

An In-Depth Review of the IEEE P1547 (Revision) Draft Standard

Session 1: Context and Overview

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IEEE Smart Grid Tutorial

January 18, 2018

NREL/PR-5D00-70773



Disclaimer

This presentation and discussion on IEEE 1547 are views of the individuals and are not the formal position, explanation, or position of the IEEE.

IEEE Std. 1547 Tutorial Outline

An In-Depth Look at the Draft Revised 1547 Standard

Four 1-Hour Sessions

- **Session 1—Thursday, January 18, 3:30 p.m. ET**
 - Summary of IEEE 1547
- **Session 2—Tuesday, January 23, 3:30 p.m. ET**
 - In-Depth Overview of IEEE 1547 Requirements – Part 1
- **Session 3—Friday, January 26, 3:30 p.m. ET**
 - In-Depth Overview of IEEE 1547 Requirements – Part 2
- **Session 4—Tuesday, January 30, 3:30 p.m. ET**
 - Overview of the important concepts and requirements for verification and testing of DER interconnected to the grid.

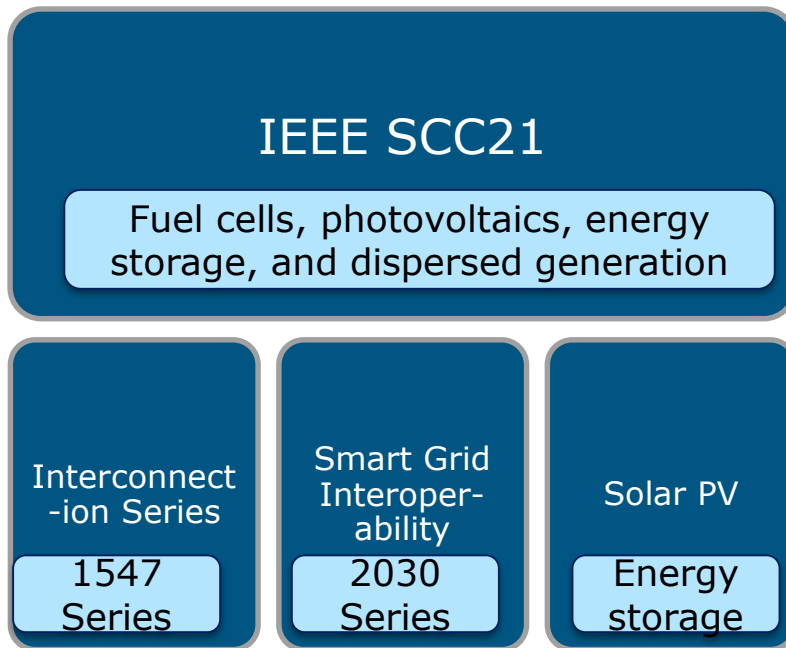
IEEE Std. 1547 Tutorial Agenda

Session 1: Context and Overview

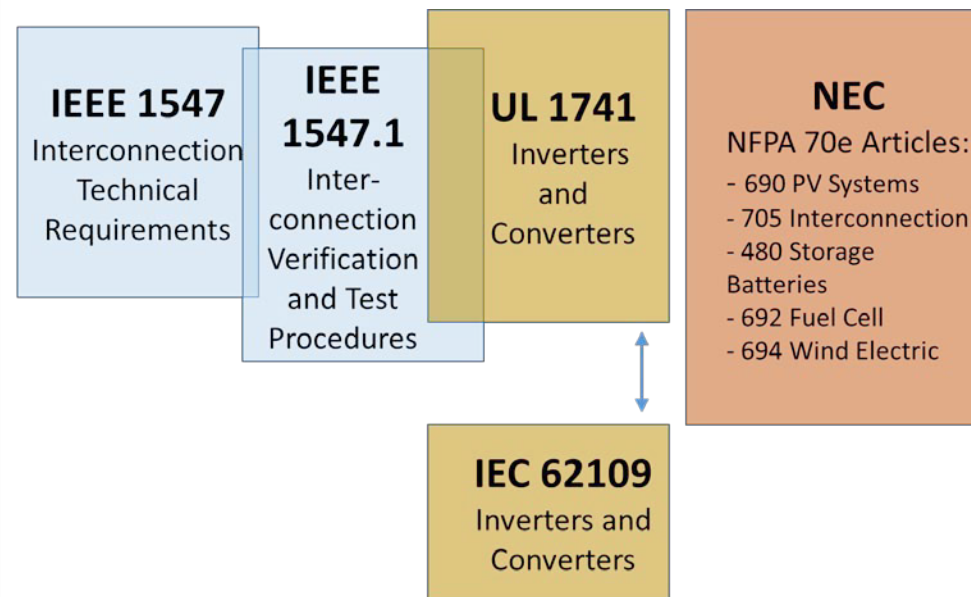
- **Summary look at the draft revised IEEE 1547 standard**
 - Related standards development
 - IEEE P1547 summary of changes
 - Technical requirements
 - Test and verification requirements.
 - IEEE P1547 status/timeline.

Standards Development:

Distributed Energy Resources

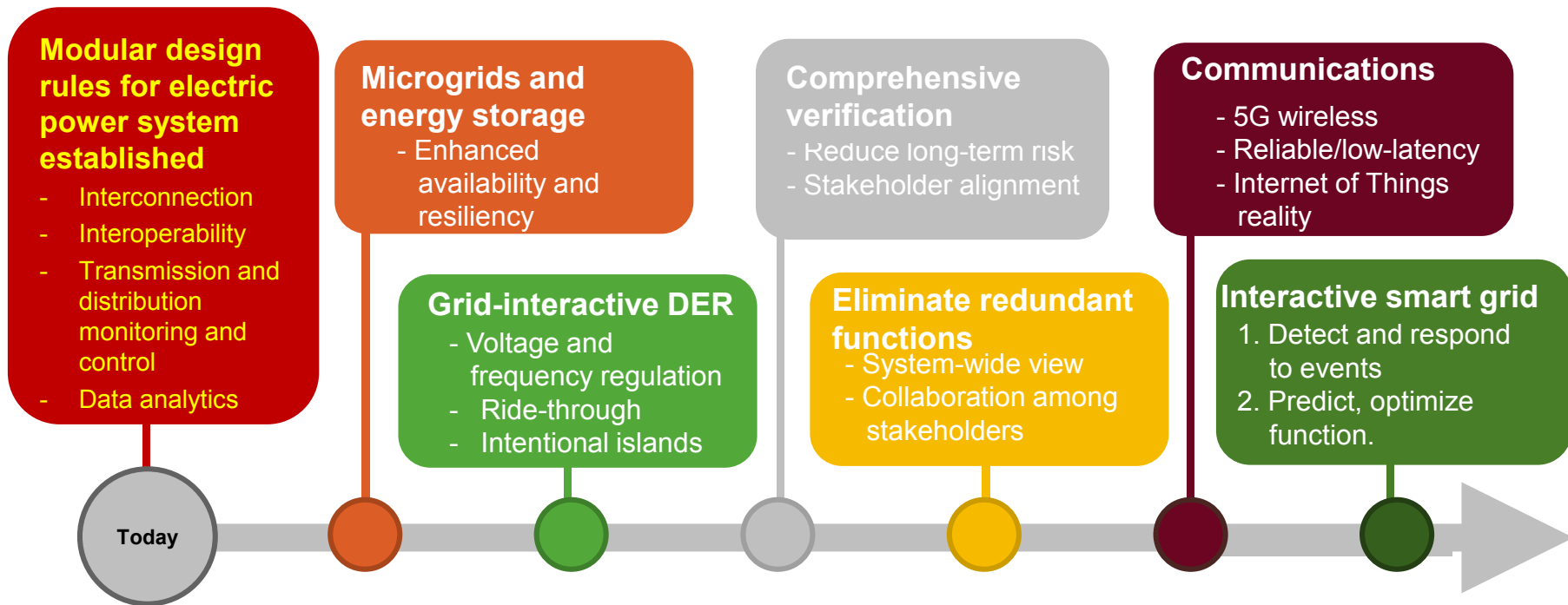


Standards Development Flow



Standards Development

Disruptive Innovation



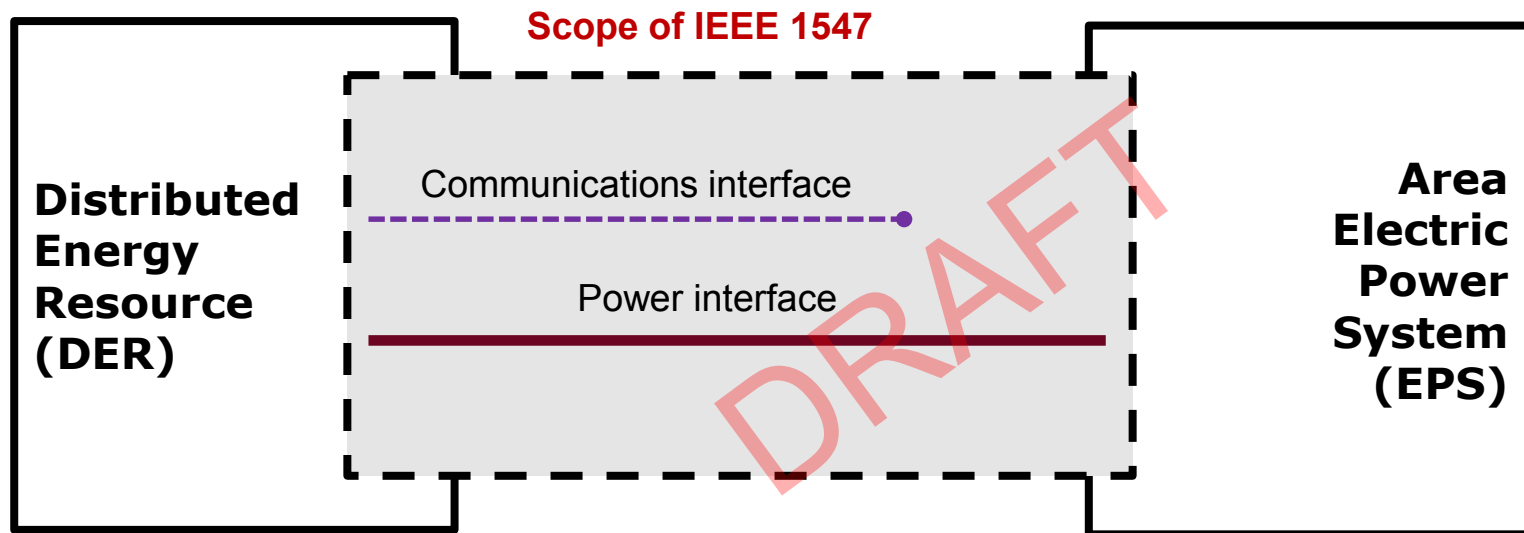
IEEE 1547: Interconnection Is the Focus

Key
Concept

IEEE 1547 covers:

- Interconnection technical specifications and requirements
- Interconnection test specifications and requirements.

Interconnection System



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

Interoperability: The capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively.

IEEE 1547 Interconnection Standards Example Use in United States

IEEE 1547

Interconnection System and Test Requirements

- Voltage Regulation
- Ride-through
- Grounding
- Disconnects
- Interoperability
- Islanding
- Etc.

IEEE 1547.1

Conformance Test Procedures

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

UL 1741*

Interconnection Equipment Safety and Performance Certification

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

NFPA70 (NEC)

- Article 690 PV Systems
- Article 705: interconnection systems (shall be suitable per intended use per UL1741)

Other articles:

- 480 Storage Batteries
- 692 Fuel Cell Systems
- 694 Wind Electric

(NEC info. Based on NEC 2011)

Local interconnection processes and standards

IEEE 1547 Uses

IEEE 1547 is:

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

**IEEE 1547 is
not:**

- A design handbook
- An application guide
- An interconnection agreement
- Prescriptive—i.e., it does not address demand-response self-protection or planning, designing, operating, or maintaining the area EPS

Timeline of P1547 Formation

- March 2014: P1547 Program Authorization Request (PAR) approved
- November 2014: Working group meeting, coalesce filtered subset of topics into six subgroups for action
- February 2017: Working group meeting, draft revision content stable, vote, and final refinements before balloting
- May–Dec 2017: IEEE-SA public balloting

More than **120 industry experts** in the working group have been meeting via phone weekly for more than a year to develop consensus language, and the working group has had 10 in-person meetings. Through their dedicated efforts, the balloting stage is complete.

Organization of IEEE P1547 Working Group

Scope	Subgroup Lead (Vice Chair)	Alternate Lead(s)	Facilitator(s)
Overall document, Annexes	D. Narang, NREL Chair Tom Basso Previous Chair	J. Boemer, EPRI Vice Chair	C. Vartanian, Mitsubishi Secretary
Voltage regulation	B. Enayati, National Grid Vice Chair	J. Berdner, Enphase	A. Huque, EPRI
Response to abnormal grid conditions	J. Berdner, Enphase Vice Chair	B. Enayati, National Grid	J. Boemer, EPRI R. Walling, WES
Interoperability and communications	B. Fox, SUNSPEC Vice Chair	B. Seal, EPRI	F. Cleveland W. Stec (Distregen)
Special interconnections, islanding, intentional islanding, storage, etc.	C. Vartanian, MEPPI Secretary	M. Ropp, NPPT L. Casey, Google	M. Coddington, NREL D. Mungovan, ConEd R. Bravo, SCE
Interconnection/interoperability test specifications and requirements, modeling and simulation	M. Siira, Comrent Vice Chair	W. Stec (Distregen)	W. Stec M. Ropp, NPPT J. Piekarz, NG
Power quality, area EPS microgrids	B. Enayati, National Grid	M. Page, Southern Co.	Mike Ropp, Chris Rowe (formerly Enphase)

IEEE P1547 Scope and Purpose

PAR Approved by IEEE-SA Standards Board on March 27, 2014

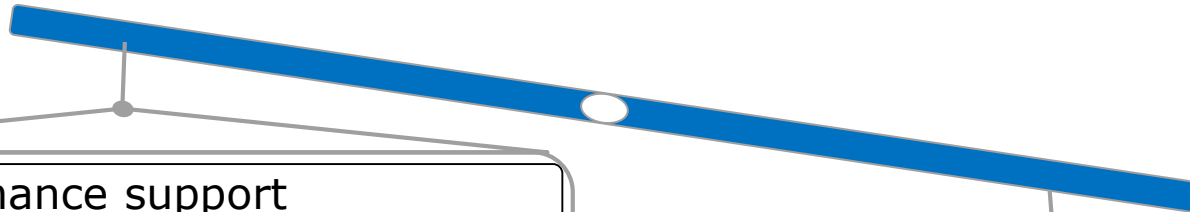
Title: Draft Standard for Interconnection **and Interoperability of Distributed Energy** Resources with **Associated** Electric Power Systems **Interfaces**

Scope: This standard establishes criteria and requirements for the interconnection of DERs with EPS and associated interfaces.

Purpose: This document provides a uniform standard for the interconnection and interoperability of DERs with EPS. It provides requirements relevant to the interconnection and interoperability performance, operation, testing, safety, maintenance, and security considerations.

Grid Planning and Operation Challenges

Increasing DER Penetration Was a Major Driver for Revising IEEE 1547.

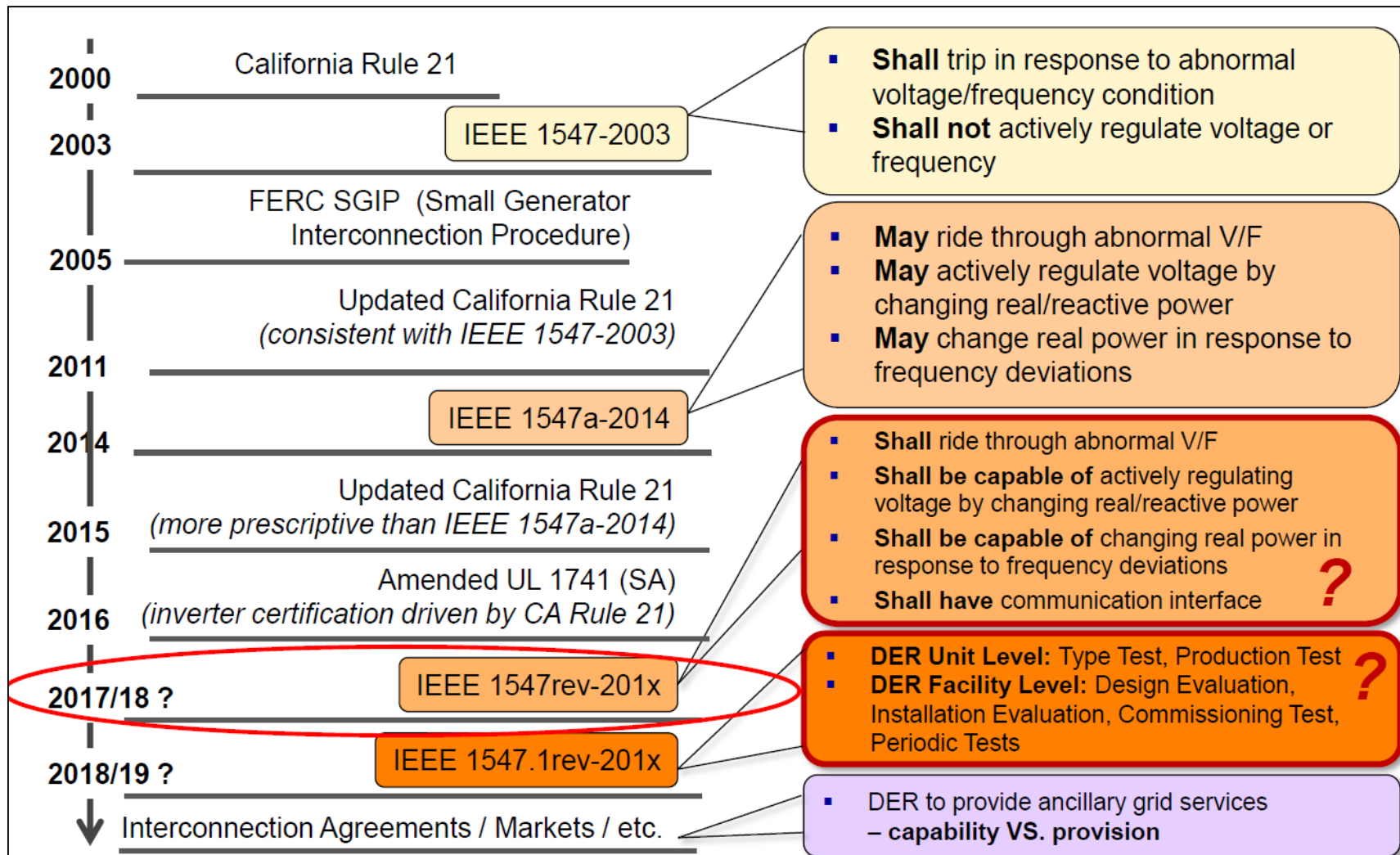


- Grid performance support
- Ride-through, stabilizing frequency response, voltage support

- Safety and reliability: Do no harm.
- Anti-islanding, no interference with primary voltage regulation

Interconnection requirements for DERs should also adequately address transmission *and* distribution system needs. Coordination with national and regional bulk power system regulators as well as state authorities is needed.

IEEE 1547: Timeline of Major Changes

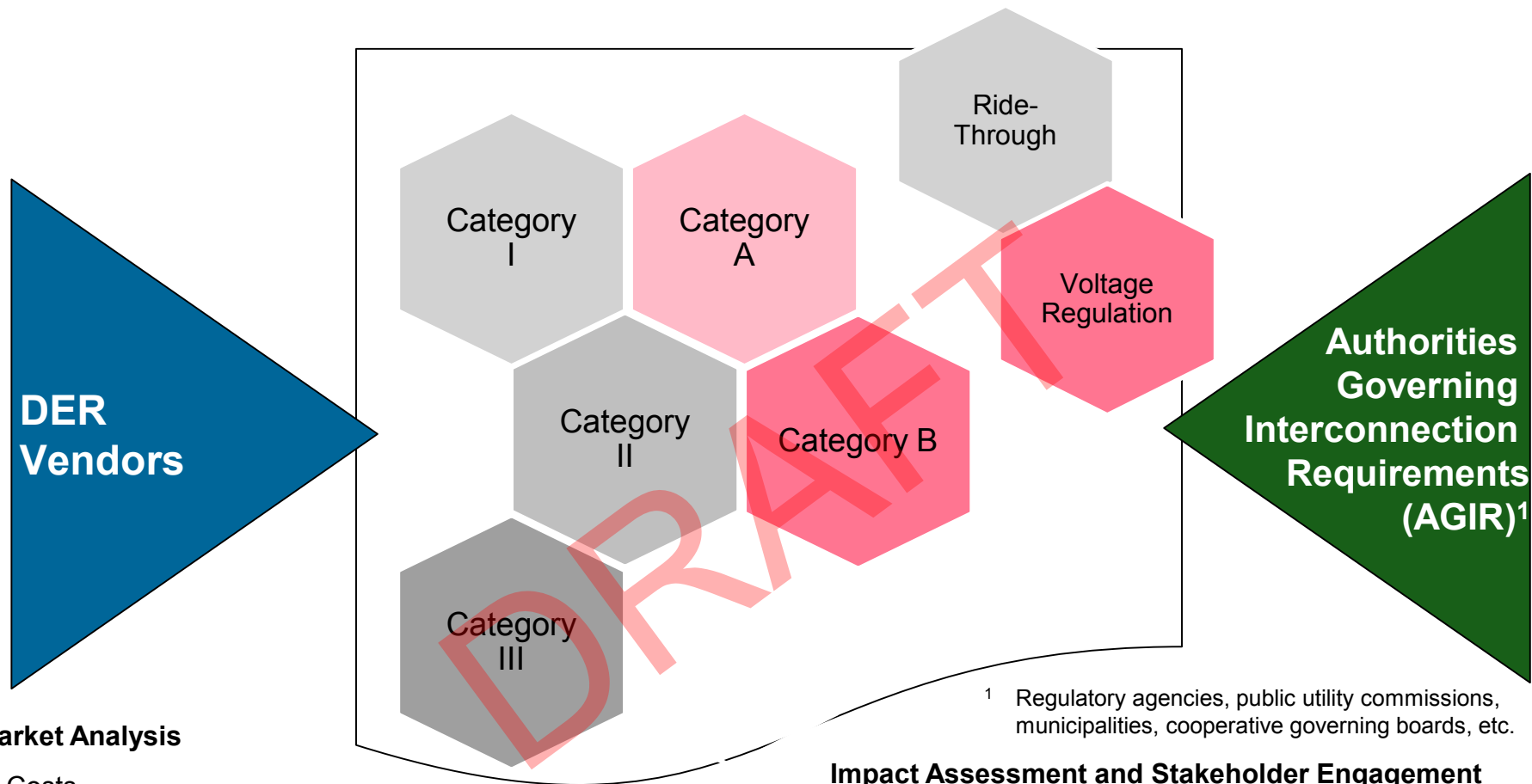


Graphics source: Electric Power Research Institute (EPRI)

Major 1547 Revision Achievements

- Performance categories established
- More coordinated operation under normal conditions
- Grid support under abnormal conditions
- New guidance for interoperability
- New guidance for intentional islands
- Testing requirements completely revised to address new capabilities
- Strikes a balance between needs for large and small installations.

Performance Category Approach



Market Analysis

- Costs
- Market segment, etc.

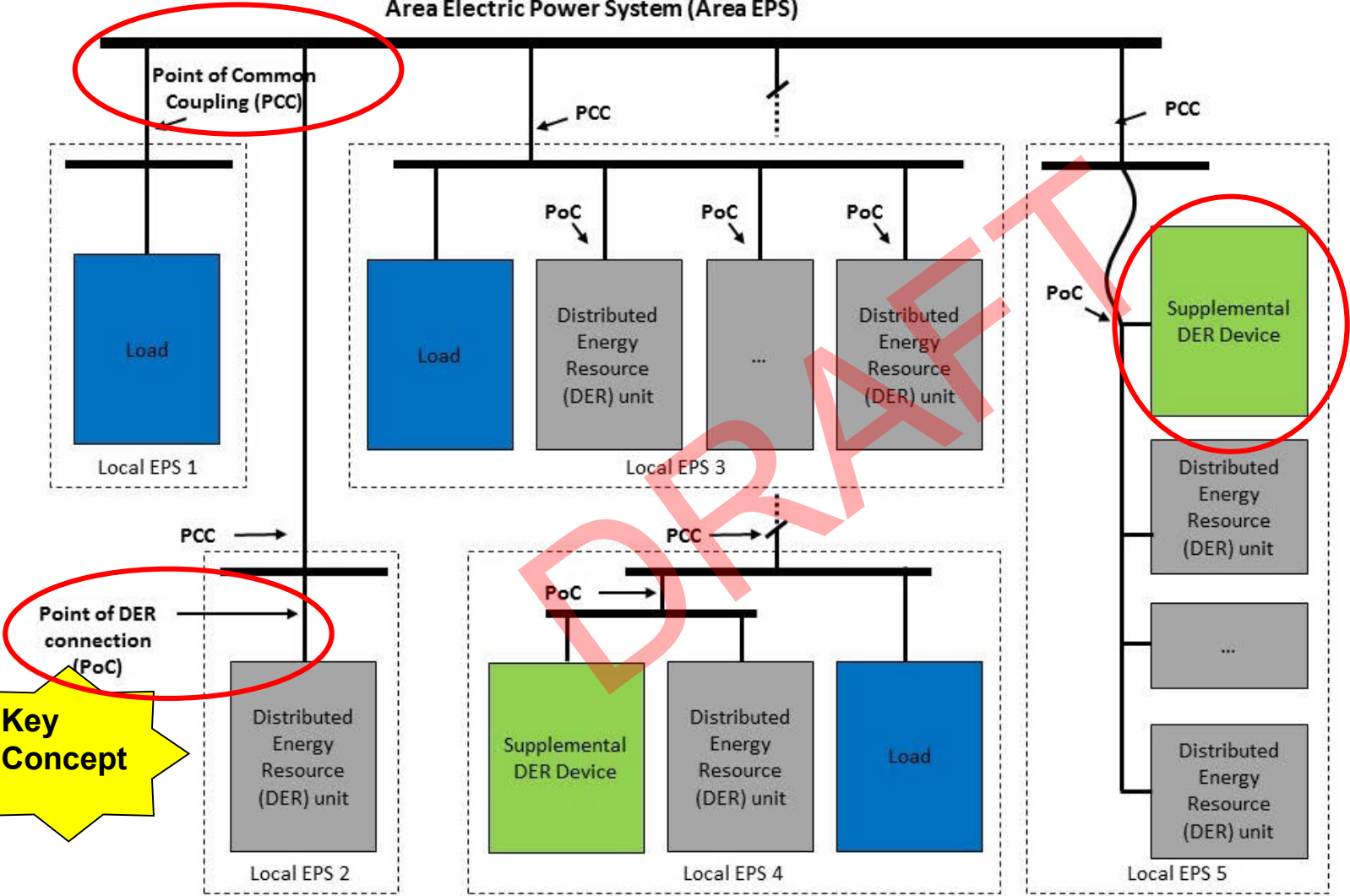
¹ Regulatory agencies, public utility commissions, municipalities, cooperative governing boards, etc.

Impact Assessment and Stakeholder Engagement

- Technical conditions: Type, capacity, and future penetrations of DERs, type of grid configuration, etc.
- Nontechnical issues: DER use case, impacts on environment, emissions, and sustainability, etc.

Points of Applicability

Area Electric Power System (Area EPS)



Voltage and reactive/active power control function requirements for DER normal operating performance categories.

DER Category	Cat A	Cat B
Voltage regulation by reactive power control		
Constant power factor mode	Mandatory	Mandatory
Voltage—reactive power mode ("voltage-var")	Mandatory	Mandatory
Active power—reactive power mode ("watt-var")	Not required	Mandatory
Constant reactive power mode ("reactive power priority")	Mandatory	Mandatory
Voltage and active power control		
Voltage—active power mode ("voltage-watt")	Not required	Mandatory

- The DER shall be capable of activating any of these modes individually.
- Adjustable constant power factor mode with unity power factor setting shall be the default mode of the installed DER unless otherwise specified by the area EPS operator.
- The area EPS operator shall specify the required voltage regulation control modes and the corresponding parameter settings. Modifications of the settings and mode selected by the EPS operator shall be implemented by the DER operator.

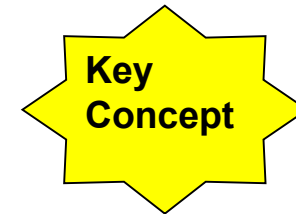
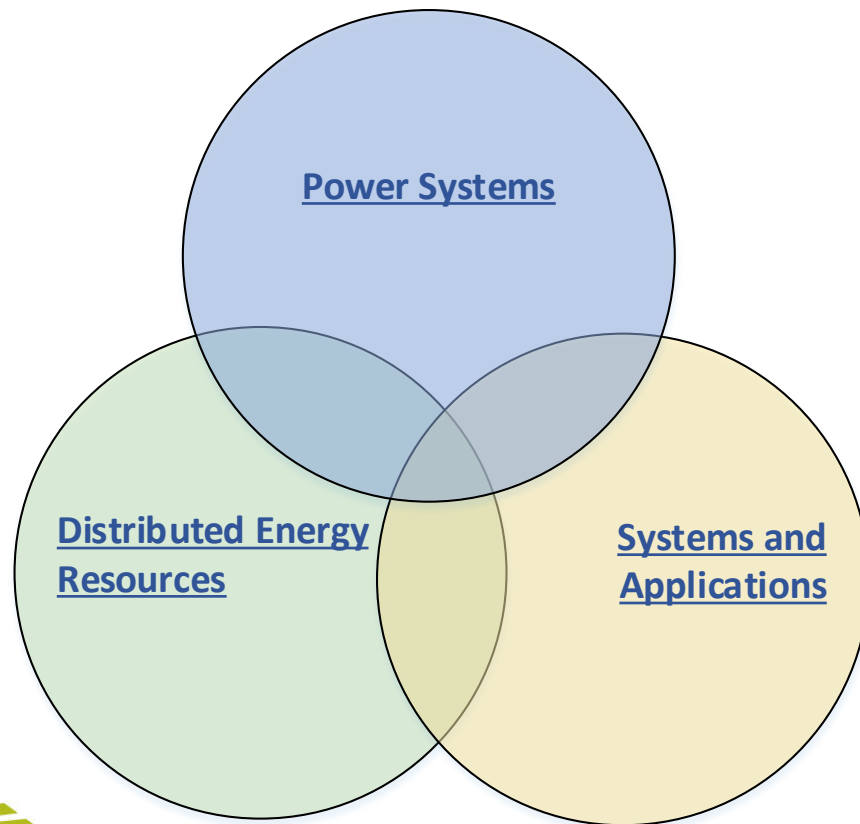
Voltage and Frequency Ride-Through

Foundations for Voltage and Frequency Ride-Through Requirements under Area EPS Abnormal Conditions

Requirement	Abnormal operating performance Category	Foundation/Harmonization	Considerations
Voltage ride-through	Category I	German grid code for medium-voltage-connected synchronous generator-based DERs	<ul style="list-style-type: none"> Essential bulk system needs Attainable by all state-of-the-art DER technologies.
	Category II	North American Electric Reliability Corporation (NERC) PRC-024-2 but without stability exception, extended low-voltage ride-through duration for 65%–88% V_{nom} <i>*Based on EPRI white paper (May 2015).</i>	<ul style="list-style-type: none"> All bulk system stability/reliability needs Coordinated with existing reliability standards to avoid tripping for a wider range of disturbances Considering fault-induced delayed voltage recovery.
	Category III	California Rule 21 and Hawaii, minor modifications	<ul style="list-style-type: none"> All bulk system needs Distribution system reliability/power quality needs Considering fault-induced delayed voltage recovery Coordinated with existing requirements for very high DER levels
Frequency ride-through	All categories (harmonized)	California Rule 21 and Hawaii, exceeds PRC-024-2 <i>*Based on EPRI white paper (May 2015).</i>	<ul style="list-style-type: none"> All bulk system needs Low inertia grids.

Interoperability

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



Interoperability

■ **Mandatory communications capability**

- A DER shall have provisions for a local DER interface capable of communicating to support the information exchange requirements specified in this standard for all applicable functions that are supported in the DER.

■ **Information to be exchanged:**

- **Nameplate:** This information is indicative of the as-built characteristics of the DERs. This information may be read.
- **Configuration:** This information is indicative of the present capacity and ability of the DERs to perform functions. This information may be read or written.
- **Monitoring:** This information is indicative of the present operating conditions of the DERs. This information may be read.
- **Management:** This information is used to update the functional and mode settings for the DERs. This information may be read or written.

■ **Communication performance requirements:**

- Availability of communication, information read response times

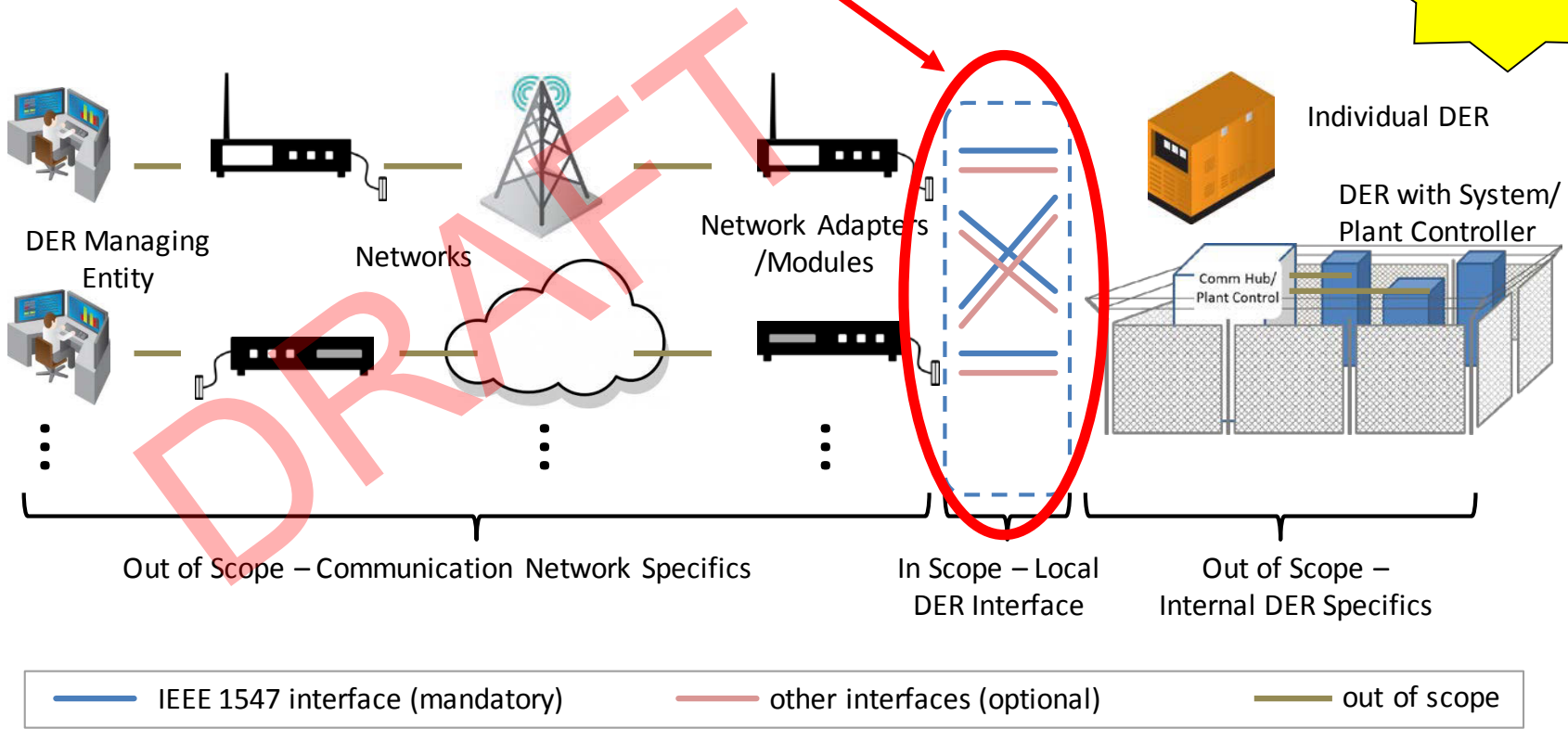
■ **Communication protocol requirements:**

- The DER shall support at least one of the protocols specified...(IEEE Std 2030.5, IEEE Std 1815, SunSpec Modbus)

Interoperability

Limited Scope of Interoperability Requirements

Key Concept



Islanding

Categories

- **Unintentional islanding**
 - Requirements also in clauses related to response to Area EPS abnormal conditions
 - Coordination with Area EPS automatic reclosing
 - Conditional extended clearing times
- **Intentional islanding:** An intentional island that includes any portion of the area EPS—an intentional area EPS island—while islanded shall be designed and operated in coordination with the area EPS operator.
 - **Scheduled:** Formed through DER operator or area EPS operator manual action or other operating dispatch means (e.g., EMS, automatic generation control) that triggers the transition from being in parallel and synchronized with the area EPS to operation as an islanded system.
 - **Unscheduled:** Unscheduled intentional islands are formed autonomously from local detection of abnormal conditions at the interface(s) with the area EPS and then automatic relay action that triggers switching to rapidly isolate the intentional island from the area EPS.
- Conditions for transition, voltage fluctuation limits, reconnection.

New Informative Annexes

Annex Contents

1. Guidelines for DER Performance Category assignment
2. DER intentional and microgrid island system configurations
3. DER communication and information concepts and guidelines
4. Basis for ride-through of consecutive voltage disturbances
5. Discussion of testing and verification requirements at PCC or PoC
6. Power Quality clause concepts and guidelines
7. Figures illustrating general interconnection technical specifications and performance requirements

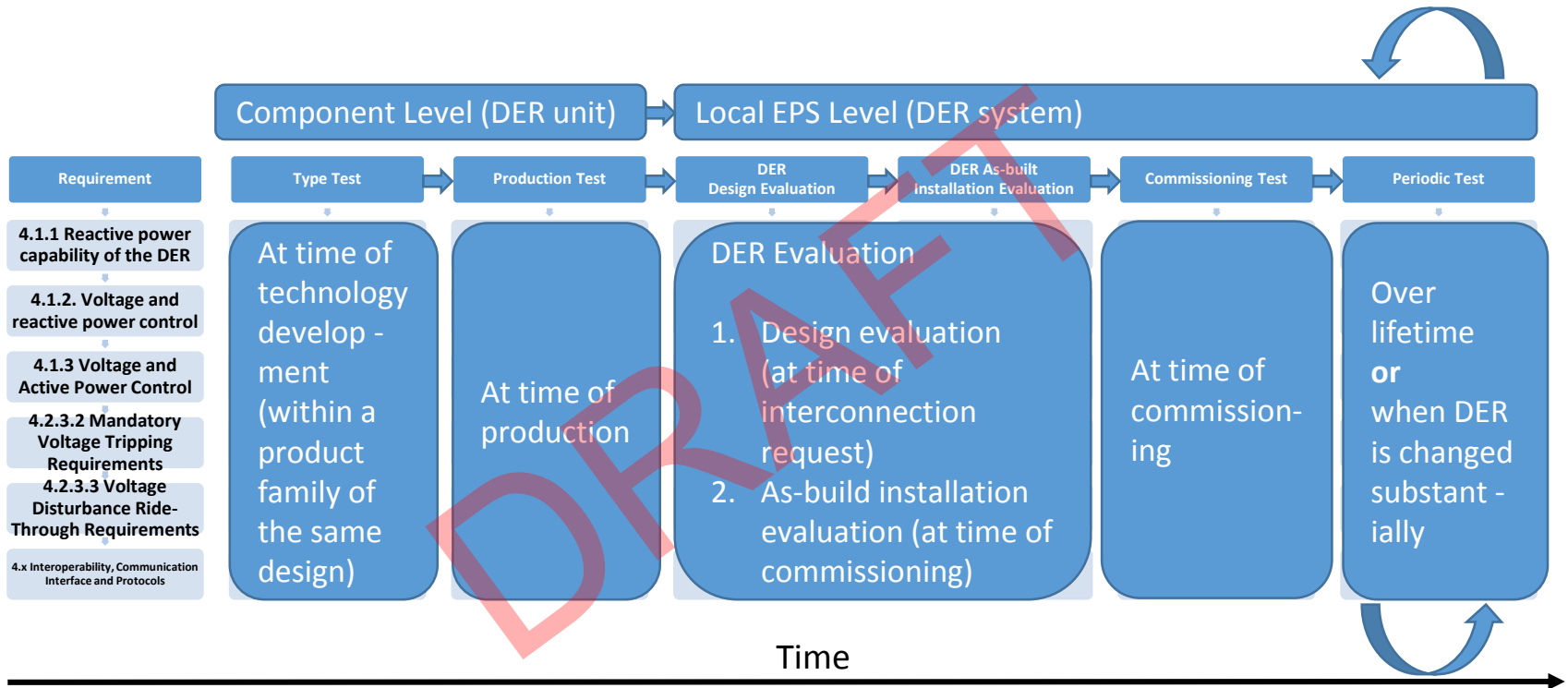
Test and Verification Requirements

Major Headings

- Type tests
- Production tests
- DER evaluation
 - DER design evaluation (desk study)
 - DER as-built installation evaluation (on-site)
 - Basic and detailed DER evaluation.
- Commissioning tests and verifications
 - Full and partial conformance testing and verification
 - Requirements met at PCC or PoC.

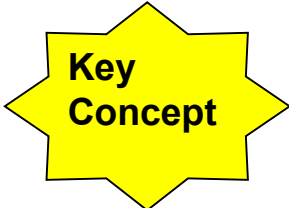
High-Level Test and Verification

Test and Verification Requirements Matrix



High-level test and verification

Requirements give guidance, yet are flexible enough to consider the large variety of actual DER setups in the field:



IEEE Std 1547™ Requirement XYZ		Applicability of Requirements	
		Point of DER Connection (PoC)	Point of Common Coupling (PCC)
DER Capability & Conformance	F ull (DER System)_ no Supplemental DER Device needed	Type Test + Basic Commissioning Test	Type Test + Basic DER Evaluation
	P artial (Composite) one or more Supplemental DER Device(s) needed	Type Test(s) + Detailed DER Evaluation + Detailed Commissioning Test	Type Test(s) + Detailed DER Evaluation + Detailed Commissioning Test

IEEE P1547 (REVISION) BALLOTING RESULTS

- IEEE P1547 has met IEEE Thresholds* for approval
 - 333 Votes (85% of ballot pool)
 - 93% Approval
- Resolved 1950 Comments
 - Initial ballot + four recirculations
 - Balloting extended from May – December, 2017

Thresholds:

Returned ballots: 75% | Approval rate: 75%

P1547 Revision Current Status

- Currently under review by IEEE SA Standards Board Review Committee – (RevCom)
 - RevCom makes recommendations on the approval or disapproval of standards submitted for IEEE SASB Standards Board approval or adoption.
 - Approval or adoption requires agreement from RevCom members that RevCom and IEEE SASB Standards Board procedural requirements have been satisfied.
- We expect RevCom results/recommendation on 1/24/18
 - Publication follows IEEE-SA Approval

IEEE STD 1547 TUTORIAL

Upcoming Sessions

Session 2 – Tuesday, January 23rd at 3:30PM ET

In-Depth Overview of IEEE 1547 Revision Requirements – Part 1

Review of Reference point of applicability, newly-introduced performance categories, New requirements for voltage and reactive power control, frequency control, response to abnormal conditions including ride-through; ranges of adjustability for control settings as well as for voltage and frequency trip settings

Session 3 – Friday, January 26th at 3:30PM ET

In-Depth Overview of IEEE 1547 Revision Requirements – Part 2

Basic criteria for the use of IEEE 1547, Applicability requirements and review of measurement accuracy requirements. A new cease to energize performance requirement and entering service criteria that are critical to meeting the new ride-through requirements, power quality requirements, islanding concepts, and Voltage regulation. New section that discusses interoperability requirements

Session 4 - Tuesday, January 30th at 3:30PM ET

Overview verification and testing Requirement

For More Information

General information:

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

Working Group meeting notes:

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

Sign up for the 1547 email listserv:

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

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