IEEE SA
STANDARDS ASSOCIATION

INTRODUCTION TO IEEE 1547 STANDARD FOR INTERCONNECTING DISTRIBUTED ENERGY RESOURCES WITH ELECTRIC POWER SYSTEMS

FOR THE VERMONT PUBLIC UTILITY COMMISSION ENERGY STORAGE SYSTEMS WORKSHOPS,

WORKSHOP #2 INSTALLATION AND OPERATIONAL QUESTIONS SURROUNDING ES FACILITIES

IEEE STANDARDS COMMITTEE 21
NOVEMBER 9, 2023

CHARLIE VARTANIAN, IEEE SC21 EDUCATION COORDINATOR

MICHAEL ROPP, SANDIA NATIONAL LAB, IEEE P1547.9 WG CHAIR

IEEE

DISCLAIMER & ACKNOWLEDGMENTS

This presentation on IEEE Std 1547-2018 and its current revision, IEEE P1547, conveys the views of the author and is not the formal explanation or position of the IEEE.

Many thanks to IEEE P1547 Officers, Working Group members, and balloters who contributed their time and efforts to develop this standard.

IEEE 1547-2018 AND IEEE 1547.1-2020: TUTORIAL OUTLINE

1. **IEEE 1547-2018 Introduction (10 minutes)**

   A high-level overview of IEEE Std 1547-2018, i.e. drivers, scope, applicability, and ongoing activities.

2. **IEEE 1547-2018 and Energy Storage (20 minutes)**

   IEEE 1547.9 – new'ish guide for applying IEEE 1547 to ES-DER

   'IEEE interconnection and interop 'performance requirements' oriented standards for ES'
   'Communication protocols/telemetry required for interconnection to grid/distribution utilities'

3. **IEEE 1547 Challenges and Outlook (10 minutes)**

   'Interconnection issues & challenges'
   'What does the future hold for interconnections standards'

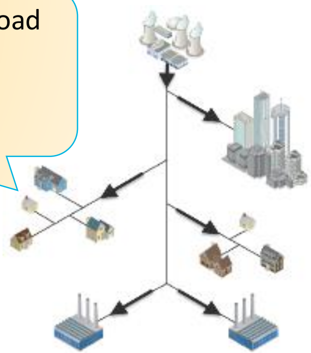
1. **IEEE 1547-2018 Introduction (10 minutes)**

A high-level overview of IEEE Std 1547-2018, i.e. drivers, scope, applicability, and ongoing activities.

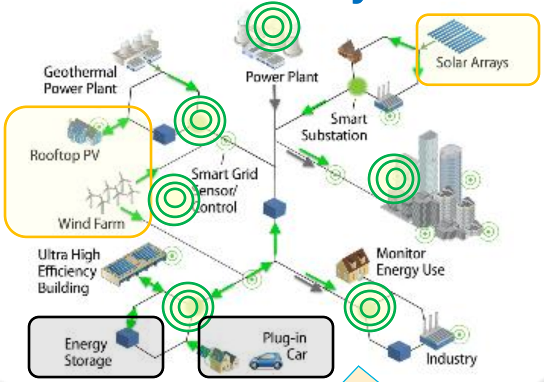
EVOLUTION OF THE GRID

Current Power System

- Resources remote from load
- Large Generation
- Central Control
- Highly Regulated



Future Power Systems



New Challenges in a Modern Grid

- New energy technologies and services
- Increasing penetration of variable renewables in grid
- New communications and controls (e.g., Smart Grids)
- Electrification of transportation
- Integrating distributed energy storage
- A modern grid needs increased system flexibility
- Updated standards – e.g., IEEE Std 1547-2018 (DER as grid assets)

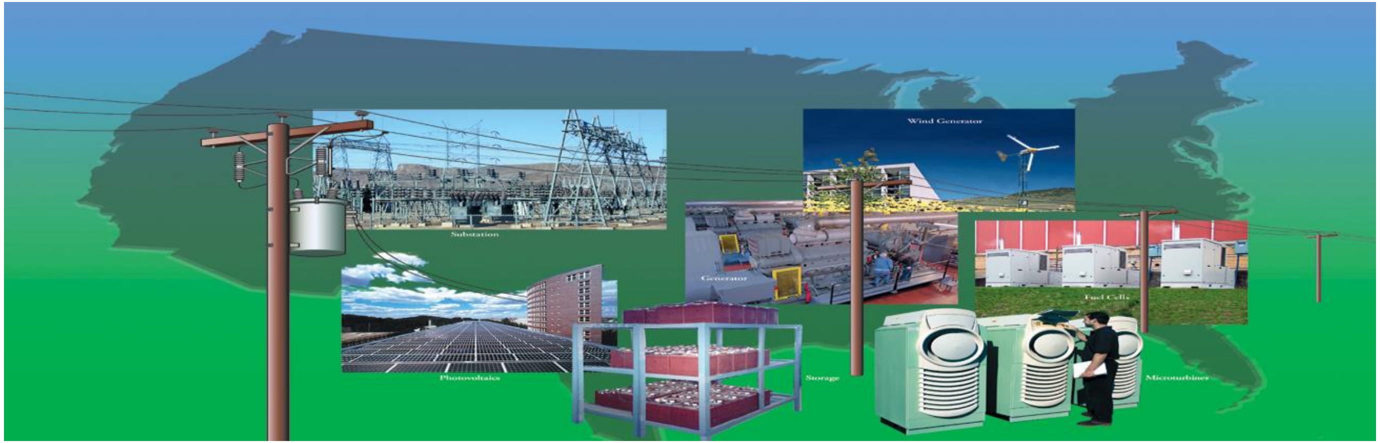
Drivers

- Increased variable generation
- More bi-directional flow at distribution level
- Increased number of smart/active devices
- Evolving institutional environment

Slide courtesy of Dr. Ben Kroposki, NREL.

IMPORTANCE OF IEEE STD 1547

- Energy Policy Act (2005) cites and requires consideration of IEEE 1547 Standards and Best Practices for Interconnection; all states use or cite IEEE Std 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 Std 1547 & 2030 series being expanded}.
- Federal ARRA (2009): Smart Grid & High Penetration DER projects {*use IEEE standards*}.



IEEE STD 1547: USES

IEEE Std 1547 is:

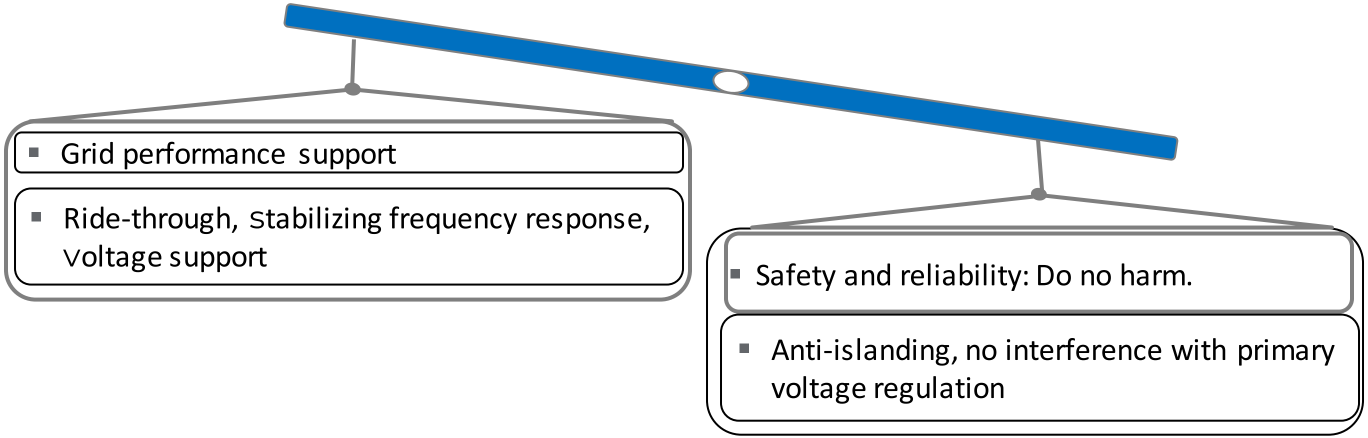
- A technical standard—functional requirements for the interconnection itself and interconnection testing
- A single (whole) document of mandatory, uniform, universal requirements that apply at the point of common coupling (PCC) or point of DER connection (PoC)
- Technology neutral—i.e., it does not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

IEEE Std 1547 is not:

- A design handbook
- An application guide (see IEEE Std 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

GRID PLANNING AND OPERATION CHALLENGES

Increasing DER penetration was a major driver for revising IEEE Std 1547-2018



IEEE 1547 SCOPE AND PURPOSE AND IEEE P1547

Title: IEEE 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, operation, testing, safety, maintenance and security considerations.

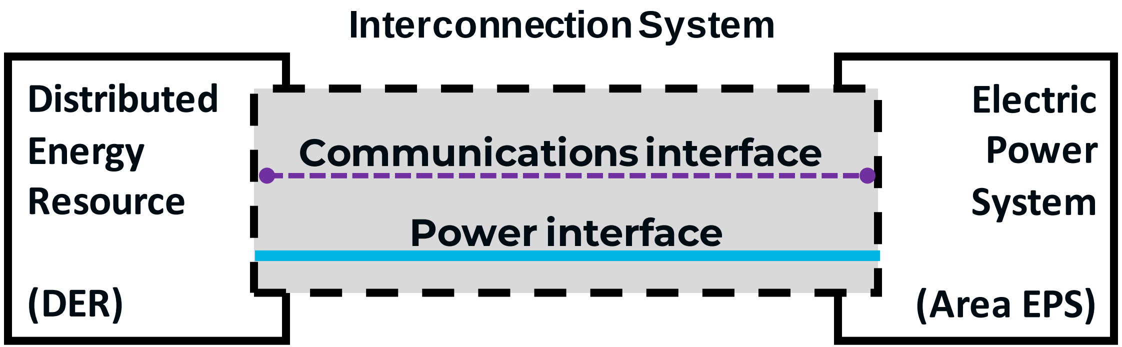
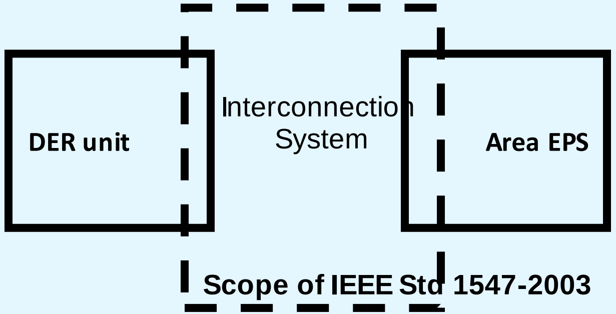


Image based on IEEE Std 1547-2018

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

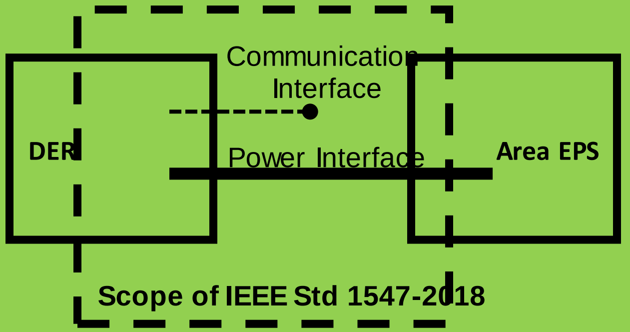
Interface: A logical interconnection from one entity to another that supports one or more data flows implemented with one or more data links.

IMPORTANT CHANGES



IEEE Std 1547-2003

- Distribution system aspects.
- Specifications for the "interconnection system" sufficiently achieve the standard's objective.
- Meant as DER interconnection standard but mainly used for equipment listing.
- Limited to electrical requirements.



IEEE Std 1547-2018

- Focused on distribution and bulk system aspects.
- Specifications encompass the whole DER.
- Can be used for equipment listing as well as system-level verification.
- Includes both electrical as well as interoperability/communications requirements.

IEEE STD 1547: INTERCONNECTION EXAMPLE USE IN UNITED STATES

IEEE Std 1547

Interconnection System and Test Requirements

- Voltage Regulation
- Ride-through
- Interoperability
- Islanding
- ....

IEEE Std 1547.1

Conformance Test Procedures

- Utility interactive tests
- Islanding
- Reconnection
- O/U Voltage and Frequency
- Synchronization
- DC injection
- ....

UL 1741

Interconnection Equipment Safety, Performance Certification

- IEEE 1547.1 Tests
- Protection against risks of injury to persons
- Specific tests for various technologies
- ....

NFPA70 (NEC)

Installation Code

- Article 690 PV Systems
- Article 705: interconnection systems (shall be suitable per intended use per UL 1741)

(NEC info. Based on NEC 2011)

Local interconnection processes and procedures

IEEE STD 1547-2018: DOCUMENT OUTLINE (CLAUSES)

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)

1.4 GENERAL REMARKS AND LIMITATIONS

- **Applicable to all DER connected at typical primary or secondary distribution voltage levels.**
  - Removed the 10 MVA limit from previous versions.
  - <u>BUT:</u> Not applicable for transmission or networked sub-transmission connected resources.
- **Specifies <u>performance</u> and <u>not design</u> of DER.**
- **Specifies <u>capabilities and functions</u> and <u>not utilization</u> of these.**
- **Does not address planning, designing, operating, or maintaining the Area EPS with DER.**
- **Emergency and standby DER are exempt from certain requirements of this standard.**
  - E.g., voltage and frequency ride-through, interoperability and communications.
- **Gives precedence to synchronous generator (SG) design standards for DER with SG units rated 10 MVA and greater.**
  - E.g., IEEE Std C50.12, IEEE Std C50.13.

CONCLUSIONS

- **IEEE Std 1547-2018 helps standardize "smart DER" and accelerate state of the art. It provides high value to the power industry.**
- **IEEE P1547 Working Group agreed on and specified safe, reliable, and cost-effective new interconnection and interoperability requirements for DER.**
- **Specification of test and verification requirements updated in IEEE Std 1547.1-2020.**
  - Interim solutions via UL 1741-SA exists in advance of full – SB certified inverter availability. ➔ support offered in EPRI project
- **IEEE Std 1547-2018 and IEEE Std 1547.1-2020 provide a solid and widely-accepted technical basis for regulatory proceedings.**
  - Action required from state regulators et al, to adopt-by-reference.
- **Revision of IEEE Std 1547-2018 has just begun.**
- **3-4 years estimated until new revision is published.**
- **If interested, please sign-up through iMeet, https://ieee-sa.imeetcentral.com/login**

MORE INFORMATION ON IEEE P1547

- **IEEE SCC21's P1547 Revision Grouper website:**
  http://grouper.ieee.org/groups/scc21/1547_revision/1547revision_index.html

2. IEEE 1547-2018 and Energy Storage (20 minutes)

IEEE 1547.9 – new’ish guide for applying IEEE 1547 to ES-DER

‘IEEE interconnection and interop 'performance requirements' oriented standards for ES’

‘Communication protocols/telemetry required for interconnection to grid/distribution utilities’

IMPACT OF REVISING 1547-2003 ON ES APPLICATIONS, UPDATES MADE TO 1547-2018 REMOVED OTHERWISE UNINTENDED BARRIERS TO SOME ES APPLICATIONS

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 7	• 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 (original table): CA PUC, AB2514 workshop 3/25/2013

WHY DOES 1547.9 GUIDE FOR ES-DER INTERCONNECTION EXIST?

- ❑ **During the drafting of IEEE Std 1547-2018, there was an effort to create a subclause dealing with interconnection aspects that were specific to energy storage.**
- ❑ **Ultimately that subclause was not included in the final document, but IEEE SA and 1547 leadership agreed that the conversation pointed to the need for an ES-specific Application Guide. 1547.9-2022 is that Guide.**
- ❑ **"Why not include this as a subclause in IEEE Std 1547.2?"**
- ❑ A key reason was that it was desired that these energy storage-specific aspects draw from the energy storage community as much as from the power systems community. Thus, ***1547.9 was co-sponsored by SCC21 and the ESSB committee, and had a co-chair from each.***
- ❑ For convenience, it was decided to split out into a separate document the guidance on application of 1547-2018 that is specific to ES DERs.

WHAT'S IN 1547.9?

1547.9 focuses on applying 1547 to energy storage. Examples:

- ES-specific terminology (e.g., "operational SoC" and "operational capacity")
- Black Start
- Clarifying volt-var support modes
- Fast Frequency Response
- Voltage and Frequency Ride-through Exemptions
- ES DERs in Secondary Networks
- ES Specific Changes in Interoperability requirements
- ES DER's specific testing requirements
- Safety
- V2G

WHAT'S IN 1547.9?

- ❑ **The clause structure of 1547.9 is identical to that of IEEE Std 1547-2018, down to the second subclause (i.e., down to Clause #.#.#). Once you get below that (Clause #.#.#.#) 1547.9 may track differently than the base standard.**
- ❑ **Exceptions:**
  - ❑1547.9 has a Clause 12 on safety. 1547-2018 doesn't have a clause 12.
  - ❑1547.9 clause 11 is partly about 1547-2018 but mostly about 1547.1-2020.
- ❑ **Direct references to 1547 clauses are shown in blue and marked with [1547], like this: "Clause #.#.# [1547]".**
- ❑ **In some subclauses, you will see this text: *"Subclause #.#.# [1547] applies to ES DER without further guidance."***

WHAT'S IN 1547.9?

Scope clarification. I.e. 'When is ES in-scope of 1547?'

Any energy storage DER that is "capable of active power export" is in-scope. What does that mean?

capable of exporting active power = any ES DER that is capable of serving load simultaneously with the Area EPS.

Examples of systems and whether they are in-scope:

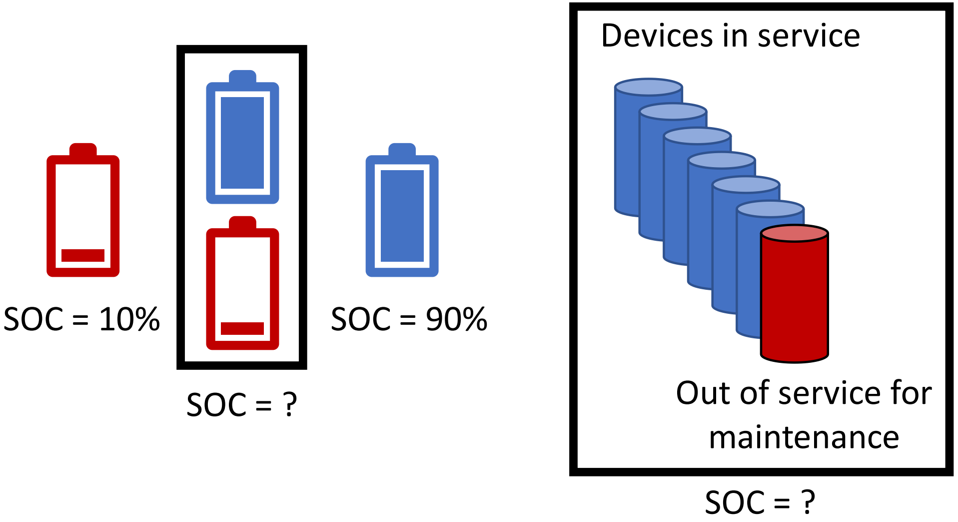
UPS?	PV + ES?	V1G?	V2G?
No	Yes	No	Yes

WHAT'S IN 1547.9?

Defines Operational State of Charge. A term used in IEEE 1547-2018.

<u>operational state of charge:</u> the usable energy stored as a proportion of the operational capacity, expressed as a percentage.

<u>operational capacity:</u> the estimated energy that an energy storage system can provide on discharge, subject to operational constraints. Examples of factors influencing operational capacity include rated energy, state of health, discharge rate, temperature, and usable state-of-charge range.



WHAT'S IN 1547.9?

Operational models.

Operational state of charge and operational capacity aren't sufficient for automated control or state forecasting. For that, an operational model is needed, and 1547.9 discusses them. The figure at the right demonstrates some of what an operational model can tell you.

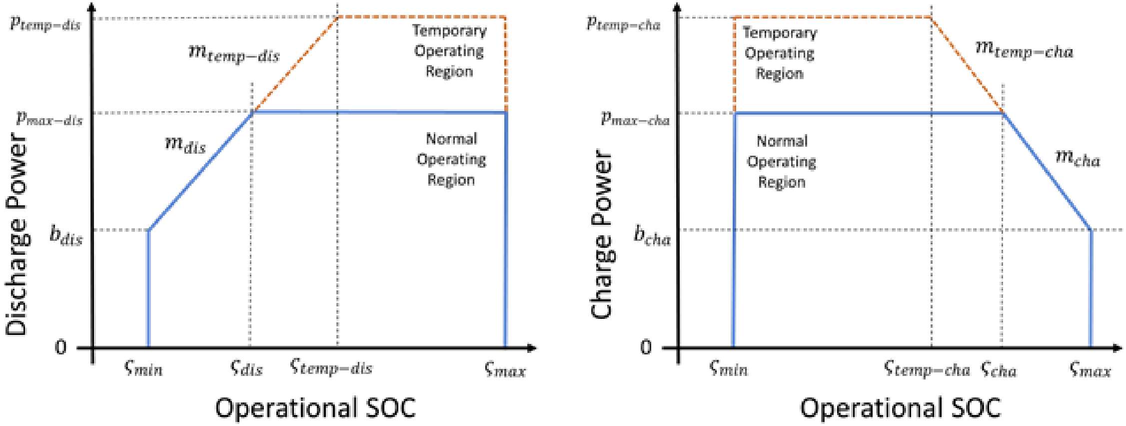


Figure 3—Discharge power (left) and charge power (right) operating regions defined by the operational model constraints

What’s in 1547.9?

Participation in black start/system restoration

- ❑ An ES DER with isochronous control capability might energize an intentional (planned) island.
- ❑ If that ES DER is allowed to temporarily energize some part of the Area EPS outside of the planned island, then it may assist in system restoration after an outage.
- ❑ However, 1547-2018 only discusses reconnexion of an intentional island system to an Area EPS *that is already energized*. There is no provision for connecting a de-energized part of an Area EPS to an energized intentional island.
- ❑ 1547.9 suggests that this kind of assistance with restoration can be allowed, in coordination with the Area EPS operator. Synchronization conditions, adjustments to some parameters, and ensuring ES DER operator awareness of the responsibilities concomitant with participation in system restoration are all discussed.

WHAT'S IN 1547.9?

Clarifies volt-var support modes while charging.

It is recommended that ES DER comply with Normal Operating Performance Category B. In Clause 5, 1547.9 clarifies how these extend into the charging region.

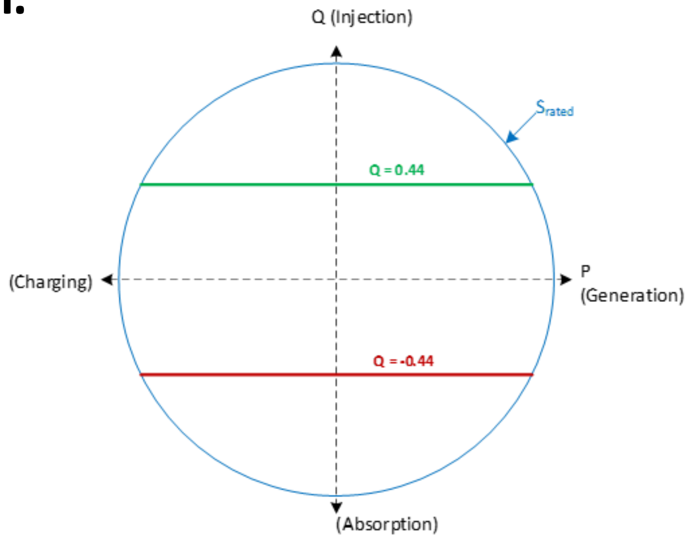


Figure 4—Reactive power capability of ESS

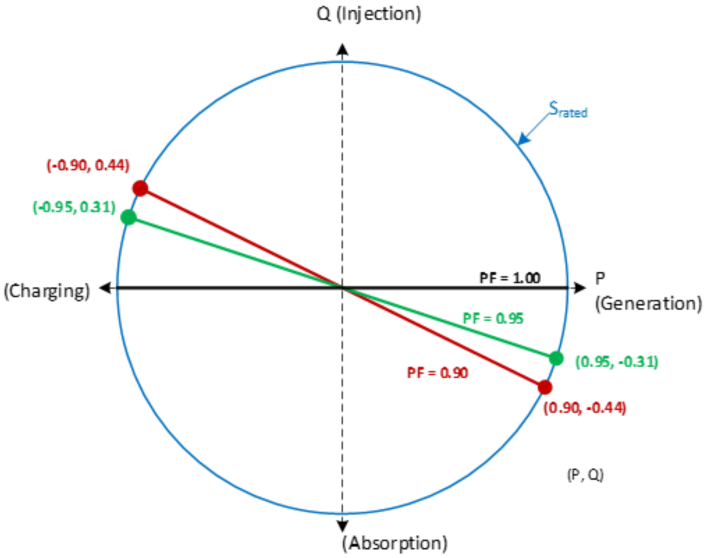


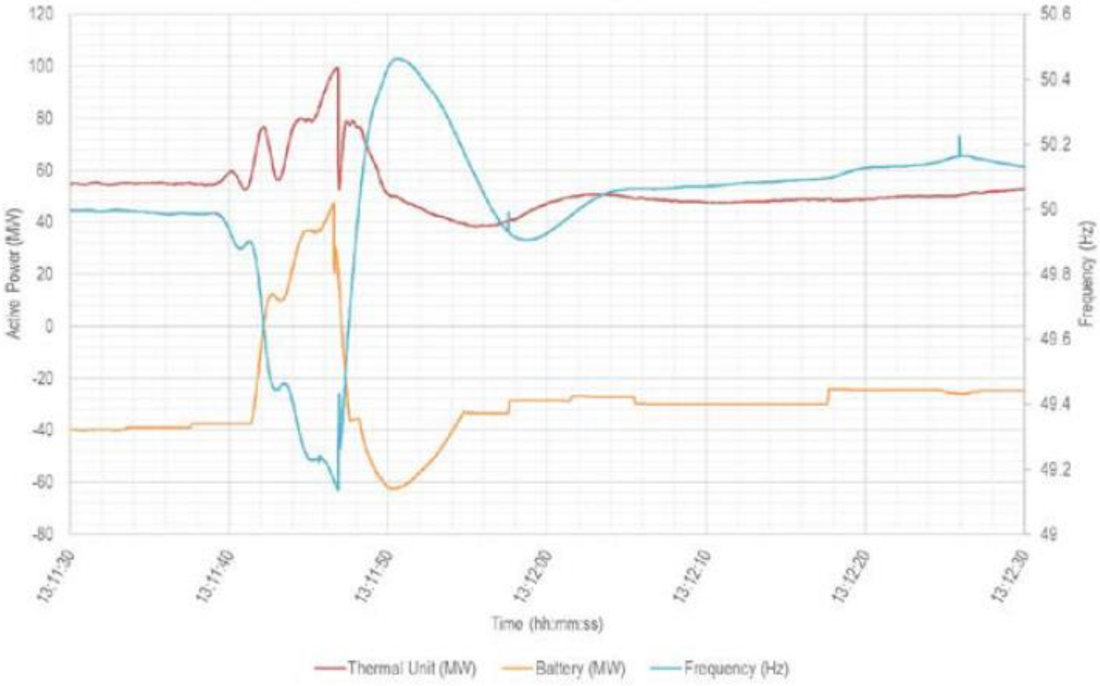
Figure 5—Constant power factor operation of ESS

WHAT'S IN 1547.9?

Fast Frequency Response (FRR).

1547-2018 permits, but does not require or further describe, fast frequency response (FFR). FFR comes in different forms such as synthetic inertial response (power ∝ *df/dt*). It is likely that FFR will be deployed in many ES DERs.

1547.9 discusses inertial response and its deployment in ES DERs. *(Note: IEEE 2800-2022 does require FFR capability and goes into detail on FFRs for transmission-connected ESSs.)*



WHAT'S IN 1547.9?

Vehicle-to-Grid (V2G).

- SAE International produces consensus standards governing vehicle systems and components.
- IEEE produces consensus standards governing interconnexion with power grids.
- Here, the two jurisdictions overlap.

In scope of 1547.9?

Charger location	V1G	V2G
Onboard	No	Yes, via SAE J3072
Offboard	No	Yes

WHAT'S IN 1547.9?

Safety.

- **This clause has no direct parallel in 1547-2018.**

- **Safety is a crucial topic when dealing with ES DERs. Thus, although *safety considerations are outside of the scope of 1547*, the 1547.9 working group thought it of value to collect examples of existing safety codes and standards and to provide some examples of safety-related topics and subsystems. Clause 12 contains this information.**

WHAT'S IN 1547.9?

Interoperability, information exchange, info. models and protocols.

Clause 10 of 1547.9 discusses energy storage-specific changes in the interoperability requirements laid down in the base standard. *Most* of the examples are cases of ES-specific parameters that need to be added to the reporting requirements.

One example is shown at right (ESS-specific additions to Table 29 in 1547-2018).

Table 29—Monitoring information [1547]

In Table 29 [1547], the following rows should be added:

Parameter	Description
State of charge	
Temperature [a]	Temperature in degrees Celsius

[a] This temperature can be the overall temperature of the ES DER unit or, for large installations, the temperatures of individual cells and/or other units.

In Table 29 [1547], the following rows should be added if the ES DER has such parameters:

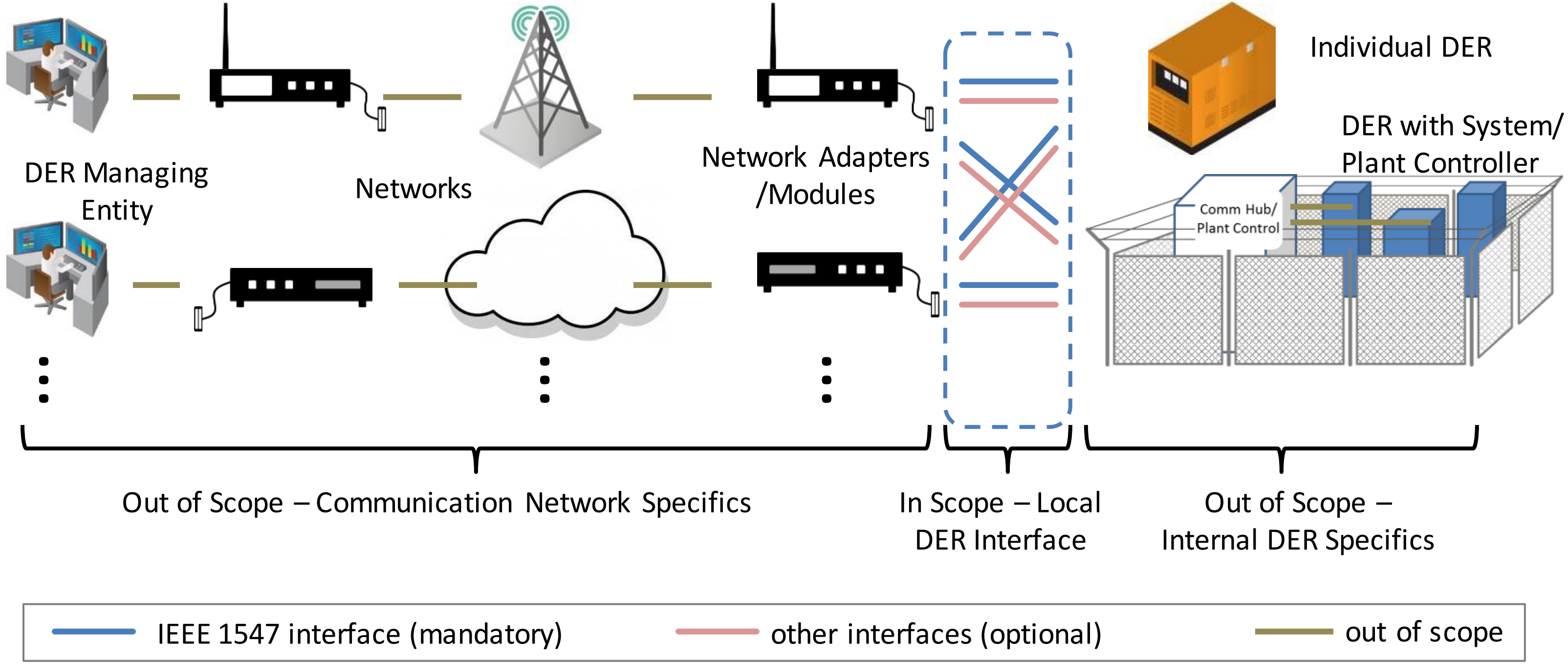
Parameter	Description
Smoke Detection	Smoke has been detected indicating fire
Flame Detection	Flame has been detected indicating fire
Off-Gas Detection	Hydrogen has been detected
Fire Protection System Detection	The fire protection system has activated

In Table 29 [1547], for ES DER the following rows should be changed as shown (**emphasis** added to identify the change):

Parameter	Description
Operational State	Operational state of the DER. The operational state should represent the current state of the DER. The minimum supported states are on and off, but additional states may also be supported. **Include charging and discharging as operational states of the DER.**

IEEE SA STANDARDS ASSOCIATION

SCOPE OF INTEROPERABILITY REQUIREMENTS



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

LOGICAL COMBINATIONS OF PROTOCOLS

Application	DNP3	IEEE 2030.5	SunSpec Modbus
Transport	TCP	TCP	N/A
IP Layer	IP	IPV6	
Network Access	Ethernet	Ethernet	RS-485
	Twisted Pair/RJ-45	Twisted Pair/RJ-45	Twisted Pair/ RJ-45/CTA-2045

Allowing for a couple of well-defined options gives vendors more flexibility and is still achievable for aggregators/integrators.

THANK YOU!

Please feel free to email me with questions:

meropp@sandia.gov

Special thanks to Dr. Imre Gyuk, DOE – Office of Electricity, Energy Storage Program.

IEEE 1547-2018 AND IEEE 1547.1-2020: TUTORIAL OUTLINE

3. IEEE 1547 Challenges and Outlook (10 minutes)

‘Interconnection issues & challenges’

‘What does the future hold for interconnections standards’

TOP 5 CONCERNS OF DISTRIBUTION GRID PLANNERS, OPERATORS, AND LINE WORKERS

- "Cease to energize" with or without galvanic separation?
- Unintentional islanding risk with DER that ride-through disturbances and regulate voltage and/or frequency.

Specify **tests** in IEEE Std 1547.1

- DER coordination with Area EPS automatic reclosing.
- DER coordination with Area EPS protection.
- DER impact on line workers' safety during hot-line maintenance.

Address in DER interconnection practices **screening**

APPLICATION OF IEEE STD 1547-2018

Stakeholder Challenges

FERC

Requirements for Small Generating Facilities

Orders for Transmission Providers
No. 827 (reactive power)
No 828 (ride-through)

Authorities Governing Interconnection Requirements

Assignment of
Categories A, B (reactive power)
Categories I, II, III (ride-through)

Coordination between new IEEE 1547.1 verification requirements and DER interconnection procedures

Utilities

Update of boilerplate interconnection agreements with new capabilities

Grid-specific tuning of DER settings (e.g., determination of volt/var parameters for increased hosting capacity[1])

Specification of local DER interface communication protocols

DER Developers

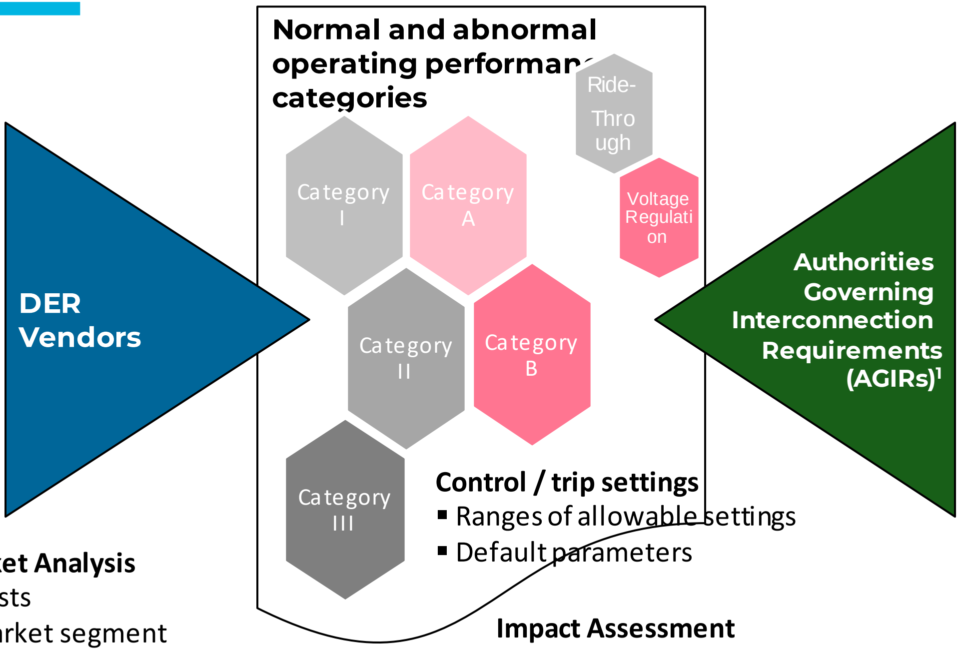
Interconnection requests,
DER design

DER Vendors

Testing of DER capabilities (type tests)

[1] *For example with EPRI's Distribution Resource Integration and Value Estimation (DRIVE) Tool (3002008293).*

ASSIGNMENT OF NEW PERFORMANCE CATEGORIES IN IEEE STD 1547-2018



Market Analysis
- Costs
- Market segment
- Etc.

Stakeholder Engagement
- Distribution utilities
- Bulk system operators & planners
- DER developers
- Others

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

Category III ~ Greatest ride-through capabilities

Category B ~ Greatest voltage support capabilities (most inverter-based DERs)

[1] State Regulator, Area EPS or bulk system operator, etc.

ABNORMAL PERFORMANCE CATEGORIES, SPECIFIED BY AN AHJ PER JURISDICTION NEEDS AND INPUT - & THOUGHTS ON ‘USING 1547 BY REF’

Category	Objective	Foundation
I	Essential bulk system needs and reasonably achievable by all current state-of-art DER technologies	German grid code for synchronous generator DER
II	Full coordination with bulk power system needs	Based on NERC PRC-024, adjusted for distribution voltage differences (delayed voltage recovery)
III	Ride-through designed for distribution support as well as bulk system	Based on California Rule 21 and Hawaii Rule 14H

Category II and III are sufficient to support bulk system reliability.

APPLICATION OF IEEE STD 1547-2018

What are "ranges of allowable settings"?

- **Definition: The range within which settings may be adjusted to values other than the specified default settings.**
- **Used for functional specifications, not for capabilities.**
- **Default values specify generic settings <u>that do not harm</u>.**
  - May not be most effective.

Used throughout the standard

- **Voltage regulation**
  - 5.3 Voltage and reactive power control
  - 5.4 Voltage and active power control
- **Voltage and frequency trip**
  - 6.4.1 Mandatory voltage tripping
  - 6.5.1 Mandatory frequency tripping
- **Momentary cessation threshold during ride-through (6.4.2.7.3)**
- **Frequency regulation**
  - 6.5.2.7 Frequency-droop (frequency-power)

UL-1741-SA SRD/CRD's for CA Tariff Rule 21 and HA Rule 14 are informative

<u>CEC's Inverter List for Self-Reporting Certification: Solar Equipment Lists Program | California Energy Commission</u>

A FEW THOUGHTS ON APPLYING IEEE STD 1547: INTERCONNECTION SCREENS USED BY SOME UTILITIES

- **System protection (Supplemental review and full impact studies).**
- **Anti-islanding protection screens may need to be revised.**
- **System DER hosting capacity.**
- **Modeling the Advanced DER. Lack of modeling tools that are widely used by the utilities for protection and load flow studies.**

✓ Interconnection study time and cost

INTERCONNECTION SCREENING

Interconnection screening may need to address DER integration issues such as protection coordination, reclosing coordination, and risk of islanding.

Majority of cases of applications compliant with IEEE Std 1547-2018

- Voltage and frequency regulation
- Frequency and voltage ride-through
- 2s anti-islanding detection/clearing time
- Trip for faults on the circuit where DER connected
- UV2 close to the IEEE 1547a-2014 default value
- "Momentary Cessation" for LVRT < 0.5 p.u.

Preliminary Screens, Fast Track

Common cases with DER in distribution areas that use **fast reclosing**

Supplemental Screen for issues, then apply **appropriate means, e.g.:**

- extend automatic reclosing times,
- block hot reclosing,
- direct transfer trip,
- very fast islanding detection

Some cases where DER may **disrupt Area EPS protection coordination** for **high-impedance faults**

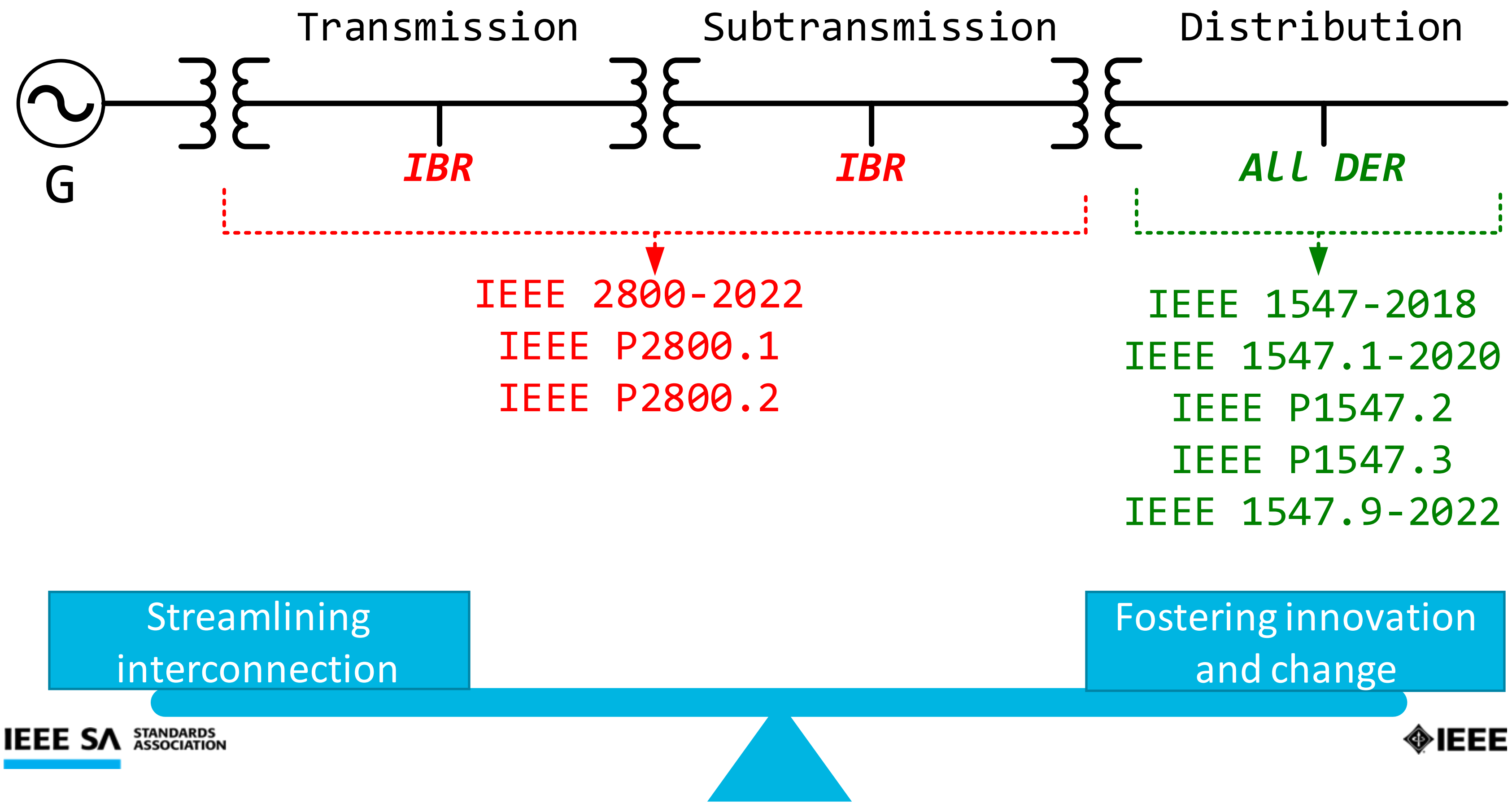
Supplemental Screen for issues, then apply means:

- DER overcurrent protection or
- DER voltage-supervised overcurrent protection

Rare cases with reduced effectiveness of **anti-islanding detection**

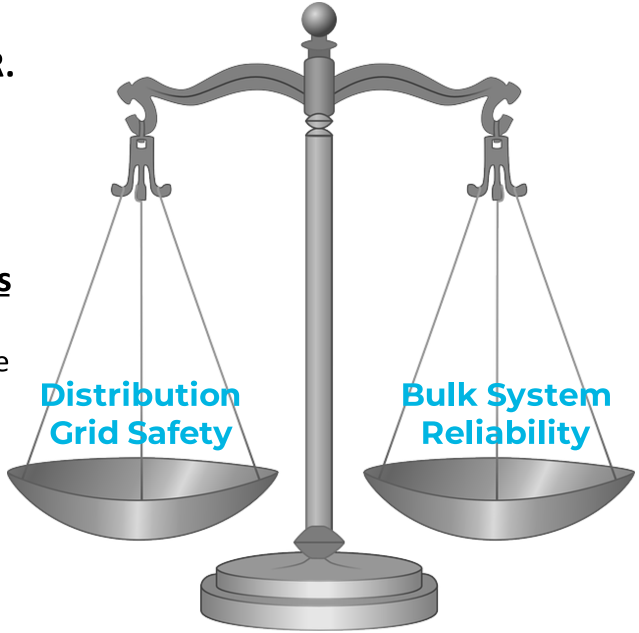
Supplemental Screen for issues, also consider extending anti-islanding detection/clearing time from 2s to up to 5s

IEEE STANDARDS APPLICABLE TO INTERCONNECTION, COORDINATING ACROSS T&D



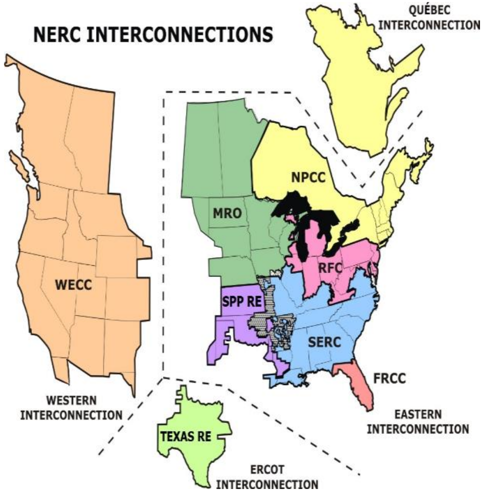
STRIKING A NEW BALANCE

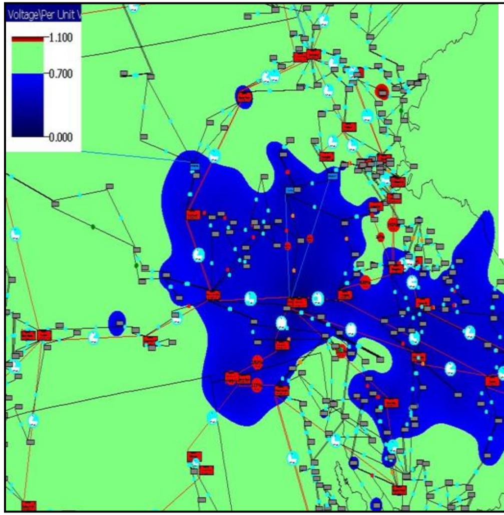
- **IEEE Std 1547-2018 mandates BOTH:**
  - Tripping requirements, and
  - Ride-through requirements
- **Ride-through is not a "setting"; it is a minimum capability of the DER.**
  - *"shall ride through for at least ... seconds"*
  - I.e., it is the minimum required DER robustness to withstand voltage 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 at latest by ... 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



DRIVER FOR NEW RIDE-THROUGH REQUIREMENTS (IMPARTED IN 1547-2018: MITIGATE POTENTIAL FOR WIDESPREAD DER TRIPPING

- System frequency is defined by balance between load and generation
- Frequency is similar across entire interconnection; all DER can trip simultaneously during disturbance
- Impact the same whether or not DER is on a high-penetration feeder





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

- Transmission faults can depress distribution voltage over very large areas
- Sensitive voltage tripping (i.e., IEEE Std 1547-2003) can cause massive loss of DER generation
- Resulting BPS event may be greatly aggravated

ACTIVE P1547 WORK, YOUR INPUT AND PARTICIPATION IS NEEDED

IEEE P1547 (Revision)

Mamadou Diong, Dominion Energy, Chair

IEEE SA - P1547

IEEE P1547.4, Guide for Intentional Islanding

Michael Ropp, Sandia National Lab, Chair

IEEE SA - P1547.4

IEEE P1547.10, Recommended Practice for DER Gateway

Abrez Mondal, EPRI, Chair

IEEE SA - P1547.10

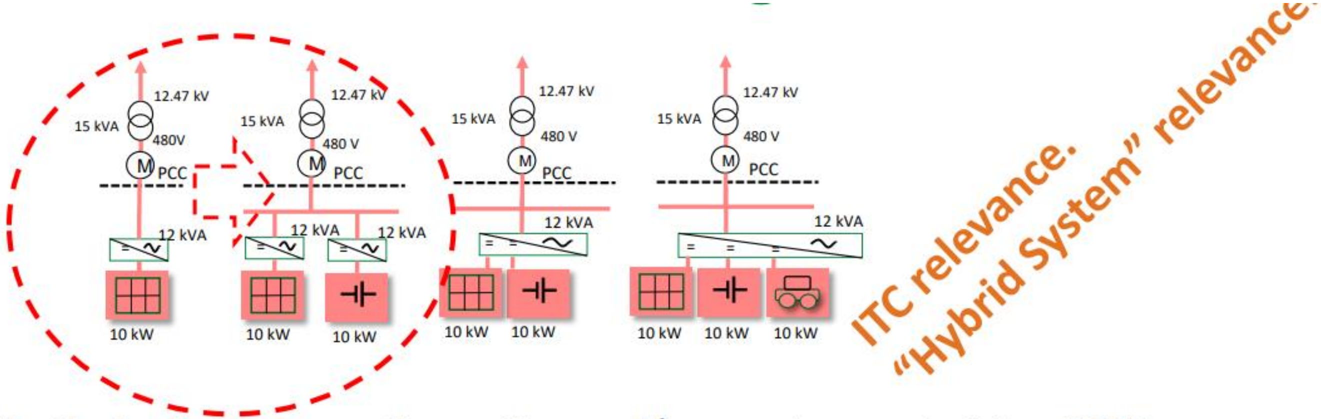
THANK YOU

Charlie Vartanian | Charlie.Vartanian**@ieee.org**

BACKUP SLIDES

HYBRID SYSTEMS CHALLENGE AND OPPORTUNITY

Control-based capacity at PCC



What's the interconnection rating and/or requirement at the PCC?
Who determines? On what basis?

IEEE 1547-2018's recognition of "system" based compliance helps, versus depending on listed-equipment based compliance only.

(However, the simple 'nameplate capacity' approach remains a useful 'fast-track' interconnection review screen, for smaller simple ESSs).

One of several reasons for AHJs' to reference revised IEEE 1547-2018.

USEFUL INFORMATION

https://standards.ieee.org/standard/1547-2018.html

https://standards.ieee.org/project/2800.html

https://cmte.ieee.org/pes-essb/

https://www.sandia.gov/ess-ssl/
https://www.sandia.gov/energystoragesafety-ssl/

https://www.nerc.com/pa/Stand/Workshops/NERC%20101.pdf

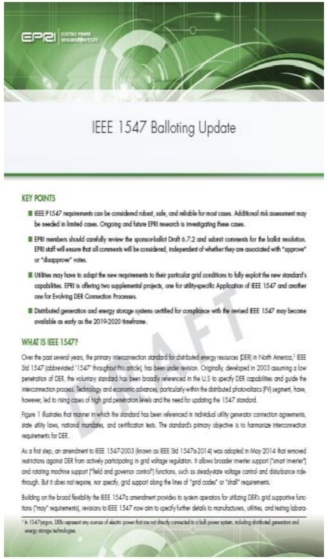
https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Inverter-Based_Resource_Performance_Guideline.pdf

https://www.nerc.com/comm/PC/Pages/Inverter-Based-Resource-Performance-Task-Force.aspx

https://www.ferc.gov/industries-data/electric/industry-activities/nerc-standards

https://www.ferc.gov/sites/default/files/2020-04/reliability-primer_1.pdf

IEEE STD 1547-2018: NRECA AND EPRI GIVE FURTHER INSIGHTS



Fact Sheet
available on
epri.com

NRECA *Revision of IEEE 1547™* Articles	Availability
1. The Background for Change, November 2016	NRECA + EPRI
2. New Reactive Power and Voltage Regulation Capability Requirements, December 2016.	NRECA + EPRI
3. New Disturbance Response Requirements, February 2017.	NRECA + EPRI
4. New Power Quality and Islanding Issues, April 2017.	NRECA + EPRI

EPRI white papers	Availability
5. Minimum Requirements for DER Ride-Through	Published
6. Communications interface and interoperability	Published
7. Power quality considerations for DER	Published
6. Impacts of DER ride-through on anti-islanding and distribution protection	Draft

APPLICATION OF IEEE STD 1547-2018 BEFORE IEEE STD 1547.1-2020, *UL-1741-SB Active w/ approval of 1547-2020. -SC for V2G pending. -SA still useful.*

UL Certification of Inverters

Utility Interactive
- Traditional UL1741
- IEEE Std 1547 & 1547.1 (1st ed.) Interconnection Requirements

Grid Support Utility Interactive
- UL 1741 SA Grid Support Functions
- Source Requirements Documents like CA Rule 21, Hawai'ian Rule 14H, IEEE Std 1547-2018 (2nd ed.)

Special Purpose Utility Interactive
- Specific Manufacturer / Utility Defined UL Verified Compliance
- Custom Source Requirements Documents

UL Certification:
- Grid Support, Utility Interactive Product

Scope:
- Safety & Electric Shock Certification to UL 1741 including UL 1741 SA for grid support and general grid interconnection per IEEE Std 1547

Includes Testing to Verify:
- UL 1741 electric shock/fire tests
- UL 1741 SA grid support tests
- Unique tests of IEEE 1547 for general grid interconnection not covered by UL 1741 SA tests

Deliverable:
- UL Certification as a Grid Support Utility Interactive product

IEEE STD 1547-2018: EXAMPLE NEW REACTIVE POWER REQUIREMENTS

5.2 Reactive power capability of the DER

The DER shall be capable of injecting reactive power (over-excited) and absorbing reactive power (under-excited) for active power output levels greater than or equal to the minimum steady-state active power capability (P_{min}), or 5% of rated active power, P_{rated} (kW) of the DER, whichever is greater.

When operating at active power output greater than 5% and less than 20% of rated active power, the DER shall be capable of exchanging reactive power up to the minimum reactive power value given in Table 7 multiplied by the active power output divided by 20% of rated active power.

Operation at any active power output above 20% of rated active power shall not constrain the delivery of reactive power injection or absorption, up to the capability specified in Table 7, as required by the active control function at the time, as defined in 5.3. Curtailment of active power to meet apparent power constraints is permissible. These reactive power requirements are illustrated in informative Figure H.3.[60]

Table 7—Minimum reactive power injection and absorption capability

Category	Injection capability as % of nameplate apparent power (kVA) rating	Absorption capability as % of nameplate apparent power (kVa) rating
A (at DER rated voltage)	44	25
B (over the full extent of ANSI C84.1 range A)	44	44

IEEE STD 1547-2018: EXAMPLE NEW REACTIVE POWER REQUIREMENTS (continued)

5.3.1 Voltage and Reactive Power Control

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.

The voltage and reactive power control functions do not create a requirement for the DER to operate at points outside of the minimum reactive power capabilities specified in of 5.2.

The DER shall, as specified in Table 6, provide the capabilities of the following mutually exclusive modes of reactive power control functions:

— Constant power factor

— Voltage-reactive power

— Active power-reactive power

— Constant reactive power

DER category	Category A	Category B
Voltage regulation by reactive power control		
Constant power factor mode	Mandatory	Mandatory
Voltage—reactive power mode[a]	Mandatory	Mandatory
Active power—reactive power mode[b]	Not required	Mandatory
Constant reactive power mode	Mandatory	Mandatory
Voltage and active power control		
Voltage—active power (volt-watt) mode	Not required	Mandatory

[a]Voltage-reactive power mode may also be commonly referred to as "volt-var" mode.
[b]Active power-reactive power mode may be commonly referred to as "watt-var" mode.

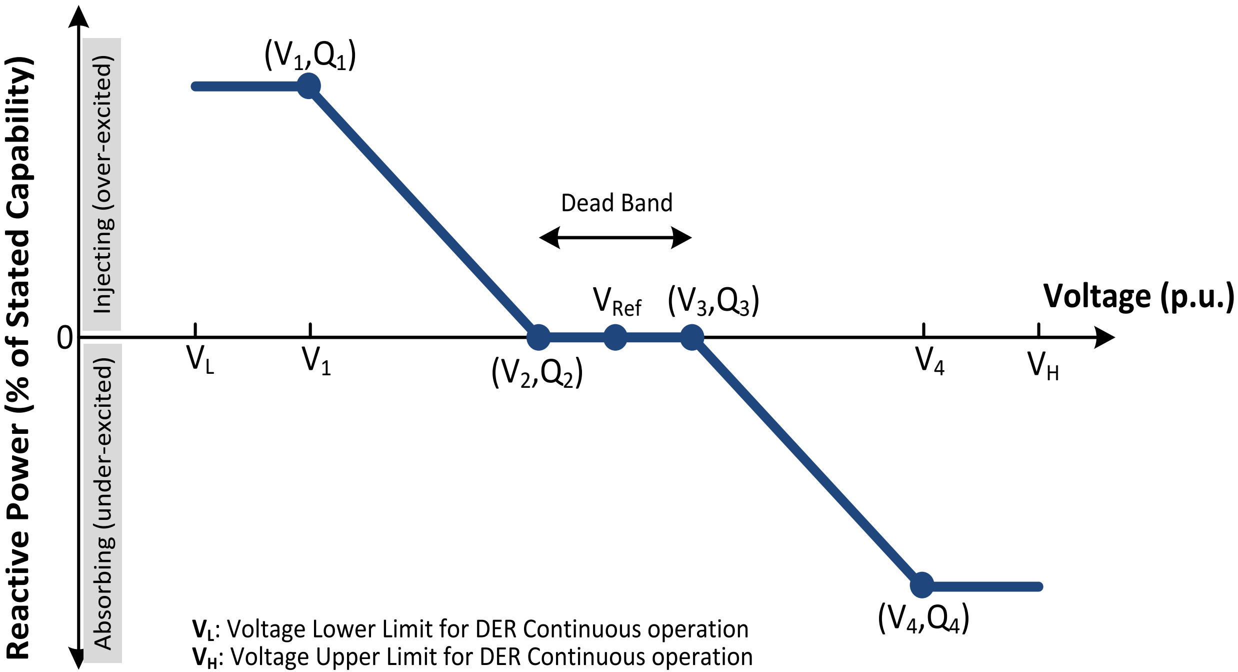
IEEE STD 1547-2018: EXAMPLE NEW REACTIVE POWER REQUIREMENTS (continued)

Constant Power factor mode

When in this mode, the DER shall operate at a constant power factor. The target power factor shall be specified by the Area EPS operator and shall not require reactive power exceeding the reactive capability requirements specified in 5.2. The power factor settings are allowed to be adjusted locally and/or remotely as specified by the Area EPS operator. The maximum DER response time to maintain constant power factor shall be 10 s or less.

IEEE STD 1547-2018: EXAMPLE NEW REACTIVE POWER REQUIREMENTS (continued)

Volt-Reactive Power Capability (Volt/Var Mode – Subclause 5.3.3)



Example voltage-reactive power characteristic

IEEE STD 1547-2018: EXAMPLE NEW REACTIVE POWER REQUIREMENTS (continued)

The Volt/VAR characteristics curve is adjustable.

Volt-var parameters	Definitions	Default Settings for Cat A DER	Default Settings for Cat B DER	Range of Allowable settings	
				Minimum	Maximum
V_{Ref}	Reference voltage	Nominal voltage (V_N)	Nominal voltage (V_N)	0.95 V_N	1.05 V_N
V_2	Dead band lower voltage limit	Nominal voltage (V_N)	V_{Ref} – 0.02 V_N	Cat A: V_{ref} Cat B; V_{Ref} – 0.03 V_N	V_{Ref} [c]
Q_2	Reactive power injection or absorption at voltage V_2	0	0	0	100% of stated reactive capability
V_3	Dead band upper voltage limit	Nominal voltage (V_N)	V_{Ref} + 0.02 V_N	V_{Ref}[c]	Cat A: V_{ref} Cat B: V_{Ref} + 0.03 V_N
Q_3	Reactive power injection or absorption at voltage V_3	0	0	0	100% of stated reactive capability
V_1	Voltage at which DER shall inject Q_1 reactive power	0.9 V_N	V_{Ref} – 0.08 V_N	V_{Ref} - 0.18 V_N	V_2 [c]-0.02 V_N
Q_1	Reactive power injection at voltage V_1[a]	25% of nameplate kVA	100% of stated reactive capability	0	100% of stated reactive capability[b]
V_4	Voltage at which DER shall absorb Q_4 reactive power	1.1 V_N	V_{Ref} + 0.08 V_N	V_3 [c]+0.02 V_N	V_{Ref} + 0.18 V_N
Q_4	Reactive power absorption at voltage V_4	25% of Nameplate kVA	100% of stated reactive capability	0	100% of stated reactive capability [b]
Open loop response time	Time to 90% of the reactive power change in response to the change in voltage	10 s	5 s	1 s	90 s

[a] The DER reactive power capability may be reduced at lower voltage
[b] If needed DER may reduce active power output to meet this requirement
[c] Improper selection of these values may cause system instability

IEEE STD 1547-2018: EXAMPLE NEW REACTIVE POWER REQUIREMENTS (continued)

Constant Reactive Power Capability

When in this mode, the DE shall operate at a constant power factor. The target power factor shall be specified by the Area EPS operator and shall not require reactive power exceeding the reactive capability requirements specified in 5.2. The power factor settings are allowed to be adjusted locally and/or remotely as specified by the Area EPS operator. The maximum DER response time to maintain constant power factor shall be 10 s or less.

ARE THE VOLTAGE REGULATION REQUIREMENTS PROPOSED TO BE MANDATORY?

Voltage regulation capability is mandatory but the performance is proposed to be at the utility's discretion (The DER will provide this capability and the utility will decide to enable/disable it and choose the proper operating modes).

IEEE STD 1547-2018

CLAUSE 7:
POWER QUALITY

NEW POWER QUALITY REQUIREMENTS

Flicker (Subclause 7.2.3)

Flicker is the subjective impression of fluctuating luminance caused by voltage fluctuations.

Assessment and measurement methods for flicker are defined in IEEE1453and IEC 61000-3-7.

- **EPst** –Emission limit for the short-term flicker severity. If not specified differently, the Pst evaluation time is 600 s.
- **EPlt** – Emission limit for long-term flicker severity. If not specified differently, the Plt evaluation time is 2 h.

Table 25—Minimum Individual DER Flicker Emission Limits[a]

E_{Pst}	E_{Plt}
0.35	0.25

[a] 95% probability value should not exceed the emission limit based on a one week measurement period.

NEW POWER QUALITY REQUIREMENTS (continued)

Limitation of Current Distortion (Subclause 7.3)

- **Harmonic current distortion and total rated-current distortion (TRD) at the reference point of applicability (RPA) shall not exceed the limits stated in Table 26 and Table 27.**
- **The harmonic current injections shall be exclusive of any harmonic currents due to harmonic voltage distortion present in the Area EPS without the DER connected.**

Table 26—Maximum odd harmonic current distortion in percent of rated current (I_{rated}) [a]

Individual odd harmonic order h	h < 11	11≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤h < 50[120]	Total rated current distortion (TRD)
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

[a] I_{rated} = the DER unit rated current capacity (transformed to the RPA when a transformer exists between the DER unit and the RPA).

Table 27—Maximum even harmonic current distortion in percent of rated current (I_{rated}) [a]

Individual even harmonic order h	h=2	h=4	h=6	8≤h<50
Percent (%)	1.0	2.0	3.0	Associated range specified in Table 26

[a] I_{rated} = the DER unit rated current capacity (transformed to the RPA when a transformer exists between the DER unit and the RPA).

NEW POWER QUALITY REQUIREMENTS (continued)

Limitation of Overvoltage Contribution (Subclause 7.4)

Limitation of overvoltage over one fundamental frequency period

The DER shall not contribute to instantaneous or RMS overvoltages with the following limits:

a) The DER shall not cause the fundamental frequency line-to-ground voltage on any portion of the Area EPS that is designed to operate effectively grounded, as defined by IEEE Std C62.92.1, to exceed 138% of its nominal line-to-ground fundamental frequency voltage for a duration exceeding one fundamental frequency period.

b) The DER shall not cause the line-to-line fundamental frequency voltage on any portion of the Area EPS to exceed 138% of its nominal line-to-line fundamental frequency voltage for a duration exceeding one fundamental frequency period.

Limitation of cumulative instantaneous overvoltage

The DER shall not cause the instantaneous voltage on any portion of the Area EPS to exceed the magnitudes and cumulative durations shown in Figure 13. The cumulative duration shall only include the sum of durations for which the instantaneous voltage exceeds the respective threshold over a one-minute time window.

TUT-04:
IEEE STD 1547-2018

CLAUSE 6: RESPONSE TO AREA EPS ABNORMAL CONDITIONS

CONTENTS

- **Normal and abnormal performance categories**
- **Response to abnormal conditions**
  - Voltage and frequency trip
  - Voltage and frequency ride-through capability
    - Dynamic voltage support capability
    - Frequency control capability
- **Default values and ranges of allowable settings for the above**

GENERAL TRIPPING AND RECLOSE COORDINATION REQUIREMENTS

- **DER must trip for any short-circuit faults on the circuit to which it is connected.**
  - Exception for faults not detectable by Area EPS protections
  - At Area EPS Operator discretion, sequential tripping can be employed
- **DER must detect and cease to energize for open phase condition directly at the <u>reference point of applicability</u> within two seconds.**
- **DER must implement means such that Area EPS circuit reclosing does not result in unacceptable stress or disturbance. Possible means include:**
  - Low DER penetration = no islanding sustained for reclose delay
  - Feeder reclosing "hot-line blocking"
  - Transfer trip
  - Anti-islanding detection proven to be faster than reclose delay

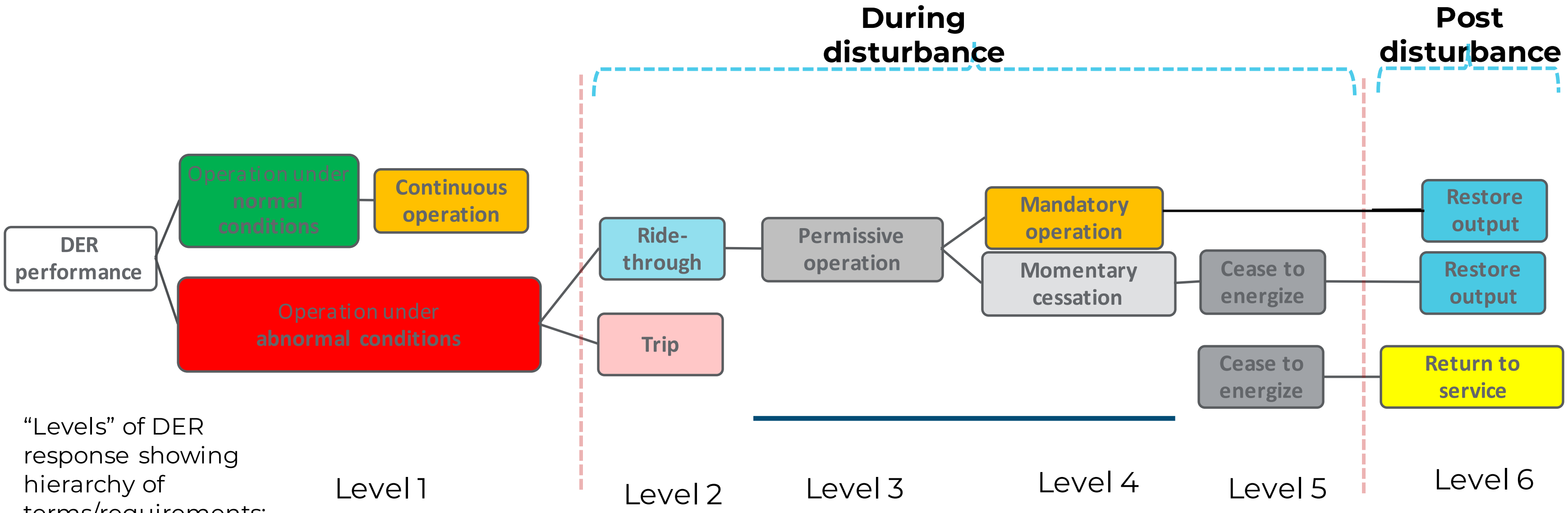
DISTURBANCE PERFORMANCE CATEGORIES ADDED IN 1547-2018

- **Not all DER technologies can meet the full extent of ride-through compatible with BPS requirements.**
  - Synchronous generators have stability issues with LVRT
  - Some "prime mover" or "energy source" systems can also have potential issues
  - Example: Engine converting landfill CH_4 to energy

- **Solution: define "disturbance performance categories"**
  - Authority Governing Interconnection Requirements (AGIR) decides which performance category will be met by each DER type and application
  - Technical criteria: type, capacity, future penetration of DER, type of grid configuration, etc.
    - AGIR may also limit cumulative capacity allowed to meet "lower-level" requirements
  - Non-technical criteria: DER use case, impacts on environment, emissions, and sustainability, etc.
    - Making non-technical judgements is outside purview of IEEE standards

Note: It's currently hard/unfeasible to retroactively change DER performance in most cases. Think 30 years ahead when choosing performance category and settings!

DISTURBANCE PERFORMANCE TERMINOLOGY



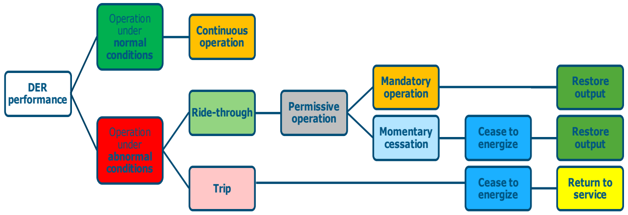
"Levels" of DER response showing hierarchy of terms/requirements:

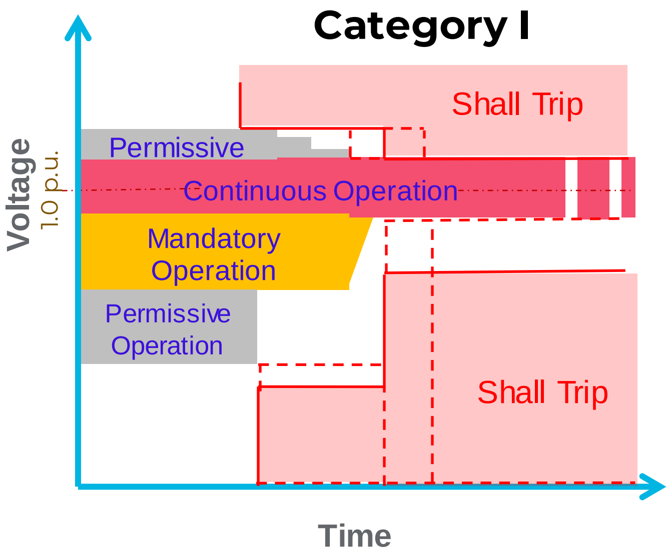
- **Ride-through** – ability to withstand voltage or frequency disturbances
  - **Permissive operation** – DER may either continue operation or may cease to energize, at its discretion
    - **Mandatory operation** – required active and reactive current delivery
    - **Momentary cessation** – cessation of energization for the duration of a disturbance with rapid recovery when voltage or frequency return to defined range
  - **Restore output** – DER recovery to normal output following a disturbance that does not cause a ***trip***.
- **Trip** – cessation of output without immediate return to service; not necessarily disconnection
  - **Return to service** – re-entry of DER to service following a trip; equivalent to start-up of DER

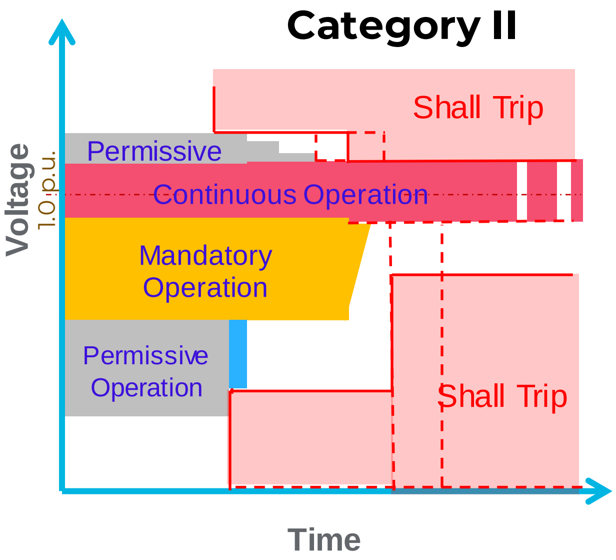
CLARIFICATION OF “CEASE TO ENERGIZE”

- **Cease to energize**
  - Refers to Point of DER Connection (PoC) of individual DER unit(s)
  - No active power delivery
  - Limitations to reactive power exchange
  - Does not necessarily mean physical disconnection
  - Used for either momentary cessation or trip

STRUCTURE OF VRT: CATEGORIES I AND II

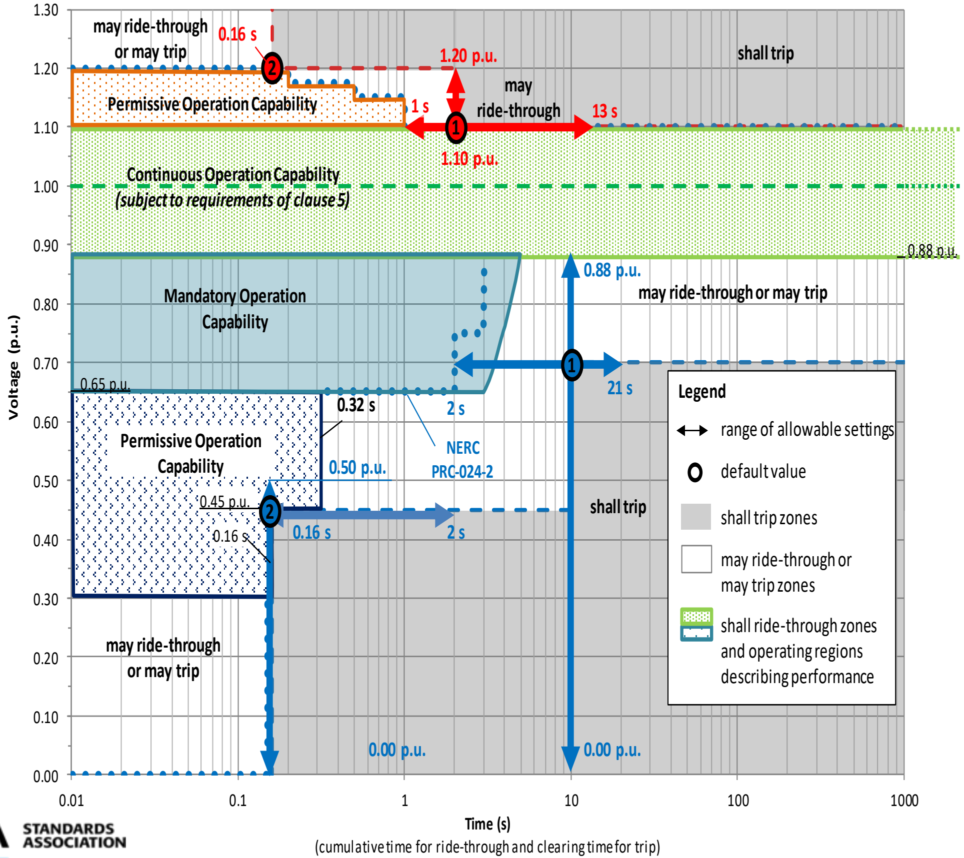






Dashed lines indicate permissible range of trip adjustment; solid lines indicate default settings.
Figure are approximate and solely for illustration. Refer to IEEE Std 1547-2018 for actual requirements.

IEEE STD 1547-2018: ABNORMAL PERFORMANCE CATEGORY II



Mandatory operation:

- Continuance of active current and reactive current exchange

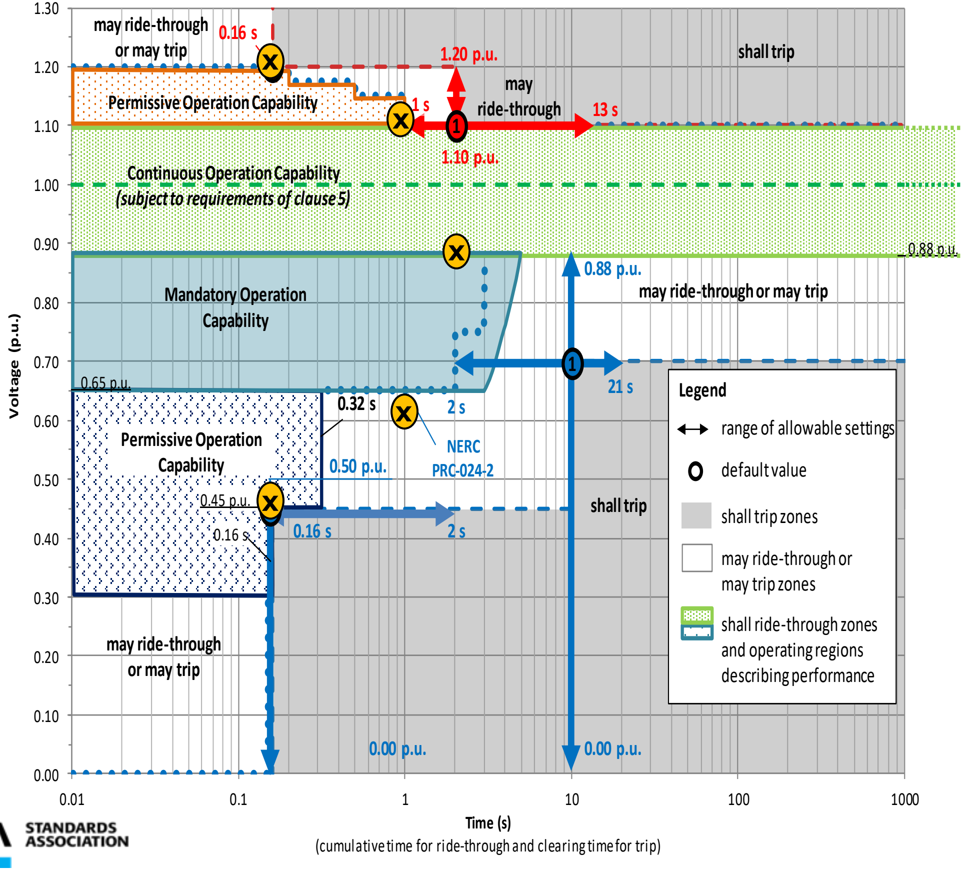
Momentary cessation:

- Temporarily cease to energize the utility's distribution system
- Capability of immediately restoring output of operation

Permissive operation:

- Either mandatory operation or momentary cessation.

ABNORMAL PERFORMANCE CATEGORY II: IEEE 1547a-2014 default settings

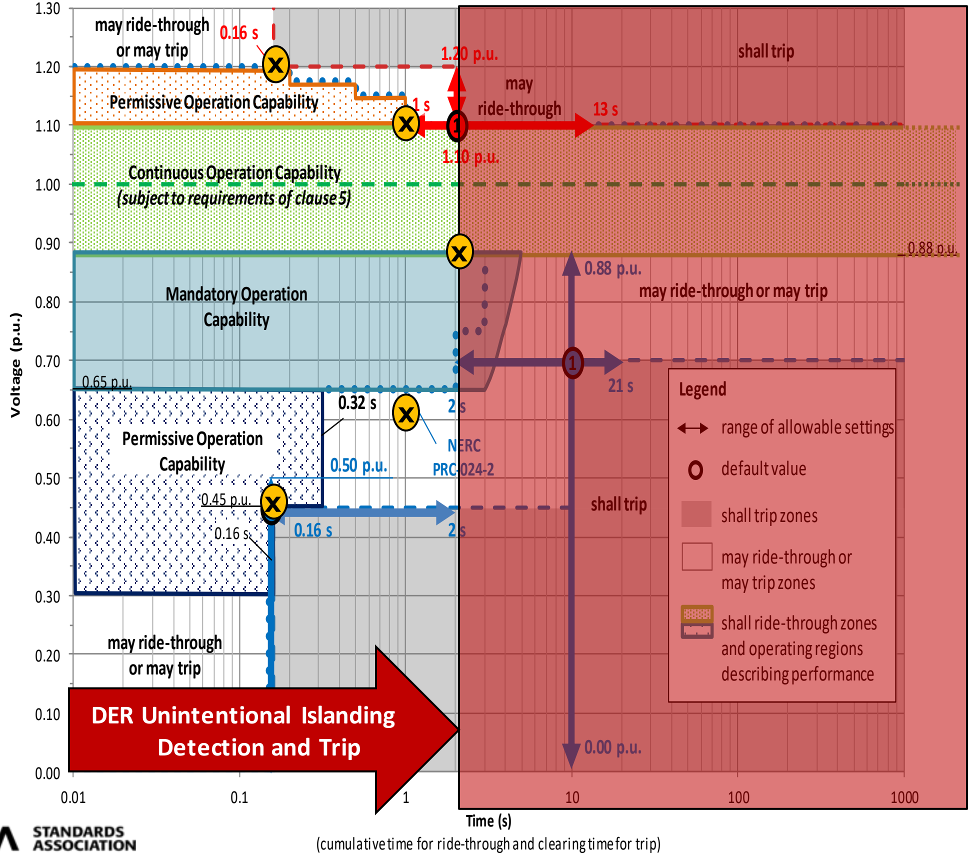


IEEE 1547a-2014 default settings.

- **Mandatory operation:**
  - Continuance of active current and reactive current exchange
- **Momentary cessation:**
  - Temporarily cease to energize the utility's distribution system
  - Capability of immediately restoring output of operation
- **Permissive operation:**
  - Either mandatory operation or momentary cessation.

APPLICATION OF IEEE STD 1547-2018

ABNORMAL PERFORMANCE CATEGORY II: IEEE 1547a-2014 default settings

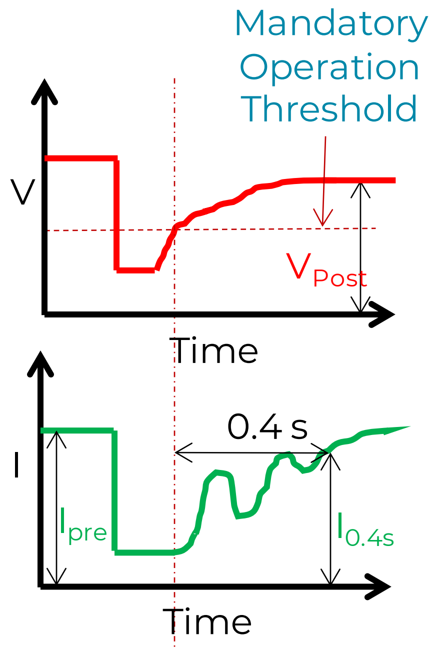


IEEE 1547a-2014 default settings.

- **Mandatory operation:**
  - Continuance of active current and reactive current exchange
- **Momentary cessation:**
  - Temporarily cease to energize the utility's distribution system
  - Capability of immediately restoring output of operation
- **Permissive operation:**
  - Either mandatory operation or momentary cessation.

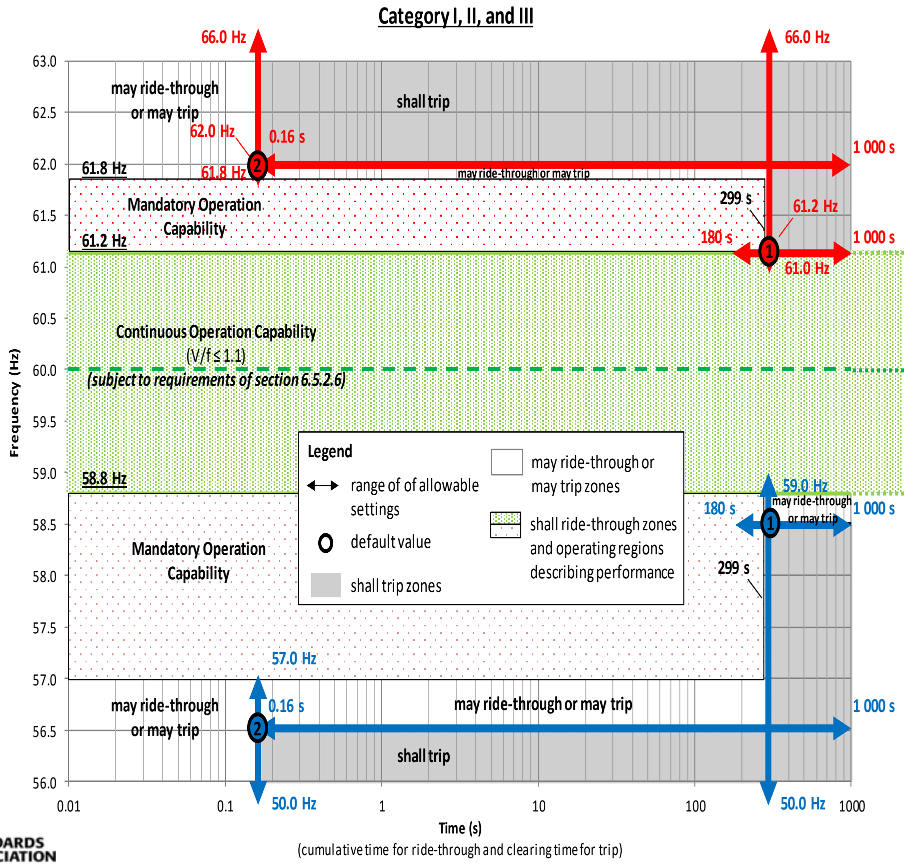
RESTORE OUTPUT AFTER RIDE-THROUGH PERFORMANCE

- DER must *restore output* to 80% of pre-disturbance active current within 0.4 s
- Time begins when applicable voltage returns to mandatory operation or continuous operation ranges
- Oscillatory power output is acceptable if positively damped (accommodates rotor angle swings of synchronous generators and imperfect control of inverters)
- If DER provides dynamic reactive power support (not mandatory), dynamic support must continue for 5 seconds before returning to pre-disturbance reactive control mode.



$I_{0.4s} \geq 0.8 \times I_{pre}$

IEEE STD 1547-2018: FREQUENCY RIDE-THROUGH AND TRIP



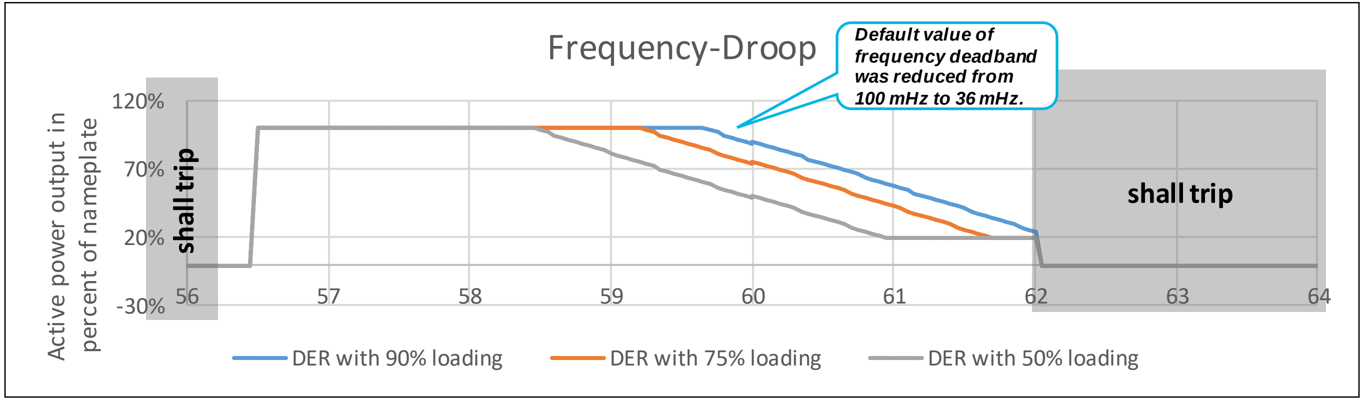
Continuous operation:

- Exchange of current between the DER and EPS within prescribed behavior while connected to the Area EPS and
- while the applicable voltage and the system frequency are within specified parameters

Mandatory operation:

- Continuance of active current and reactive current exchange

FREQUENCY SUPPORT



- **Overfrequency: all DER required to provide droop response**
- **Underfrequency: Cat II and III DER required to provide droop response <u>if power is available</u>**
- **Only a functional capability requirement**
  - Utilization remains outside the scope of IEEE Std 1547-2018.
- **Adjustable dead bands and droop**
- **Response time requirements (not “as fast as technically possible”)**

DOES RIDE-THROUGH COMPROMISE ISLAND DETECTION?

- **Sensitive undervoltage trip does help avoid an island being energized by DER, in most cases.**
- **However, most detectable distribution faults reduce voltage on a substantial portion of a feeder to < 0.5 p.u. on at least one phase.**
  - At least some DER will trip or momentarily cease in most cases.
  - Tripping upsets generation-load balance required for island to sustain.
- **DER are required by IEEE Std 1547-2018 to detect island in less than two seconds even with perfect generation-load balance and for any voltage or frequency trip setting within allowable range.**
- **Duration of island (within 2 second limit) may be slightly lengthened.**
  - Only an issue if anti-islanding is used to coordinate with feeder reclosing.
- **In general, there is virtually no material increase of islanding risk due to ride-through requirements specified in IEEE Std 1547-2018.**

- **NREL report on multi-inverter anti-islanding with ride-through and other grid support functions:** NREL/TP--5D00-66732

FURTHER READING

NERC (2017): Distributed Energy Resources. Connection, Modeling, and Reliability Considerations. North American Electric Reliability Corporation (NERC). [Online]

Boemer, J.C., et al. (2017): Status of Revision of IEEE Std 1547 and 1547.1. In 2017 IEEE PES General Meeting. Chicago, IL, 16-20 July. IEEE Power & Energy Society.

Boemer, J.C., et al. (2016): Status of Revision of IEEE Std 1547 and 1547.1. Informal report based on IEEE P1547/Draft 5.0 (August 2016). In 6th International Workshop on Integration of Solar Power into Power Systems. Vienna, Austria, November 14-15. [Online]

van Ruitenbeek, E., et al. (2014): A Proposal for New Requirements for the Fault Behaviour of Distributed Generation Connected to Low Voltage Networks. In: 4th International Workshop on Integration of Solar Power into Power Systems. Berlin, Germany, November 10-11. [Online]

Hoke, A., et al. (2016): Experimental Evaluation of PV Inverter Anti-Islanding with Grid Support Functions in Multi-Inverter Island Scenarios, National Renewable Energy Laboratory, NREL/TP-5D00-66732. [Online]

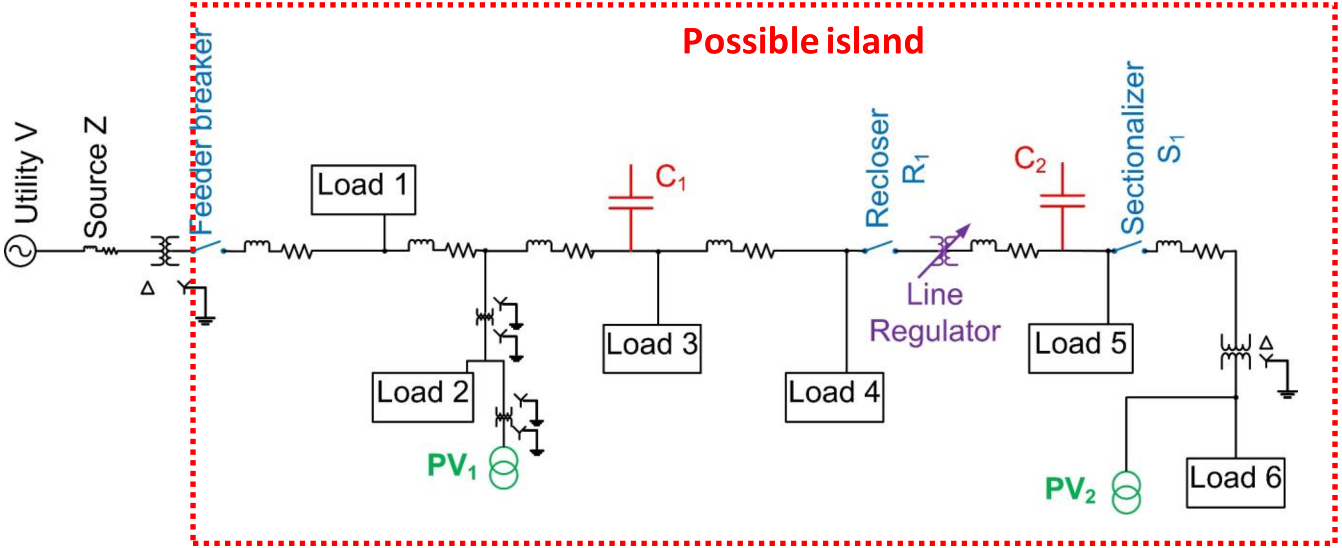
IEEE STD 1547-2018

CLAUSE 8: ISLANDING

CONTENTS

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".



ISLAND TERMINOLOGY

- **Intentional island: one that is planned, has a defined boundary, and has V/f regulation controls. Types:**
  - Microgrid
  - Emergency/standby power supply
  - Island power system (as in, on an actual island)
  - Remote community grid
  - Military bases
  - Remote resource extraction operations
- **Unintentional island: one that isn’t planned and doesn’t have V/f regulation control.**

HOW CAN AN UNINTENTIONAL ISLAND FORM?

- **Two key things have to happen at once.**
  - You have to have a close source-sink balance in the island in both real and reactive power.
  - You have to have a breaker, recloser, etc., open, without a fault in the island. (If there is a fault, there's almost no way to get a source-sink balance in the island.)
- **The likelihood of either one of these events is low; the likelihood of both happening in sequence is *very* low. So, an unintentional island is a very low-likelihood event.**

RISKS

- **Unintentional islands pose the following risks:**
  - Damage to equipment via asynchronous reclosure
  - Impediment to service restoration
  - Damage to equipment via uncontrolled voltage and frequency
  - Potential risk to human health and safety—people may be unaware that a line is energized from the customer side (line worker performing maintenance, “downed wire on a car” scenario)

STARTING POINT: WHAT IEEE STD 1547-2003 SAID

- **On the subject of unintentional islanding:**
  - 4.1.5 (Inadvertent energization): the DR shall not energize the Area EPS when the Area EPS is de-energized.
  - 4.4.1 (Unintentional islanding): it's the responsibility of the DR to detect an unintentional island and trip offline within 2 s.
  - 4.2.2 (Area EPS reclosing coordination): the DR shall cease to energize the Area EPS prior to reclosure by the Area EPS, even if that reclosure is in less than 2 s.
- **On the subject of intentional islanding:**
  - 4.4.2 (Intentional islanding): punted to a future revision.

4.4.2 Intentional islanding

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

MAJOR CHANGES IN IEEE STD 1547-2018

Unintentional islanding

- **Now subclause 8.1.**
- **The main change: There is a new, optional 5 s clearing time limit that can be used upon mutual agreement between the DER operator and the Area EPS operator.**
  - Allows the use of novel islanding detection that may work better in high-pen cases but may need a bit more time to achieve sensitivity *and* selectivity.
- **The default clearing time is still 2 s as it was in IEEE Std 1547-2003; therefore, the default case is no change from the previous version.**
- **There is new *emphasis* placed on the recloser coordination clause, but not a new *requirement*.**

NEW HIGH-PEN CHALLENGES

- **Mixtures of different inverters—will they interact in such a way that degrades islanding detection?**
  <u>(Initial indications: yes, they can.)</u>

- **Ride-throughs—will requiring LVRT and L/HFRT degrade islanding detection?**
  <u>(Initial indications: yes, a little bit, but not much.)</u>

- **Mixtures of inverters and rotating machines—do these mess each other up?**
  <u>(Initial indications: definitely yes.)</u>

ISLANDING DETECTION METHODS

- **Passive inverter-resident**
- **Active inverter-resident**
- **Non-inverter-resident**
  - Communication-based
    - DTT
    - Synchrophasors
    - PLCP
  - System configuration changes
    - Capacitor toggling
    - Shorting switches

INTENTIONAL ISLANDS: WHAT'S IN SCOPE?

An intentional island that contains any part of the Area EPS is in scope.

Intentional island behavior at the PCC, and impacts on the Area EPS, are in scope.

What happens "behind the meter" within a microgrid that does *not* include any Area EPS elements is out of scope.

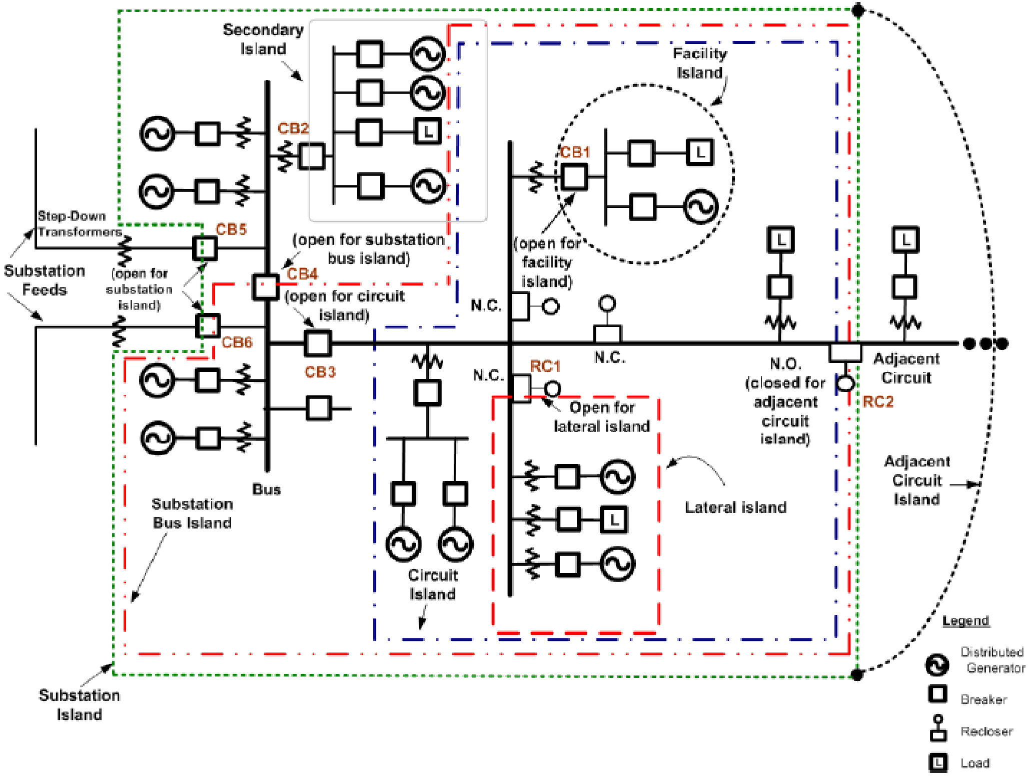


Figure C-1—Examples of DR island systems from IEEE Std 1547.4-2011

IEEE STD 1547-2018 AND INTENTIONAL ISLANDS

- **In this presentation, Intentional Island = II**
- **Two types of transitions into II mode (on-grid to off-grid): scheduled and unscheduled.**
  - Scheduled: initiated by manual action or dispatch.
  - Unscheduled: automatically initiated due to abnormal Area EPS conditions.
- **Power systems designated by the AHJ as Emergency, Legally Required, or Critical Operations are exempted.**

WHEN CAN AN II 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.

LIMITS ON AREA EPS IMPACT WHEN LEAVING THE AREA EPS

- **If an II 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 II "takes its load with it"—i.e., when the II leaves the grid, it causes an amount of load equal to 90% to 110% of its rating to leave the grid also;
  - The II is an emergency or standby generator that is on grid for testing purposes only.

LIMITS ON AN II COMING BACK ONTO THE AREA EPS

- An II can reconnect when the “return-to-service” requirements of subclause 4.10 are met (basically, the voltage and frequency are within defined limits).
- When the II reconnects, the requirements of subclause 4.10.4 (“synchronization”, which defines how well synched to the grid the II must be in both voltage and frequency).

DER CATEGORIES FOR II USE

- **The standard defines four categories of DER for II use:**
  - Uncategorized: not designed for off-grid operation at all. These are not allowed to energize an II.
  - II Capable: can disable anti-islanding and meet all the settings adjustments requirements on the previous slide.
  - Black Start Capable: can energize an EPS that contains no other energy sources.
  - Isochronous Capable: is Black Start Capable *and* can regulate V and f in an EPS that does contain other sources.

IEEE STD 1547-2018

CLAUSE 10: INTEROPERABILITY, INFORMATION EXCHANGE, INFORMATION MODELS, AND PROTOCOLS

INTEROPERABILITY REQUIREMENTS

- Communication requirements
- Identified functions to communicate
- Scope of interoperability
- Protocols

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.

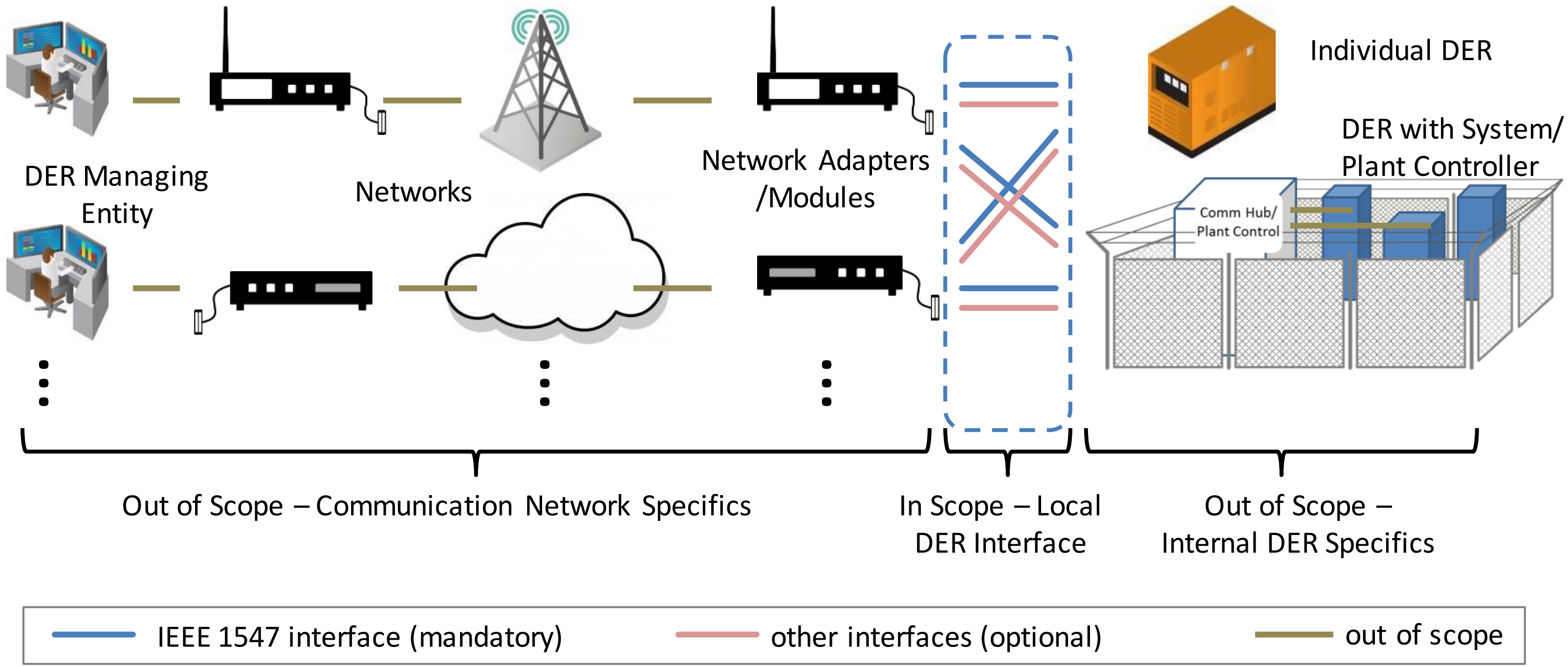
INFORMATION CATEGORIES

- **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.

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

SCOPE OF INTEROPERABILITY REQUIREMENTS



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

LOGICAL COMBINATIONS OF PROTOCOLS

Application	DNP3	IEEE 2030.5	SunSpec Modbus
Transport	TCP	TCP	N/A
IP Layer	IP	IPV6	
Network Access	Ethernet	Ethernet	RS-485
	Twisted Pair/RJ-45	Twisted Pair/RJ-45	Twisted Pair/RJ-45/CTA-2045

Allowing for a couple of well-defined options gives vendors more flexibility and is still achievable for aggregators/integrators.

COMMUNICATION PERFORMANCE REQUIREMENTS

Parameter	Requirement	Description
Availability of communication	When DER is operational	The **local DER communication interface shall be active and responsive whenever the DER is operating** and in a continuous operation region or mandatory operation region.
Information read response time	≤ 30 s	The maximum amount of time to respond to read requests.