IEEE 1547-2018 Revision Overview, with Additional ES Considerations

for NELHA ESS 2018 Conference, Second Conference on Energy Storage Trends and Opportunities

Panel Session: IEEE 1547-2018 DER Interconnection Standard Revision: Implications and Applications for Evolving Interconnection Needs

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Kona, HA
12/6/2018

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Disclaimer

- *This presentation on IEEE 1547-2018 presents the author's views and is not the formal position of the IEEE or PNNL*

- *The author acknowledges the contribution of the IEEE 1547-2018 Working Group and Officers*

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Presentation Outline

1) IEEE 1547 Background
2) Revised 1547-2018, New Requirements Highlights
3) IEEE 1547-2018 and Smart Inverters
4) IEEE 1547-2018 and ES Considerations

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Importance of IEEE 1547

- Energy Policy Act (2005) Cites and requires consideration of IEEE 1547 Standards and Best Practices for Interconnection; all states use or cite 1547.
- Energy Independence and Security Act (2007) IEEE cited as a standards development organization partner to NIST as Lead to coordinate framework and roadmap for Smart Grid Interoperability standards and protocols {IEEE 1547 & 2030 series being expanded};
- Adoption by the majority of jurisdictional entities across N. America that set DER interconnection rules

IEEE 1547 Uses

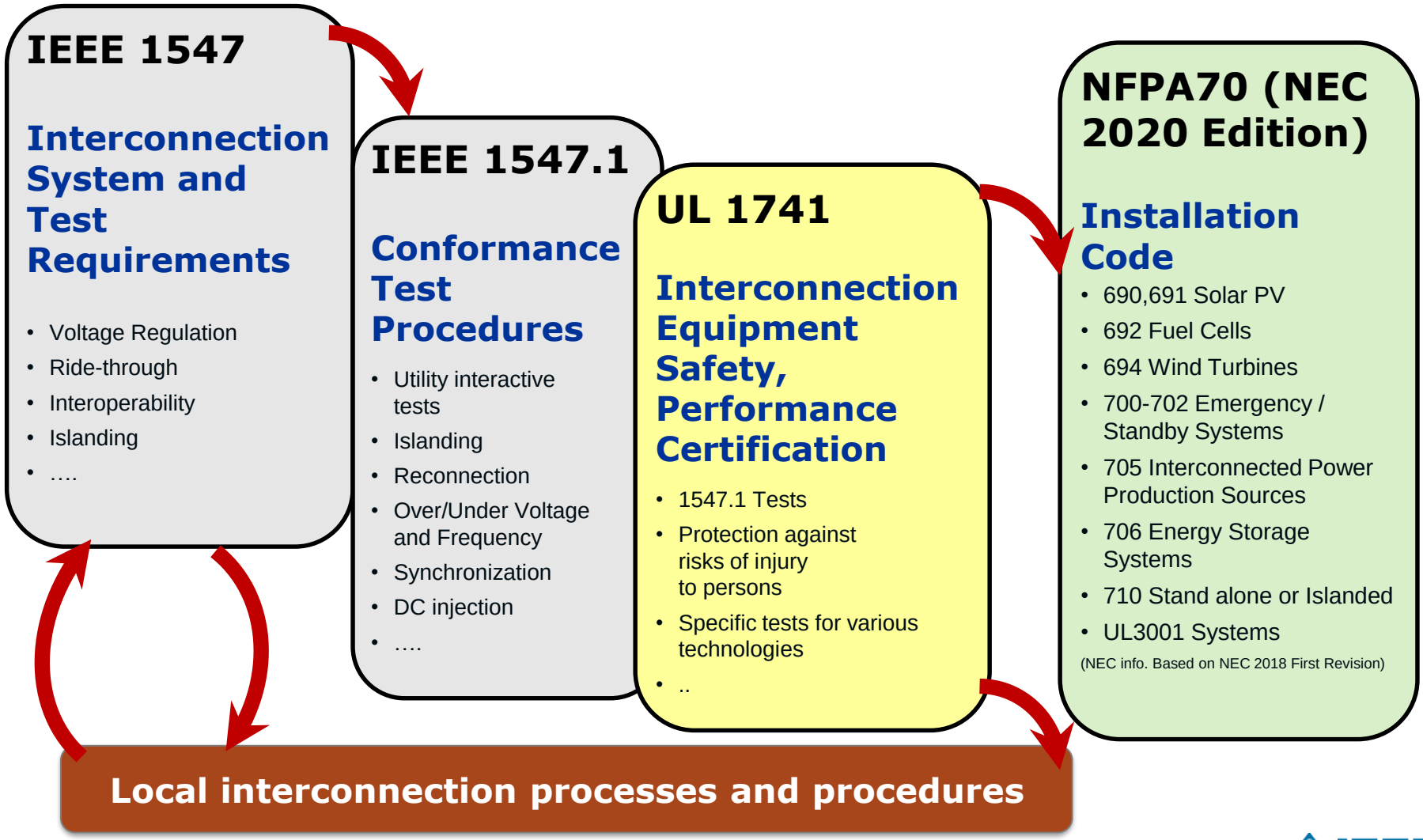
IEEE 1547 is:

- 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
- 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 Interconnection Example Use in United States



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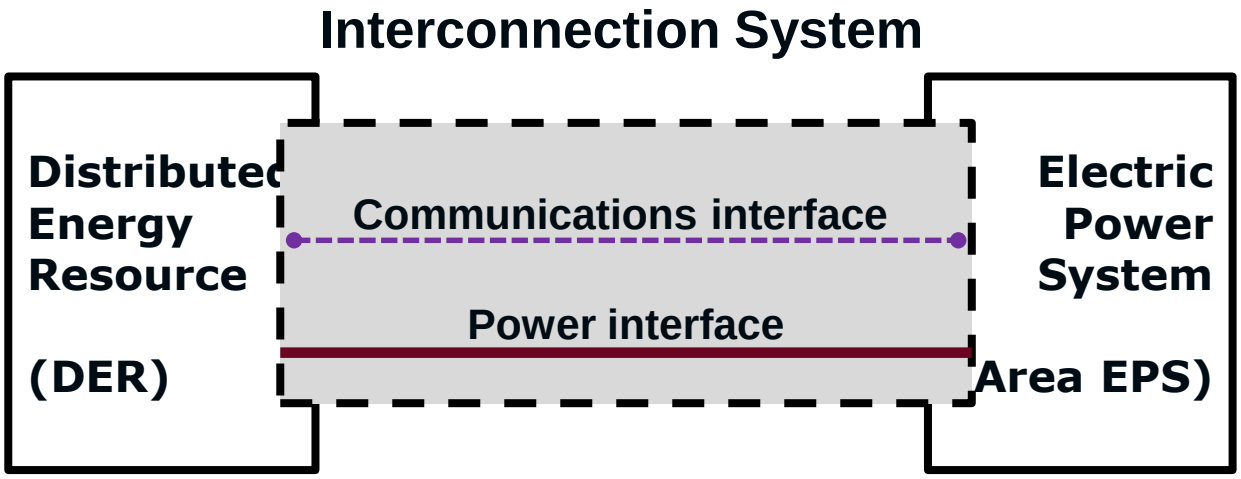
IEEE 1547 Scope and Purpose

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.

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IEEE 1547 Evolution of Grid Support Functions

IEEE 1547-2003

- Shall NOT actively regulate voltage
- Shall trip on abnormal voltage/frequency

IEEE 1547a-2014 (Amendment 1)

- **May** actively regulate voltage
- **May** ride through abnormal voltage/frequency
- **May** provide frequency response[1] (frequency-droop)

IEEE 1547-2018

- **Shall be capable of** actively regulating voltage
- **Shall** ride through abnormal voltage/frequency
- **Shall be capable of** frequency response[2]
- **May** provide inertial response[3]

1 Frequency response is capability to modulate power output as a function of frequency
2 Mandatory capability for Categories II and III under high frequency conditions, Mandatory for Categories II and III under low frequency conditions, optional for Category 1
3 Inertial response is capability for DER to modulate active power in proportion to the rate of change of frequency

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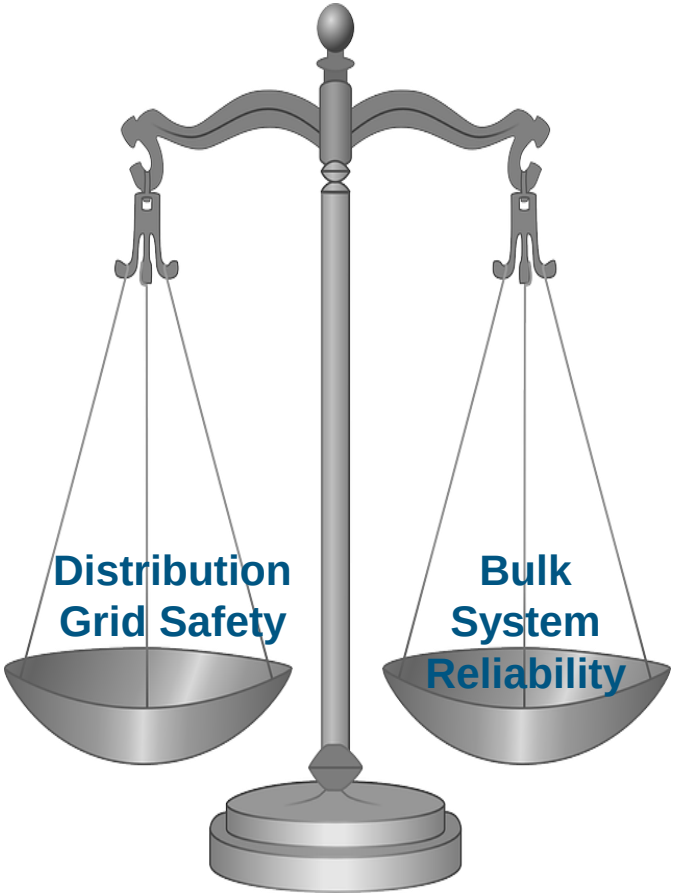
Revising 1547-2003: Striking a New Balance

- IEEE 1547-2018 mandates BOTH:
  - Tripping requirements, and
  - Ride-through requirements
- Ride-through is not a "setting", it is a minimum *capability* of the DER
  - *"shall ride through <u>for at least</u> … seconds"*
  - I.e., it is the minimum required DER robustness to withstand voltage and frequency disturbances
  - May or may not be fully utilized, or it may be exceeded
- Trip thresholds and clearing times are maximum operational *settings*
  - *"shall trip <u>at latest by</u> … seconds"*
  - May differ from *default settings* and are adjustable over a 'range of allowable settings'
  - Specified ranges do not allow DER tripping to seriously compromise bulk power system reliability
  - Tripping points specified by the distribution utility may account for utility-specific practices but may also be constrained by the ***regional reliability coordinator***



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Evolving Standards Support Accessing DER's Value Stack
ES Applications – from CA AB2514

Category	Storage "End Use"
ISO/Market	• Frequency regulation • Spin/non-spin/replacement reserves • Ramp • Black start • Real time energy balancing • Energy price arbitrage • Resource adequacy
VER Generation	• Intermittent resource integration: wind (ramp/voltage support) • Intermittent resource integration: photovoltaic (time shift, voltage sag, rapid demand support) • Supply firming
Transmission/ Distribution	• Peak shaving: off-to-on peak energy shifting (operational) • Transmission peak capacity support (upgrade deferral) • Transmission operation (short duration performance, inertia, system reliability) • Transmission congestion relief • Distribution peak capacity support (upgrade deferral) • Distribution operation (Voltage Support/VAR Support) • Outage mitigation: micro-grid
Customer	• Time-of-use /demand charge bill management (load shift) • Power quality • Peak shaving (demand response), Back-up power

1547-2003 vs. new CA 21 & 1547Revision

Source(table): CPUC Staff, AB2514 workshop, 3/25/2013

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IEEE 1547-2018 Document Outline

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

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Clause 1.4, General remarks and limitations

- Applicable to all DERs connected at typical primary or secondary distribution voltage levels.
- Specifies performance and not design of DER.
- Specifies capabilities and functions and not utilization of these.
- Does not address planning, designing, operating, or maintaining the Area EPS with DER.
- Emergency and standby power systems are exempt from certain requirements of this standard.
  - E.g., voltage and frequency ride-through, interoperability and communications.

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Active Voltage Regulation Requirements – Normal Operation Conditions

"The DER shall provide voltage regulation capability by changes of reactive power. The approval of the Area EPS Operator shall be required for the DER to actively participate in voltage regulation."

Capability required for all DER – (Category A, B)

- Constant power factor mode
- Constant reactive power mode ("reactive power priority")
- Voltage-reactive power mode ("volt-var")

"State-of the art" DER – Category B

- Active power-reactive power mode ("watt-var")
- Voltage-active power mode ("volt-watt")

The area EPS operator shall specify the required voltage regulation control modes and the corresponding parameter settings.

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Categories For Grid Support – Normal Operation Conditions

Voltage Regulation Capabilities

Category A

- Meets minimum performance capabilities needed for Area EPS voltage regulation
- Reasonably attainable by all state-of-the-art DER technologies

Category B

- Meets all requirements in Category A plus…
- Supplemental capabilities for high DER penetration, where the DER power output is subject to frequent large variations.
- Attainable by most smart inverters

Specified by Area EPS Operator, other requirements by mutual agreement with DER Operator

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Grid Support Requirements - Abnormal Operating Conditions

Ride-through:

ability to withstand voltage or frequency disturbances

Required

1. Voltage ride-through
2. Frequency ride-through
3. Rate-of-change (ROCOF)
4. Voltage phase angle change
5. Frequency droop[1,2]

Other allowed capabilities

- Inertial response[3]

[1]Frequency response is capability to modulate power output as a function of frequency
[2]Mandatory capability for Categories II and III under high frequency conditions; Mandatory for Categories II and III under low frequency conditions, optional for Category 1
[3]Inertial response is capability for DER to modulate active power in proportion to the rate of change of frequency

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Performance Categories – Abnormal Operating Conditions

Ride Through Capabilities

Category I

- Essential bulk power system needs
- Attainable by all state-of-the-art DER technologies.

Category II

- Full coordination with all bulk system power system stability/ reliability needs
- Coordinated with existing reliability standards to avoid tripping for a wider range of disturbances (more robust than Category I)
- Based on NERC PRC-024, adjusted for distribution voltage differences (delayed voltage recovery)

Category III

- Designed for all bulk system needs and distribution system reliability/power quality needs
- Coordinated with existing requirements for very high DER levels
- Based on CA Rule 21 and HA Rule 14

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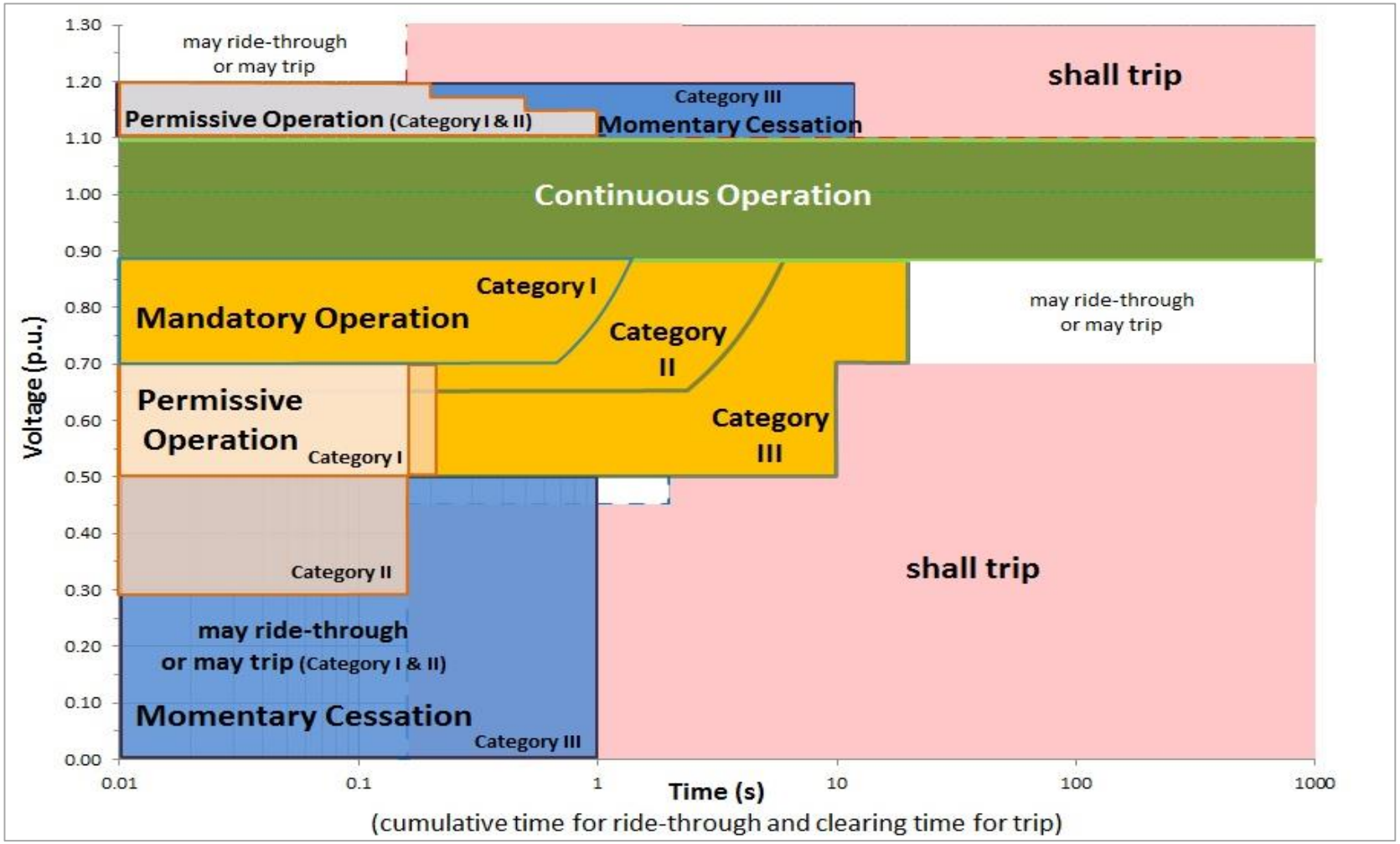
Voltage Ride-Through
(All Categories)



based on IEEE 1547-2018

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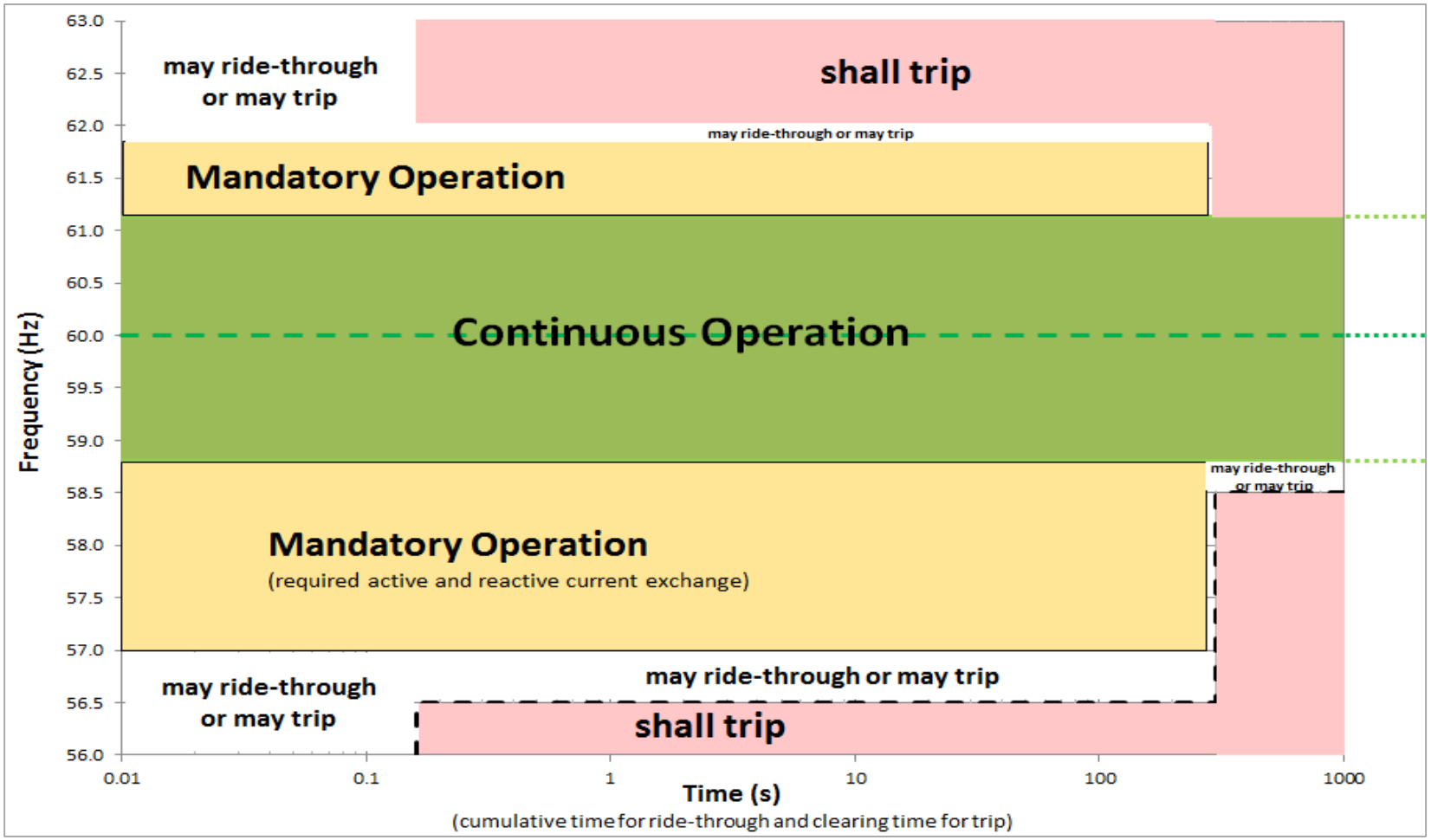
Frequency Ride-Through
(Default Values for All Categories)



Based on IEEE -2018

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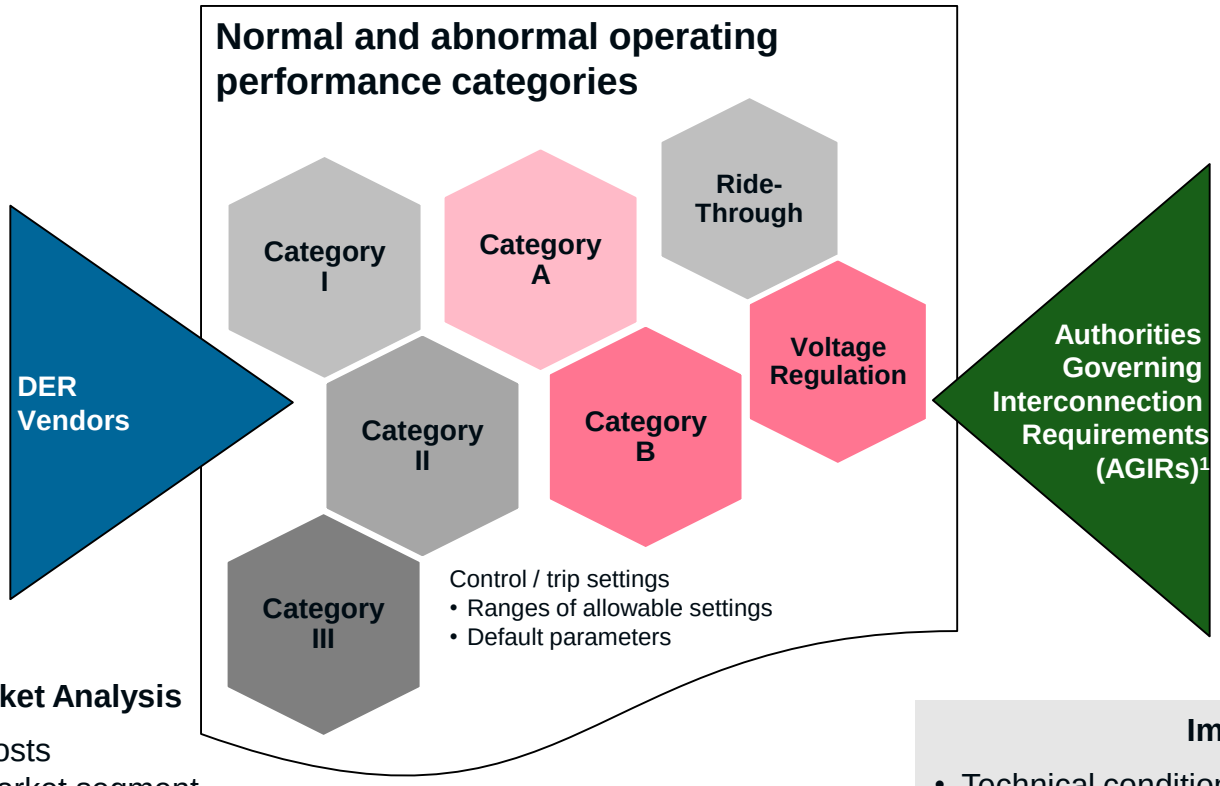
Assignment of new IEEE 1547 Performance Categories



Stakeholder Engagement

- Distribution utilities.
- Bulk system operators & planners.
- DER developers.
- Others.

Market Analysis

- Costs
- Market segment
- Etc.

Impact Assessment

- Technical conditions: type & capacity & future penetration of DER, type of grid configuration, etc.
- Non-technical issues: DER use case, impacts on environment, emissions, and sustainability, etc.

[1] Regulatory agencies, public utility commissions, municipalities, cooperative governing boards, etc.

Courtesy of Dr. J. Boemer/EPRI

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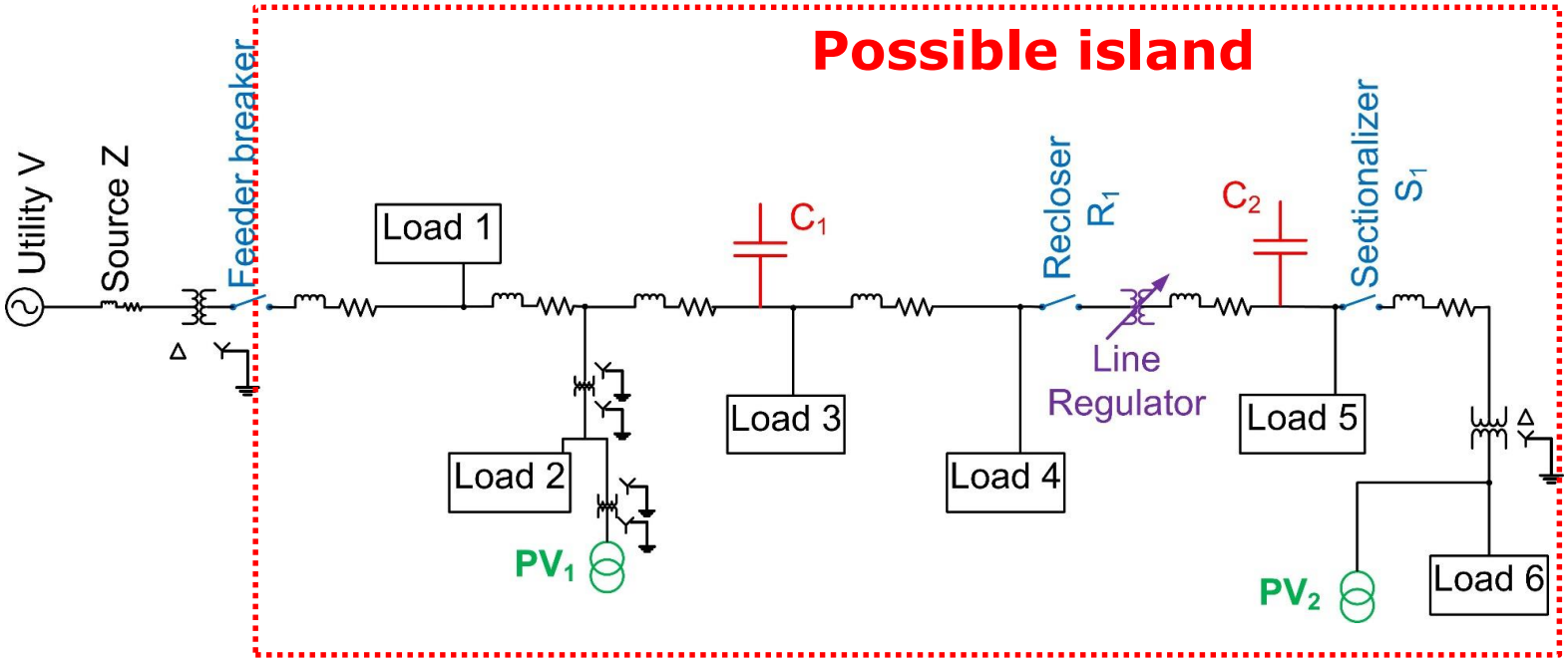
What is an island?

- An electric power island is a section of a power system with its own sources and loads, so that it can self-power or "self-excite".



1547-2018: When can an I.I. leave the grid?

- When conditions are met that are mutually agreed-to by the Area EPS and DER operators;
- If any of the abnormal voltage or frequency trip conditions is met; or
- If an unintentional island is detected.

For these latter two cases, one may substitute entry into intentional island mode for tripping.

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Limits on Area EPS impact when leaving the Area EPS

- If an I.I. disconnects from the Area EPS for any of the reasons listed on the previous slide, it shall do so without causing a voltage fluctuation greater than ±5% of the nominal voltage at any PCC between the Area EPS and the intentional island.
- There are two exceptions to this requirement:
  - If the I.I. "takes its load with it"—i.e., when the I.I. leaves the grid, it causes an amount of load equal to 90% to 110% of its rating to leave the grid also;
  - The I.I. is an emergency or standby generator that is on-grid for testing purposes only.

1547-2018 *New* Interoperability Requirements

The capability of two or more networks, systems, devices, applications, or components to ***externally exchange and readily use information securely and effectively*** *(IEEE 2030).*

Mandatory communications capability

A DER **shall have provisions for** a local DER interface capable of communicating…

Information to be exchanged:

Nameplate: as-built characteristics of the DERs (read)

Configuration: present capacity and ability of the DERs to perform functions (read/write)

Monitoring: present operating conditions of the DERs (read)

Management: information to update the functional and mode settings for the DERs (read/write)

Communication performance requirements:

Availability of communication (DER is operating in continuous or mandatory operation region)

Information read response times (≤ 30 s, maximum amount of time to respond to read requests)

Communication protocol requirements:

Shall support at least one of these protocols …(IEEE Std 2030.5, IEEE Std 1815, SunSpec, Modbus)

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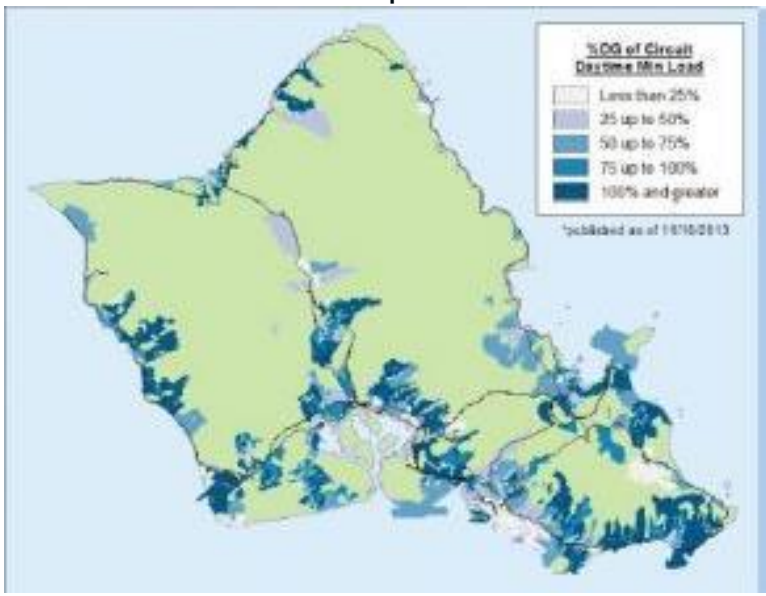
Importance Of Interoperability Functions

- Hawaii Case Study

- In 2014, Hawaii was headed for a repeat of Germany's "50.2 Hz problem"
  - Inverters could trip en masse due to frequency excursion, worsening excursion and potentially blacking out grid
- In February 2015, Enphase remotely reprogrammed 800,000 inverters (154 MW) in Hawaii to enable frequency ride-through
- Required close coordination between utility and inverter manufacturer

Oahu feeder PV penetration



Enphase inverter locations

Figure credit: https://www.greentechmedia.com/articles/read/enphase-to-help-hawaii-ride-its-solar-energy-wave#gs.4gZ7w1Q

Slide used with courtesy of Dr. Andy Hoke, NREL

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Communication Requirements

- A DER shall have provisions for an interface capable of communicating (local DER communication interface) to support the information exchange requirements specified in this standard for all applicable functions that are supported in the DER.
- Under mutual agreement between the Area EPS Operator and DER Operator additional communication capabilities are allowed.
- The decision to use the *local DER communication interface* or to deploy a communication system shall be determined by the Area EPS operator.

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List of Eligible Protocols

Protocol	Transport	Physical Layer
IEEE Std 2030.5™ (SEP2)	TCP/IP	Ethernet
IEEE Std 1815™ (DNP3)	TCP/IP	Ethernet
SunSpec Modbus	TCP/IP	Ethernet
	N/A	RS-485

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1547-2018 Information Categories

- Information to be exchanged:
  - Nameplate Data – As-built characteristics of the DER.
  - Configuration Information – Each rating in Nameplate Data may have a configuration setting.
  - Monitoring Information – Latest value measured.
  - Management information – This information is used to update functional and mode settings for the DER.

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UL 1741-SA and Smart Inverters

Advanced Inverter Deployment

Which Standards are Used for Advanced Inverter Testing?

- UL 1741 SA specifies the test methods to evaluate compliance with electric utility Source Requirement Document (SRD) for limits and parameter settings. The UL 1741 Supplement SA is part of UL 1741 and was published on Sept 7, 2016.
- California Electric Rule 21 made by the California Public Utility Commission (CPUC) is an SRD which can be used with UL 1741 SA. Other SRD's like Hawaiian Electric HECO 14H may also be used with the UL1741 SA.
- Changes to California Rule 21 and Hawaiian Electric 14H will require all inverters to be certified "listed" as a UL1741SA "Grid Support Interactive Inverter" for all new installations on Sept 7, 2017.

Source: UL

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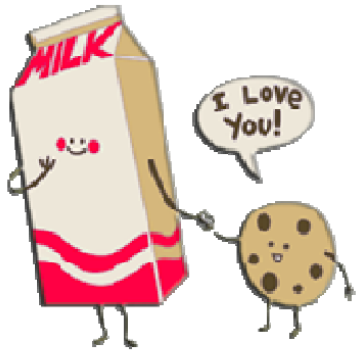
UL 1741-SA and 1547 and Updating UL 1741

Use of UL1741 SA with IEEE 1547, 2nd Ed. Until IEEE 1547.1 2nd Ed. Publication

- There is some utility interest to make use of IEEE 1547 2nd edition ASAP.
- It is difficult to implement 1547 edition 2 without a test protocol.
- Even with using UL1741 SA as a seed document and fast track task group efforts 1547.1 edition 2 is still ~1.5yrs away from publication.
- There is growing support / agreement to use the published 1547 edition 2 to develop a Source Requirements Document (SRD) such that we can use the existing published UL1741 SA standard and test protocols to provide a certification that addresses a majority of the 2nd edition 1547 requirements.
- This hybrid certification will quickly address a majority of our needs ASAP!

- Once both the 2nd editions of 1547 and 1547.1 are published UL1741 will be revised to replace the Supplement SA with the 2nd edition references and… All will be right with the world.



Source: UL

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1547-2018's DER Definitions

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

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

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[23]Equivalent to "distributed resources (DR)" as defined and used in IEEE Std 1547-2003.

ES is not defined within IEEE 1547-2018, nor is the type of ES bounded/limited in context of IEEE 1547-2018's technical requirements.

IEEE 1547-2003 and -2018 are technology neutral, and apply to DER.

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1547-2018 Guidance on Perf. Cat. For ES

Table B.1—Example abnormal performance category assignment grid[137]

	DER type	DER application purpose						
		Retail self generation	Combined heat and power	Waste fuel recovery	Renewable energy	Merchant generation[a]	Critical backup[b]	Peak shaving
		A	B	C	D	E	F	G
1	Engine or turbine driven synchronous generator	Category I	Category I	Category I	Category I	Category I	Category I	Category I
2	Wind turbines (all types)	Category II	N/A	N/A	Category II	Category II	N/A	N/A
3	Inverters sourced by solar PV	Category II[c]	N/A	N/A	Category II[c]	Category II[c]	N/A	N/A
4	Inverters sourced by fuel cells	Category I	Category I	Category I	Category I	Category II	Category I	N/A
5	Synchronous hydrogenerators	Category I	N/A	N/A	Category I	Category I	Category I	N/A
6	Other inverter applications	Category II	Category II	Category II	Category II	Category II	Category II	N/A
7	Inverters sourced by energy storage	Category II	N/A	N/A	N/A	Category II	Category II	Category II
8	Other synchronous generators	Category I	Category I	Category I	Category I	Category I	Category I	N/A
9	Other induction generators	Category II	Category II	Category II	Category II	Category II	Category II	Category II

[a]Merchant generation in this table is intended to characterize DER facilities installed for the express purpose of exporting power, and is not intended to imply only FERC-jurisdictional generation or other regulatory definitions.

[b]Only applies to critical backup generation interconnected to the Area EPS for the purposes of periodic testing. If backup generation is also used for merchant generation or other purposes, the performance requirements of those purposes apply.

[c]Category III should be required where DER penetration on a distribution feeder exceeds [% VALUE TO BE SPECIFIED BY AGIR], or on the distribution system supplied from a given distribution substation bus exceeds [% VALUE TO BE SPECIFIED BY AGIR].

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1547-2018 Abnormal Grid Conditions & ES

From subclause 6.5.2.1 General Requirements & Exceptions, for abnormal frequency response:

The frequency disturbance ride-through specified in the remainder of 6.5.2 shall not apply and DER may *cease to energize* the Area EPS and trip without limitations if any of the following applies:

a) The net active power exported[100] across the *point of common coupling* into the Area EPS is continuously maintained at a value less than 10% of the aggregate rating of DER connected to the Local EPS prior to any frequency disturbance, and the Local EPS disconnects from the Area EPS, along with Local EPS load to intentionally form a Local EPS island, or

b) An active power demand of the Local EPS load equal or greater than 90% of the pre-disturbance aggregate DER active power output is shed within 0.1 s of when the DER ceases to energize the Area EPS and trips.

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[100] Energy Storage DER operating in a manner that modulates active power, i.e., importing and exporting active power, shall be evaluated for this exception based solely on the maximum positive power point over the modulated power range.

Concept could potentially be extended to support increased PV hosting capacity, and/or intentional island transition, via ES implemented to meet limited power exchange at PCC.(cv)

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IEEE 1547-2018

- **Shall be capable of** actively regulating voltage
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- **Shall be capable of** frequency response[2]
- **May** provide inertial response[3]

SEE PNNL SLIDES

[1]**Frequency response is capability to modulate power output as a function of frequency**

[2]Mandatory capability for Categories II and III under high frequency conditions, Mandatory for Categories II and III under low frequency conditions, optional for Category 1

[3]**Inertial response is capability for DER to modulate active power in proportion to the rate of change of frequency**

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P1547.9, an Outcome of 1547 Revision

ES Interconnection Standard Gap Identified, and Action Taken

1.1 Project Number: P1547.9
1.2 Type of Document: Guide
1.3 Life Cycle: Full Use

2.1 Title: IEEE 1547.9 Guide for Interconnection of Energy Storage Distributed Energy Resources with Power Systems

5.2 Scope: This Guide provides information on and examples of how to apply the IEEE Std 1547, for the interconnection of Energy Storage Distributed Energy Resources (DER ES). Scope includes DER ES connected to area Electric Power Systems (local EPSs) that are capable of bidirectional real and reactive power flow, and are capable of exporting real power to the EPS. Guidance is also provided for non-exporting DER ES, such as UPS type systems that support onsite loads, or EV chargers, with charging attributes that could have power system impacts, e.g. modulating rate of charge proportionally to system frequency.

The first P1547.9 Working Group will be held at NERC, in February 2019. Please contact Charlie Vartanian to be placed on the Interest e-List.

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Thanks!

Questions?

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http://grouper.ieee.org/groups/scc21/1547/1547_index.html
https://standards.ieee.org/findstds/standard/1547-2018.html

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BESS Modeling & Simulation: key tool to define next gen ES applications

Pacific Northwest NATIONAL LABORATORY

Inertial Equivalent, Preserve and Enhance Wide Area Stability

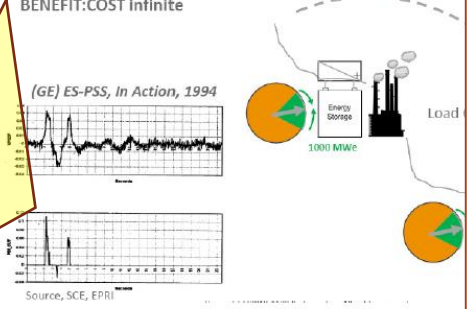
A123 SYSTEMS

Storage to Avoid Blackouts, PMU-equipped Storage to Detect and Damp Inter-area Oscillations

Benefit = $1Billion/event avoided
Cost = Included with storage units

BENEFIT:COST Infinite

Chino BESS w/ ES- PSS



A123 presentation to CA PUC, March 17, 2010

Inertial Equivalent, Providing H (MW-S), IS CRITICAL

A123 SYSTEMS

Q: Can it be done with a battery interfaced to the grid with an appropriate inverter?

A: Yes.

Timescale/response rate of advanced storage is a major plus. Timeframe is a matter of economics: No technical barrier. (see Cazalet/Vartanian paper, CMU 2008)

SUBSTANTIAL EMERGING RELEVANCE

1) Complimentary support to variable resources that may have this requirement imposed as condition of interconnection, then

2) Pathway to 50% renewables with coincident 50% improvement in grid reliability

+ ***CMU-ECE AND OTHER POWER SYSTEMS RESEARCHERS, PLEASE LEAD THE WAY***

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Source, A123 Systems

https://www.archive.ece.cmu.edu/~electriconf/2011/pdfs/A123-CMUElectricityIndustry-09MAR2011-v2.pdf

BESS Modeling & Simulation Example

Pacific Northwest NATIONAL LABORATORY

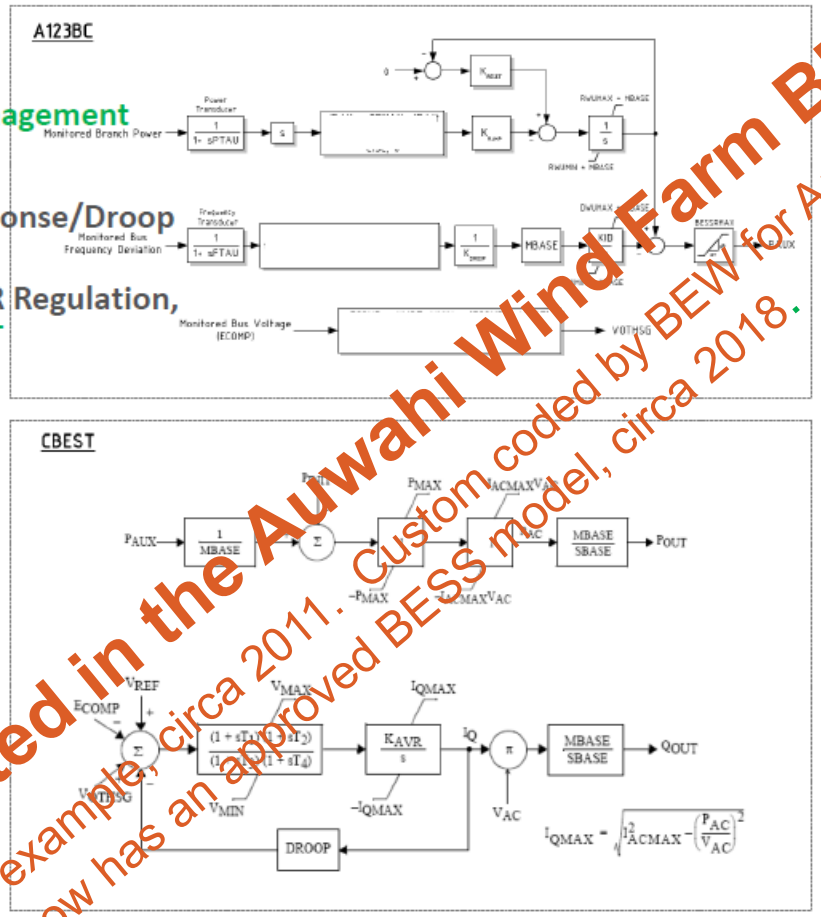
PSSE Example, A123 Battery Storage

A123 SYSTEMS

Ramp Rate Management

Frequency Response/Droop

Volt/VAR Regulation, and LVRT



Implemented in the Auwahi Wind Farm BESS

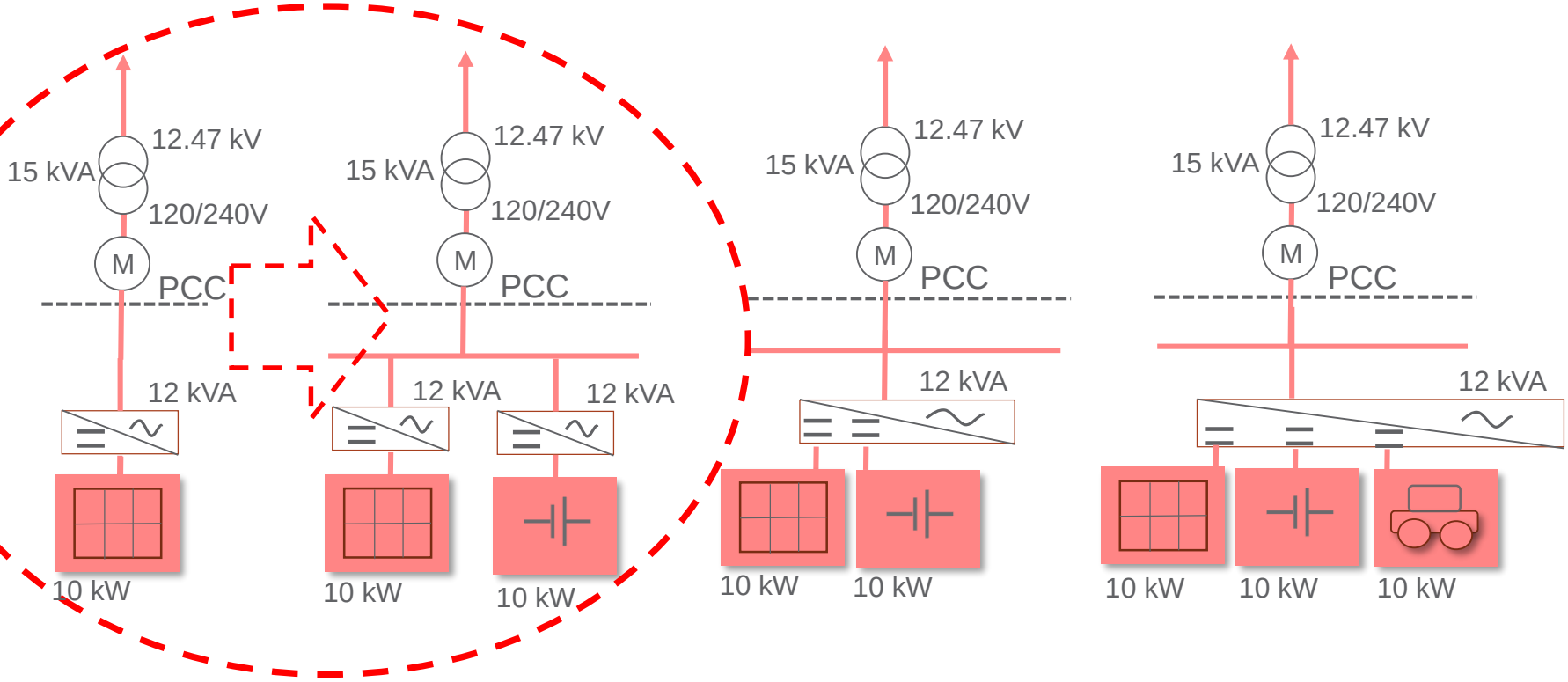
Industry example, circa 2011. Custom coded by BEW for A123.

WECC now has an approved BESS model, circa 2018.

Source, A123 Systems

https://www.archive.ece.cmu.edu/~electriconf/2011/pdfs/A123-CMUElectricityIndustry-09MAR2011-v2.pdf

Power Capability vs Controlled Capacity vs Rating at the Point of Common Coupling (PCC)



What's the interconnection rating and/or requirement at the PCC?

Who determines? On what basis?

Does amount of metered demand, and how its connected, have an impact?

Power Capability vs Controlled Capacity vs Rating at the Point of Common Coupling (PCC)

mm1. Technical System Size: Technical System Size as used herein applies to photovoltaic inverter-based generation, including those paired with energy storage systems. Technical System Size for all other types of Generating Facilities will be handled on a case-by-case basis. Technical System Size refers to the maximum possible simultaneous generation (including discharge of energy storage systems) of the Generating Facility, and is calculated as the lesser of the sum of all inverter strings of the aggregate system or the maximum amount of export as permitted by the existence of an on-site limiting element that caps the amount of the Generating Facility's export at the Point of Common Coupling ("PCC"). Each inverter string is calculated as the sum of all simultaneous kWdc per inverter string or the inverter kWac per inverter string, whichever is less. Technical System Size is used as part of the technical review process as described herein.

From HECO Rule 14H

What's the interconnection rating and/or requirement at the PCC?

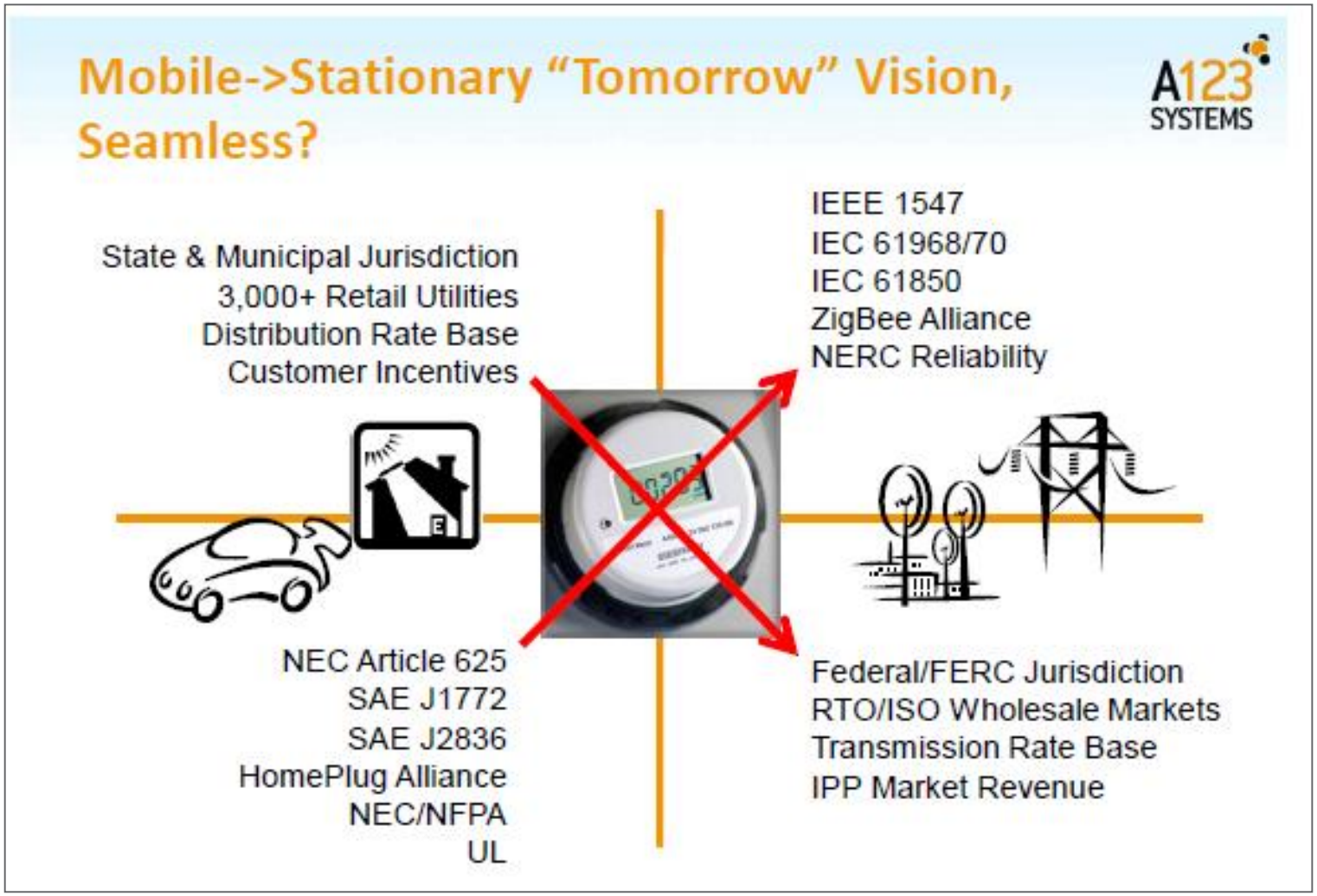
A great start, but some room for more improvement:
'and vs or'?, sizing for SCD and abnormal vs normal(the req't).

UL's CRD for Power Control Systems is a useful venue/tool.

Considerations for Rule 14H in context of ES:

- Update generation definition per SRD V1.1 and cite ES explicitly
- Add a section on intentional islanding
- Conform ramp rate limits – and delineate starting ramp (enter or return to service) vs operating ramp (power level changes)
- Cite required and/or permitted protocol capability and minimum info exchange (consistent with Rule 14H min. activation states reporting)
- Conform the min time for cease to energize for detection of island to conform with 1547-2018
- Require a minimum H (inertia) MW-S equivalent?

Technical Standards Facilitate Coordination Across Jurisdictions, and Industries



Source, A123 Systems' presentation to NEMA, C. Vartanian, January 15, 2009

IEEE 1547-2018 Revision Overview, with Additional ES Considerations

for NELHA ESS 2018 Conference, Second Conference on Energy Storage Trends and Opportunities

Panel Session: Hawaii's Rule 14 and IEEE 1547

JBerdner@Enphaseenergy.com

Charlie.Vartanian@PNNL.gov

Kona, HA

12/6/2018

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Disclaimer

- *This presentation on IEEE 1547-2018 presents the author's views and are not the formal position of the IEEE, Enphase or PNNL*

- *The author acknowledges the contribution of the IEEE 1547-2018 Working Group and Officers*

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What is Rule 14H ?

- **Rule 14H is the Interconnection Rule in Hawaii**
  - Defines the technical and functional requirements for DER interconnected on the grids operated by the Hawaiian Electric Inc. companies. HECO, HELCO, MECO
    - https://www.hawaiianelectric.com/billing-and-payment/rates-and-regulations/hawaiian-electric-rules
- **Rule 14H is embodied in Tariff language. Related Rules & Tariffs include:**
  - Rule No. 22 - Customer Self-Supply
  - Rule No. 23 - Customer Grid-Supply
  - Rule No. 24 - Customer Grid-Supply Plus
  - Rule No. 25 - Customer Smart Export
  - Rule No. 26 - Community-Based Renewable Energy Program
- **SRD V 1.1 outlines the specific requirements for Grid Support Inverters**
  - https://www.hawaiianelectric.com/Documents/clean_energy_hawaii/producing_clean_energy/SRD_UL1741_SA_V1.1_20170922_final.pdf

ENPHASE.

Source: Enphase,
from J. Berdner presentation w/ input from HECO, EUCI Codes & Standards October 2018

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1547-2018's and Rule 14H's DER Definitions

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

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

[23]Equivalent to "distributed resources (DR)" as defined and used in IEEE Std 1547-2003.

11. Generating Facility (or Generating Facilities) - Customer or utility-owned electrical power generation that is interconnected to the utility. This includes both generation and energy storage technologies. from HECO 'SA" SRD V1.1

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Significant Result from P1547 Activity

Active collaboration across DER stakeholder groups, for coordination and consistency.

Updated: 9/26/2017

HAWAIIAN ELECTRIC COMPANIES
GRID SUPPORT UTILITY-INTERACTIVE INVERTER STANDARDS
SOURCE REQUIREMENTS DOCUMENT
FOR CERTIFICATION WITH
UNDERWRITERS LABORATORIES 1741 SUPPLEMENT SA

Part I – General

Hawaiian Electric Companies'[1] Grid Support Utility-Interactive Inverter Standards set forth in either documents SRD-UL-1741-SA-V1.0, issued March 10, 2017 or SRD-UL-1741-SA-V1.1, updated September 26, 2017, shall serve as the Source Requirements Document[2] ("SRD") to be used with Underwriters Laboratories 1741 – Standard for Safety Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources, Supplement SA – Grid Support Utility-Interactive Inverters and Controllers ("UL 1741 Supplement SA") certification and sets forth the specific parameter settings to be used with the test methods of the UL 1741 Supplement SA.

This updated SRD-UL-1741-SA-V1.1 is intended to resolve any potential conflicts between the prior SRD-UL-1741-SA-V1.0, the Companies proposed revisions to Tariff Rule 14H, filed in Docket No. 2014-0192 – Instituting a Proceeding to Investigate Distributed Energy Resource Policies, and the pending update to the umbrella standard IEEE 1547.

https://www.hawaiianelectric.com/products-and-services/customer-renewable-programs/advanced-inverters

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Industry Engagement Example – Smart Inverters

Rule 14H Functions Matrix

		Interconnection Standards			Rule 14H		Listing/ Certification		
Function Set	Advanced Functions Capability	IEEE 1547-2003	IEEE 1547a-2014	IEEE 1547-2018	2015	2018 SRD V1.1	UL 1741	UL 1741(SA) 2016	IEEE 1547.1-201?*
All	Adjustability in Ranges of Allowable Settings		√	‡					Δ
Monitoring & Control	Ramp Rate Control			‡ ?	‡	‡ ?		Δ	Δ ?
	Communication Interface			‡		‡			Δ
	Disable Permit Service (Remote Shut-Off)			‡					Δ
	Limit Active Power			‡		‡ CSS,NEM+			Δ
	Monitor Key DER Data			‡					Δ
Scheduling	Set Active Power								
	Scheduling Power Values and Models					‡ CGS+, smart CSS			
Reactive Power & Voltage Support	Constant Power Factor	√	√	‡	‡	‡	√	Δ	Δ
	Voltage-Reactive Power (Volt-Var)	X	√	‡		‡		Δ	Δ
	Autonomously Adjustable Voltage Reference			‡					Δ
	Active Power-Reactive Power (Watt-Var)	X		‡					Δ
	Constant Reactive Power	√	√	‡	‡	‡	√		Δ
	Voltage-Active Power (Volt-Watt)	X	√	‡		‡ Opt		Δ	Δ
	Dynamic Voltage Support during VRT			√					
Bulk System Reliability & Frequency Support	Frequency Ride-Through (FRT)			‡	‡	‡		Δ	Δ
	Rate-of-Change-of-Freq. Ride-Through			‡					Δ
	Voltage Ride-Through (VRT)			‡	‡	‡		Δ	Δ
	Voltage Phase Angle Jump Ride-Through			‡					Δ
	Frequency-Watt	X	√	‡		‡		Δ	Δ

Legend: X Prohibited, √ Allowed by Mutual Agreement, ‡ Capability Required, Δ Test and Verification Defined
[…] Subject to clarification of the technical requirements and use cases, !!! Important Gap

Source: EPRI.

ENPHASE.

Source: EPRI, J.Boemer, Enphase, J. Berdner

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Power Capability vs Controlled Capacity vs Rating at the PCC

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1547-2018's List of Eligible Protocols

Protocol	Transport	Physical Layer
IEEE Std 2030.5™ (SEP2)	TCP/IP	Ethernet
IEEE Std 1815™ (DNP3)	TCP/IP	Ethernet
SunSpec Modbus	TCP/IP	Ethernet
	N/A	RS-485

OpenADR would need to be updated to include all the monitor and/or control points called out in 1547-2018.

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1547-2018 Management Information

- Constant power factor mode parameters
- Voltage-Reactive power mode parameters
- Active power-reactive power mode parameters
- Constant reactive power mode parameters
- Voltage-active power mode parameters
- Voltage trip and momentary cessation parameters
- Frequency trip parameters
- Frequency droop parameters
- Enter service parameters
- Cease to energize and trip
- Limit Maximum active power

Rule 14H's SRD V1.1 calls for remote upgrade capability. These will need expansion for ES; a topic for 1547.9.

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Significant Result from P1547 Activity

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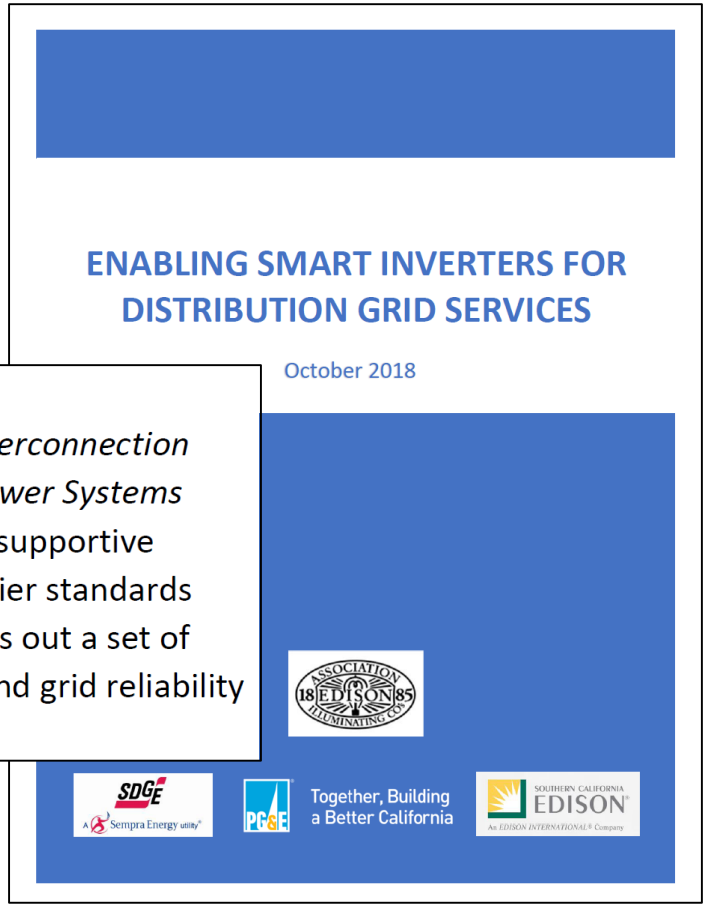

E. Technical Certification Activities

In February 2018, a major revision to IEEE Standard 1547-2018 *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*[4] was approved. This standard requires DERs to provide specific grid supportive functionalities per the California SIWG recommendations. In contrast with earlier standards that provided one set of requirements for all DERs, the new IEEE 1547-2018 lays out a set of options for deployment based on generator system characteristics (e.g. size) and grid reliability requirements.

https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/Joint-IOU-SI-White-Paper.pdf

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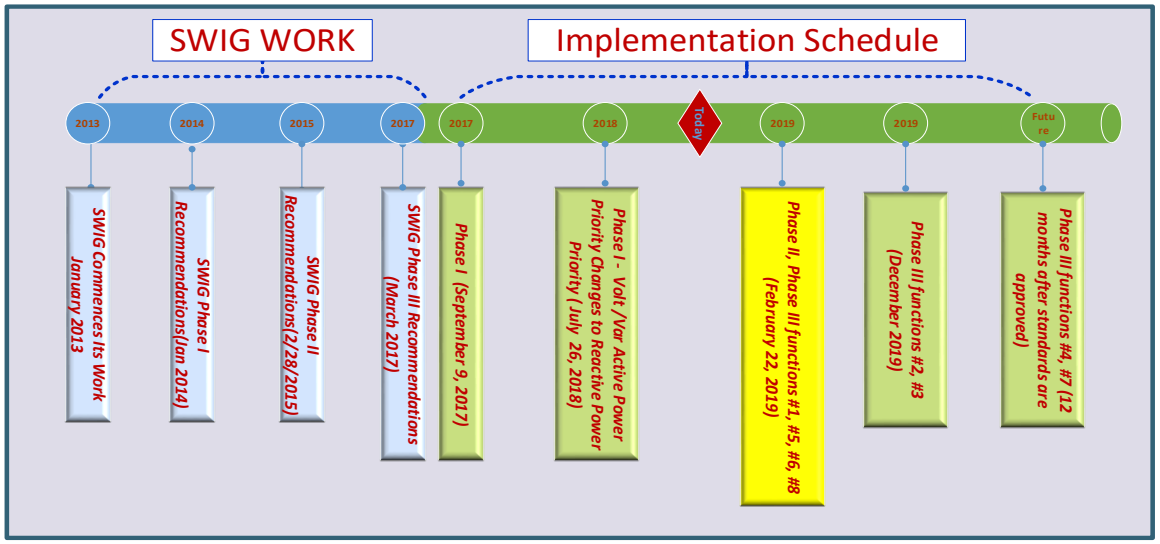
Industry Engagement Example – Smart Inverters



Phase I (Autonomous Functions)

Function 1: Low/High Voltage Ride-through
Function 2: Low/High Freq. Ride-through
Function 3: Dynamic Volt/Var
Function 4: New Fixed Power Factor Req'ts
Function 5: Reconnect By Soft Start Req'ts
Function 6: Ramp Control Requirements

Phase II (Communications)

- Establishes communication capabilities requirements between Generating Facilities and Utility
- February 22, 2019, new IR must meet one of three methods available to communicate to Smart Inverters
  - Direct to inverter
  - Through GF-EMS
  - Through Aggregator
- Default Protocol is the IEEE2030.5 Other may be used
- End Device (Inverter, GFEMS, Aggregator) must be certified under SunSpec Alliance Test

Phase III (Advanced Functions)

Function 1: Monitor Key DER data
Function 2: DER Disconnect and Reconnect Commands
Function 3: Limit Max. Active Power Mode
Function 4: Set Active Power Mode
Function 5: Frequency Watt Mode
Function 6: Volt Watt Mode
Function 7: Dynamic Reactive Support
Function 8: Scheduling Power Values and Modes

Source: SCE, R. Salas

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Thanks!

Questions?

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