Impacts of the IEEE 1547, Standard of DER Interconnections, on Smart Inverters

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IEEE 1547 Scope and Purpose

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IEEE 1547 is:

- A technical standard—functional requirements for the interconnection itself and interconnection testing
- A single (whole) document of mandatory, uniform, universal, requirements that apply at the point of common coupling (PCC) or point of DER connection (PoC)
- Technology neutral—i.e., it does not specify particular equipment or type
- Should be sufficient for most installations

IEEE 1547 is not:

- A design handbook
- An application guide (see IEEE 1547.2)
- An interconnection agreement
- Prescriptive—i.e., it does not prescribe other important functions and requirements such as cyber-physical security, planning, designing, operating, or maintaining the area EPS with DER

IEEE 1547 Scope and Purpose

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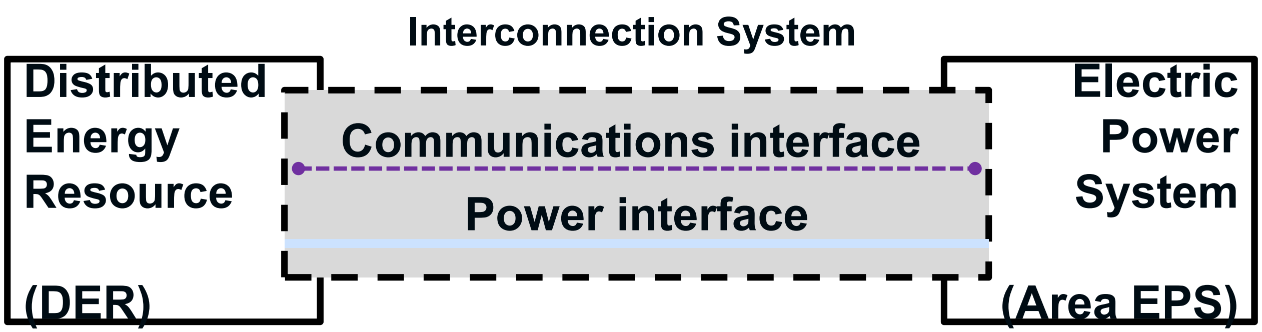
Title: *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*

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



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.*

Image based on IEEE 1547-2018

Interconnection system: The collection of all interconnection equipment and functions, taken as a group, used to interconnect DERs to an area EPS. Note: In addition to the power interface, DERs should have a communications interface.

Interface: A logical interconnection from one entity to another that supports one or more data flows implemented with one or more data links.

IEEE 1547 Document Outline (Clauses)

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1. Overview
2. Normative references
3. Definitions and acronyms
4. General specifications and requirements
5. *[normal grid]* Reactive power, voltage/power control
6. Response to Area EPS abnormal conditions
7. Power quality
8. Islanding
9. Distribution secondary grid and spot networks
10. Interoperability
11. Test and verification

12. Seven new annexes (Informative)

IEEE STANDARDS ASSOCIATION ◆IEEE

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

IEEE Standards Coordinating Committee 21

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

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1547™-2018
(Revision of IEEE Std 1547-2003)

DOE Whitepaper

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Prepared for
Michael Pesin and Joe Paladino
U.S. Department of Energy
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IMPACT OF IEEE 1547 STANDARD ON SMART INVERTERS

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IEEE

- IEEE PES issued a whitepaper for DOE on the impact of IEEE 1547 on smart inverters.
- The paper can be downloaded from the IEEE PES Resource Center via: http://resourcecenter.ieee-pes.org/pes/product/technical-publications/PES_TR0067_5-18

Dynamic Volt/VAR

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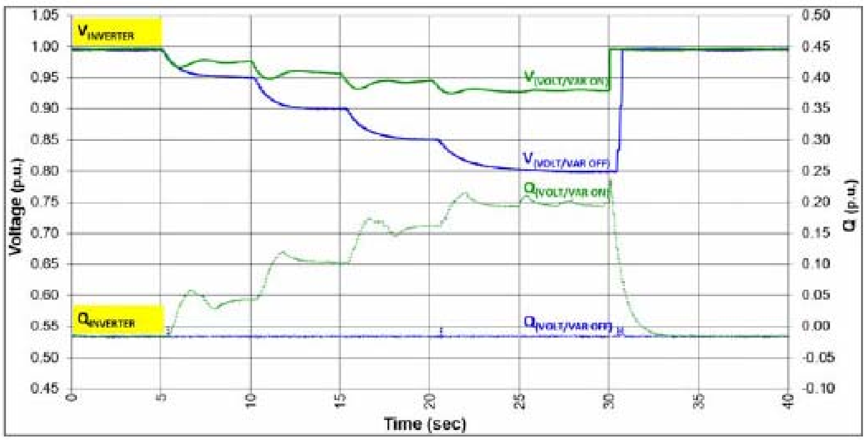
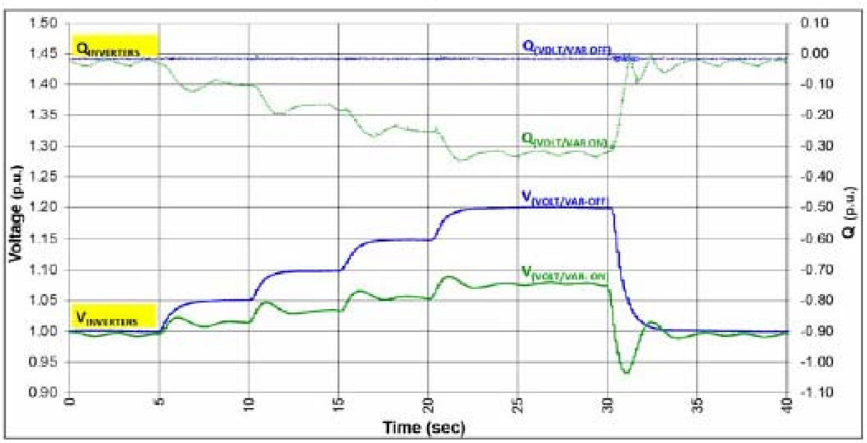
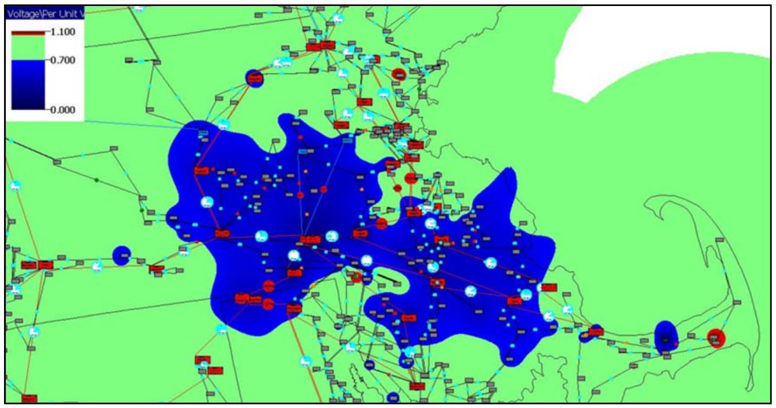


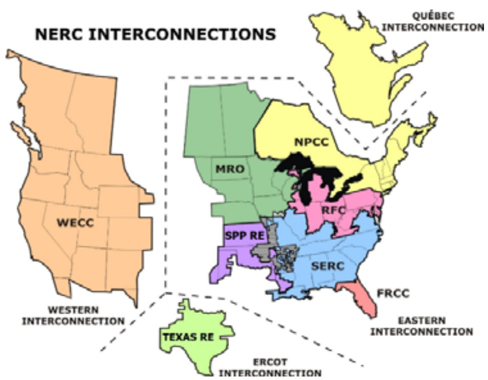


- IEEE 1547-2003 does not provide dynamic voltage support requirements on DER
- The new IEEE 1547-2018 will include dynamic voltage support by means of supplying or absorbing reactive power
- during under-voltage and over-voltage events, respectively.
- This is to support and stabilize the local voltage

Ride Through



Voltage profile for 345 kV fault in East Mass., all BPS power plants **online**



- In August 2016, a normally cleared 500 kV fault caused by the Blue Cut Fire in the Southern California area resulted in approximately 1200 MW of BPS-connected solar PV resources tripping offline due to frequency and voltage related protective functions.
- On October 9, 2017, normally cleared faults on the 220 kV and 500 kV systems resulted in approximately 900 MW of BPS-connected solar PV resources tripping by voltage protective relay actions.
- Ride-through requirements for DER connected to the distribution system are specified in the IEEE 1547-2018 standard, focusing particularly on voltage and frequency ride-through as well as voltage phase angle changes and rate-of change-of-frequency. Requirements are separated into abnormal performance Categories I, II, and III for disturbance ride-through.

Power Quality

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1547 PQ Emissions Section	2003 PQ[1]	2018 PQ[1] Requirements
DC Injection Limit	.5% current	No change
Synchronization	±5% ΔV at PCC	Δf, ΔV, ΔΦ ranges at PCC
RVC	None	New ΔV MV-3%, LV-5%
Flicker	Shall not cause	New Pst < .35, Plt < .25
Harmonic Current	<5% TDD	<5% TRD, Relaxed Evens[2]
Harmonic Voltage	None	None
OV Temporary	No disturbing GFO	New ≤138% $V_{l\text{-}g \text{ or } l\text{-}l}$[3] for GFO&LRO
OV Cumulative Instantaneous	None	New 2pu@1.5ms/1.4pu@16ms

- New flicker requirements
- New OV requirements (grounding)
- New Rapid Voltage Changes (RVC) requirements
- Modified harmonics requirements
- New inter-harmonics requirements

Fault Current Characteristics of an Inverter

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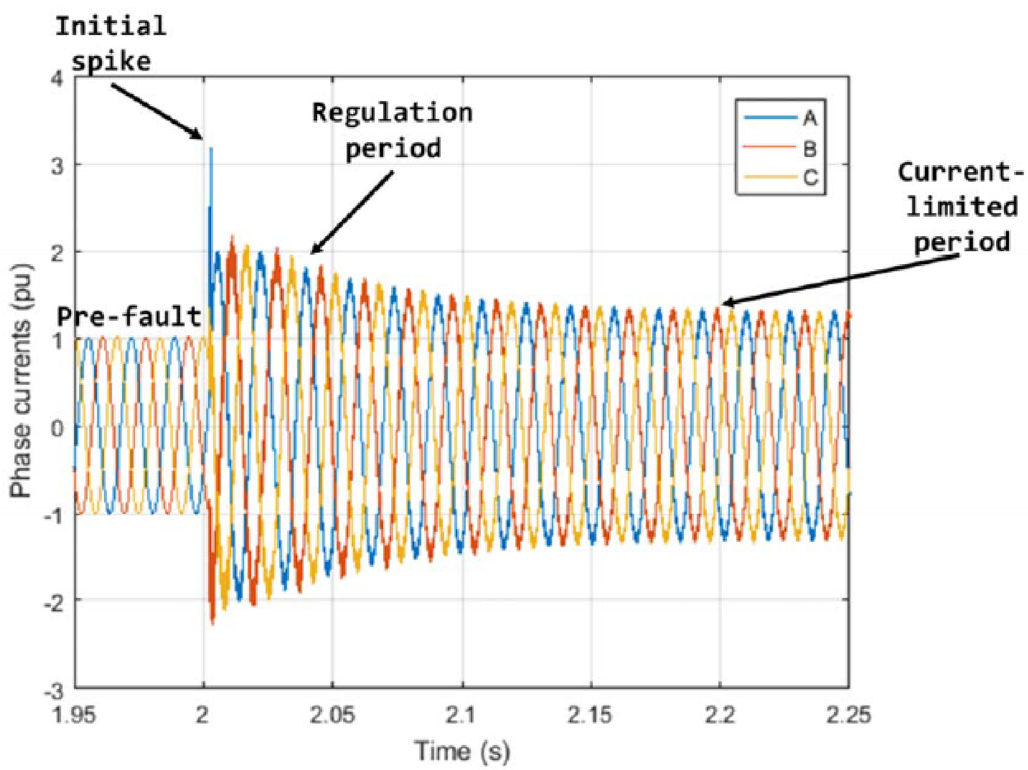

Typical or generic inverter fault current response

- The magnitude and duration of the initial spike will depend on system and inverter impedances, and it may not always be present.
- During an arcing fault or other situation in which the voltage at the inverter terminals becomes very "noisy", the inverter output may become non-sinusoidal as the inverter attempts to follow the noisy voltage.
- The inverter may cease to energize at any point during these three periods for many different reasons
- The speed of inverter controls will make a significant difference in the response.

Impact of Advanced Inverter Functionality on Fault Current

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- Fundamentally, advanced inverter functionality should have very little impact on inverter fault current response.
- The three basic regions of the fault response, and the current-limiting mechanisms will remain essentially unchanged.
- The *duration* of an inverter's response to certain faults will be impacted.
- This is deliberate; it is actually desirable that distribution-level inverters continue to produce output during, and maintain output after, remote fault events that do not cause the terminal voltage to fall below 0.5 pu (default point for momentary cessation).

Impact of Advanced Inverter Functionality on Unintentional Islanding Detection

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1. Ride through

- It is intuitive that ride-throughs will extend the run-on times of active inverter-resident islanding detection methods because the trip limits they use have been moved "farther away" meaning that it will take at least slightly more time to reach them.
- However, simulation-based and experimental evidence has found that while this is true, the impact appears small and in many cases will not lead to non-compliance with the 2 s detection requirements in P1547.

2. Grid Support functions (This is still an active area of investigation)

- Expected to adversely impact the islanding detection effectiveness of passive inverter-resident methods, particularly when used in conjunction with ride-throughs.
- It is less clear how grid support functions, such as frequency-watt and volt-var droops, will impact inverter-resident active methods, but there are preliminary indications that this impact may be negligible in part because the droop functions operate much more slower than the anti-islanding.

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