding/Misapplication (limited experience/knowledge)
- User Disagreement (not all utilities and DERs are alike)

Some Key 1547 Standards Development Issues

-- Issues that would benefit from further R&D

- Develop improved interconnection/interoperability technologies (advanced functionalities)
- Address field testing vs. type testing
- Interconnection/interoperability equipment certification
- Evaluate secondary grid and spot networks
- Develop grid/DER monitoring, control, & communications
- Better understand voltage regulation/stability/ride-through
- Establish basis for DER penetration/aggregation
- Develop advanced islanding methods and requirements
- Address grounding/faults (... T&D crossover effects, etc.)

IEEE P1547

IEEE Grouper web pages, Getting Involved

http://grouper.ieee.org/groups/scc21/1547_revision/1547revision_index.html

- FIRST STEP, Sign up for P1547 ListServe
- NEXT, Participate in Working Group. Identify yourself to Folder Subgroup Leads to get connected and involved in specific Folder subgroup for notices of activity and participation

P1547 Going Forward (target 2016 ballot)

| <u>Meeting</u> (2/year) | <u>Meeting Location</u> (<u>Sponsor</u>) | <u>Meeting Duration</u> { 3-1/2 days } | <u>Meeting Format</u> (Breakouts and full WG) |
|---|---|--|--|
| April 23 – 25, 2014 | Las Vegas NV | 2-1/2 days | One group |
| June 26-27, 2014 | Las Vegas NV | 1-1/2 days | One group |
| Nov 4-7, 2014 | Atlanta GA (NERC) | 3 days | breakouts |
| Feb 10 - 12 2015 | Arlington VA (NRECA) | 3 days | One group |
| June 1-3, 2015 | Nat'l Grid, Waltham, MA | 3 days | One group |
| Oct 27-29, 2015 | AZ (Salt River Project) | 3 days. 2 ½ 1547 Rev, ½ 1547.1 Rev Work Shop | One group |
| Winter 2016, Week of Feb 22, or Feb 29 | FL, NextEra Energy | TBD | TBD |
| Summer 2016 | TBD | TBD | TBD |
| Fall 2016 (sooner or later?) | WG final draft to IEEE for ballot | TBD | TBD |

THANK YOU!

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SCC21: *Fuel Cells, Photovoltaics, Dispersed Generation, & Energy Storage*

<http://grouper.ieee.org/groups/scc21/>

- **IEEE 1547 series** of Smart Grid Interconnection and
- **IEEE 2030 series** of Smart Grid interoperability standards and
- **IEEE PV standards,**