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IEEE 1547-2018
Adapting to the Distributed Energy Future –
Major Revisions of the
IEEE 1547 DER Interconnection Standard
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Disclaimer and Acknowledgment

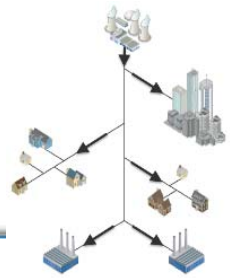
- *This presentation on IEEE 1547-2018 represents the author's views and are not the formal position, explanation or position of the IEEE or the IEEE Standards Association*

- *The presenter acknowledges the contribution of the IEEE 1547-2018 Working Group, Balloters and Officers*

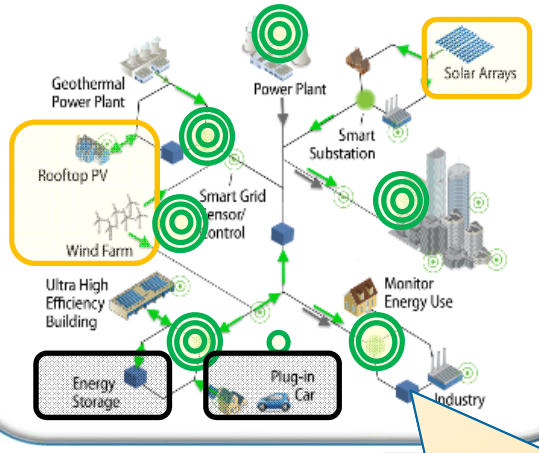
Evolution of the grid

- Large generation systems
- Central control
- Highly regulated

Current Power System



Future Power Systems



New Challenges

- New energy technologies and services
- Penetration of variable renewables in grid
- New communications and controls (e.g., Smart Grids)
- Electrification of transportation
- Integration of distributed energy storage
- Regulatory advances

DRIVERS

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

IEEE 1547-2018 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.*

Changes from IEEE 1547-2003 shown in red

Definition of Distributed Energy Resource

In the context of IEEE 1547:

"A source of electric power that is not directly connected to a bulk power system."

- Includes distributed generators.
- Includes distributed energy storage technologies.
- Does not include controllable loads used for demand response.

IEEE 1547 evolution of grid support functions

IEEE 1547-2003

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

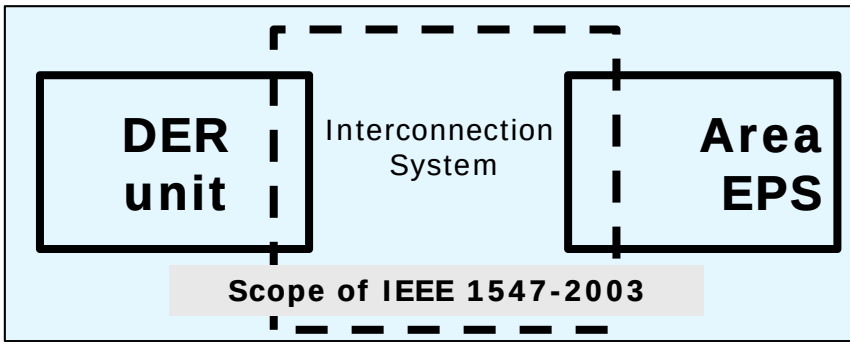
IEEE 1547a-2014 (Amendment 1)

- **May** actively regulate voltage
- **May** ride through abnormal voltage or frequency
- **May** provide frequency response

IEEE 1547-2018

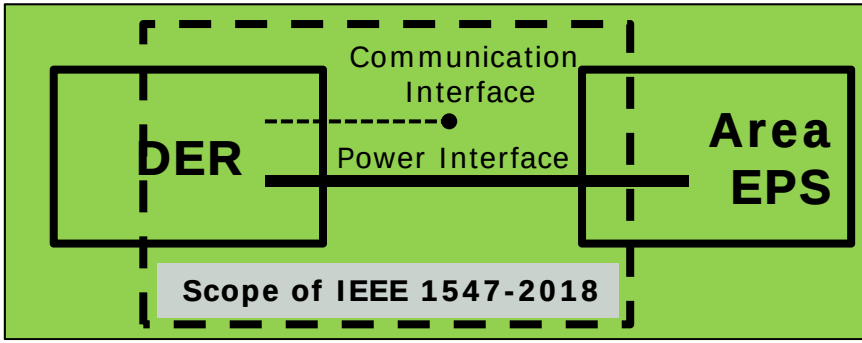
- **Shall be capable of** actively regulating voltage
- **Shall** ride through abnormal voltage/frequency
- **Shall be capable of** frequency response

Important changes in focus and coverage



IEEE Std 1547-2003

- Focused only on distribution system
- 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 P1547

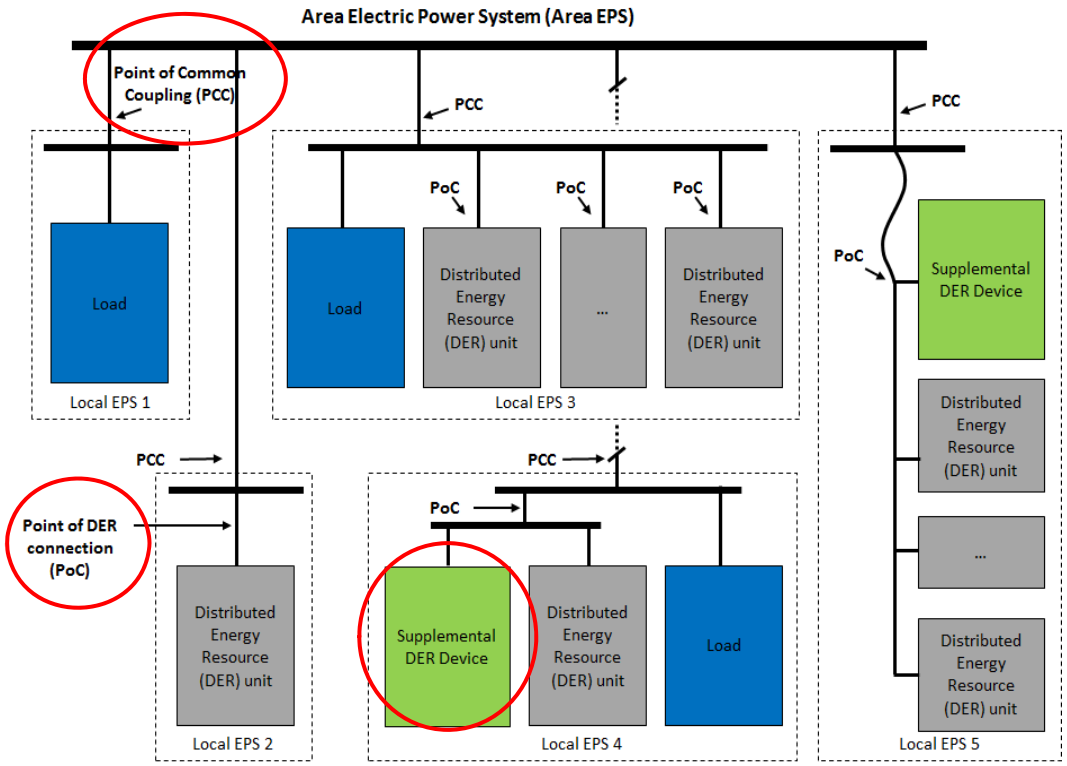
- Focused on distribution and bulk system
- Specifications encompass the whole DER
- Equipment listing as well as plant-level verification.
- Includes both electrical as well as interoperability/communications requirements.

IEEE 1547-2018 Document Outline (Clauses)

1. Introduction
2. Overview
3. Normative references, definitions and acronyms
4. **General specifications and requirements**
5. **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**

General Specifications & Requirements

Reference Point of Applicability



- **RPA is where performance requirements apply**
- IEEE 1547 specifies RPA depending on three criteria:
  - Aggregate DER rating
  - Average load demand
  - Zero sequence continuity
- Generally:
  - PoC (DER terminals) for small and load-immersed DER
  - PCC for large exporting installations

Definitions and Exemptions for standby DER

- A DER that is operated in parallel to the Area EPS:
  - For testing purposes only and tests are not performed more frequently than 30 times per year; or
  - During load transfer in a period of less than 300 seconds to or from the Area EPS

  shall be exempt from the following:

  a) Voltage disturbance ride-through requirements (6.4.2)
  b) Frequency disturbance ride-through requirements (6.5.2)
  c) Interoperability, information exchange, information models, and protocols (10)
  d) Intentional islanding requirements (8.2)

  and may cease to energize the Area EPS or may separate from the Area EPS without limitations.

Cease to Energize performance requirement

In the ***cease to energize*** state, the DER shall not deliver active power during steady-state or transient conditions.

- **Aggregate DER rating < 500 kVA:** *reactive power exchange shall be less than 10%* of nameplate DER rating and shall exclusively result from passive devices.

- **Aggregate DER rating ≥ 500 kVA:** the *reactive power exchange shall be less than 3%* of nameplate DER rating and shall exclusively result from passive devices..

Enter Service criteria

- Prior to *Enter Service* or *Return to Service* after a trip, applicable voltage must be within specified voltage magnitude and frequency range continuously for a defined period
- Also *Permit Service* logical must be set to *Enabled*
- Voltage, frequency, and delay period are all adjustable within a defined range
- The DER must be capable of ramping up its power either continuously or in small steps (<20%) after entering service.
  - Exception: Smaller DER installations (<500 kVA) can alternatively return to service in one step after a randomized additional delay

Operational control

DER must be capable of responding to remote commands:

- Change of *Permit Service* logical to disabled and shut down
- Limit active power output
- Change control modes and parameters
  - Voltage and reactive regulation functions
  - Trip settings

Interoperability capabilities allow Area EPS Operator a great level of DER control if communication infrastructure is implemented

Reactive power, voltage/power control

Categories of grid support – 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
- Reactive power capability: 0.25 p.u. lagging, 0.44 p.u. leading

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
- Reactive power capability: 0.25 p.u. lagging, 0.44 p.u. leading

Category assignment specified by Area EPS Operator

Active voltage regulation capability requirements

DER must possess capability – implementation is at the discretion of area EPS Operator (mode and parameters)

Capability required of all DER – (Cat A, B)

Constant power factor mode

Constant reactive power mode (“reactive power priority”)

Voltage-reactive power mode (“volt-var”)

“State-of the art” DER – Cat B

Active power-reactive power mode (“watt-var”)

Voltage-active power mode (“volt-watt”)

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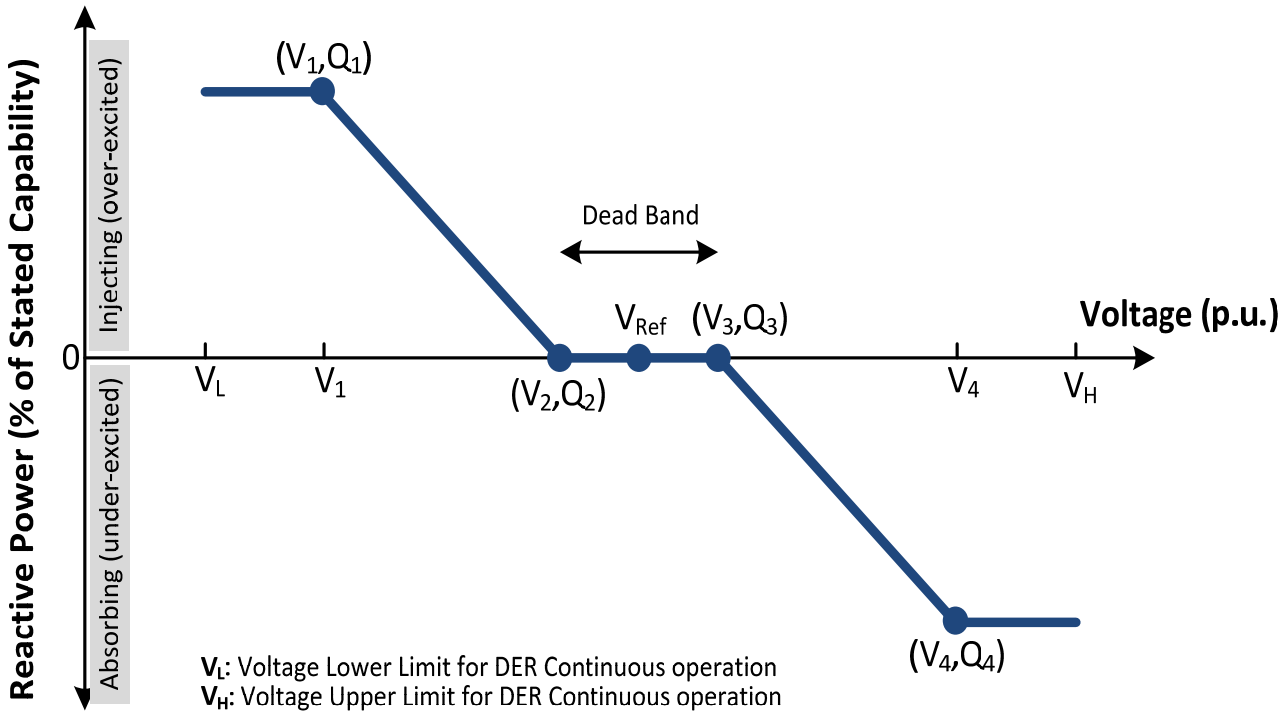
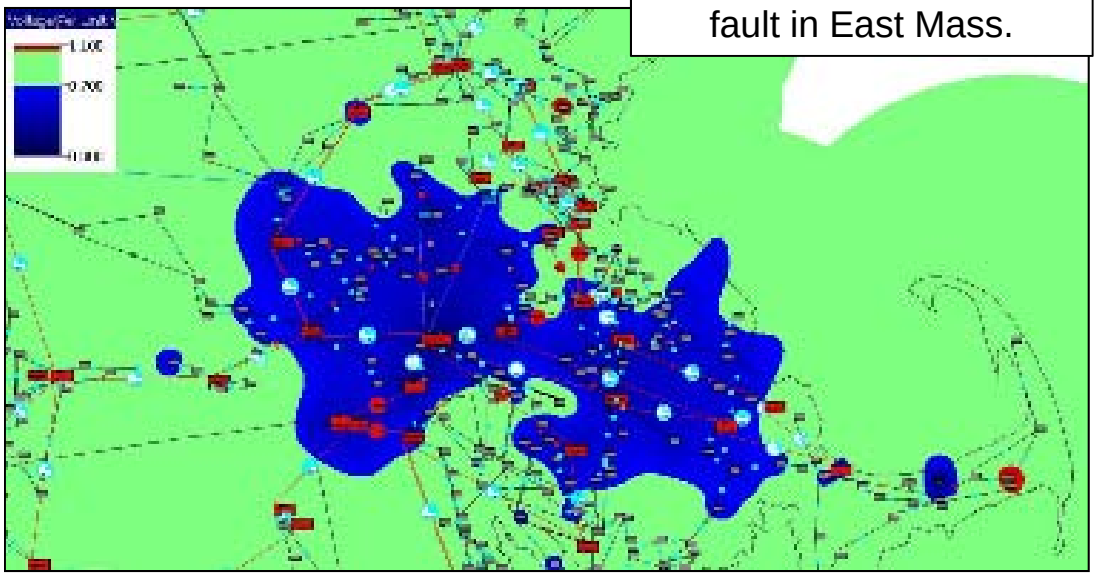
Voltage-Reactive Power mode



Response to abnormal conditions

Driver for new ride-through requirements



Voltage profile for 345 kV fault in East Mass.

Source: ISO-New England

IEEE 1547-2018 mandates BOTH:

- Tripping requirements, and
- Ride-through requirements

Ride-through is not a "setting", it is a capability of the DER

- i.e., it is the DER's robustness

Tripping points are adjustable over an allowable range

- Range does not allow DER tripping to seriously compromise BPS security
- Tripping points specified by the Area EPS Operator (utility) within constraints of the regional reliability coordinator

Categories of abnormal performance requirements

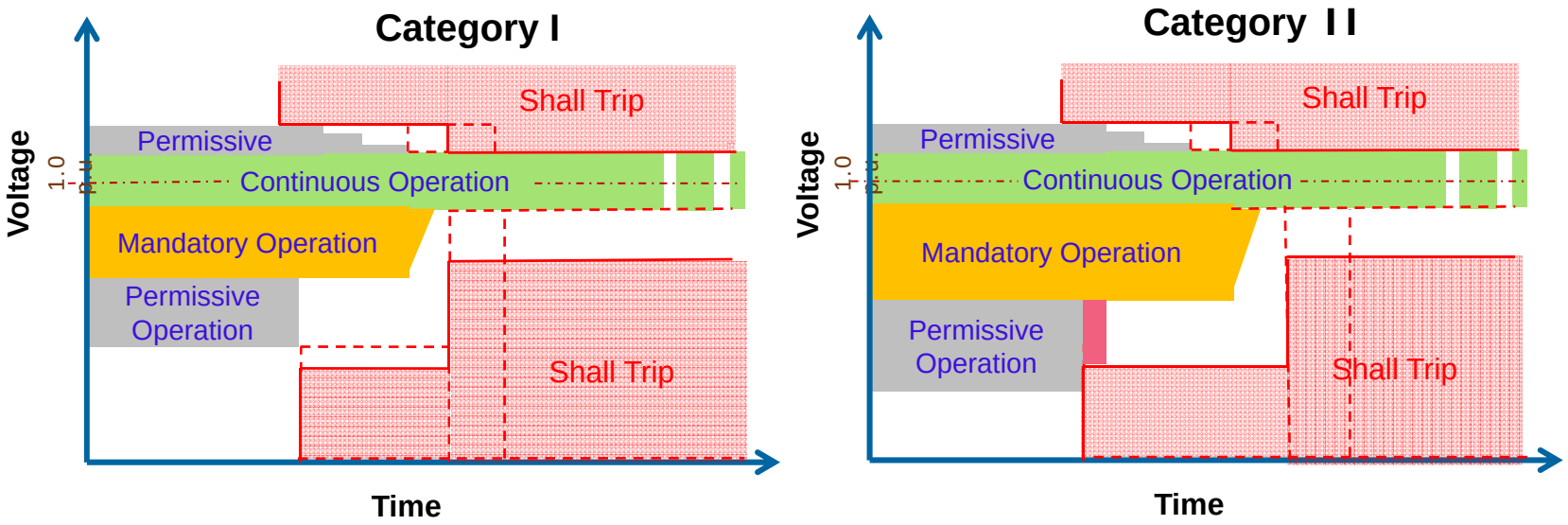
Category	Objective	Foundation
I	Essential bulk system needs and reasonably achievable by all current state-of-art DER technologies	German grid code for synchronous generator DER
II	Full coordination with bulk power system needs	Based on NERC PRC-024, adjusted for distribution voltage differences (delayed 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 for bulk system reliability.

Specific performance terminology

- **Trip** – cessation of output without immediate return to service; not necessarily disconnection
- **Cease to energize** – no active power delivery, limitations to reactive power exchange; Does not necessarily mean physical disconnection. Can be either a *momentary cessation* or a *trip*
- **Permissive operation** – DER may either continue operation or may cease to energize, at its discretion
- **Mandatory operation** – required active and reactive current exchange
- **Momentary cessation** – cessation of energization for the duration of a disturbance with rapid recovery when voltage or frequency return to defined range
- **Return to service** – re-entry of DER to service following a trip
- **Restore output** – DER recovery to normal output following a disturbance that does not cause a ***trip***.

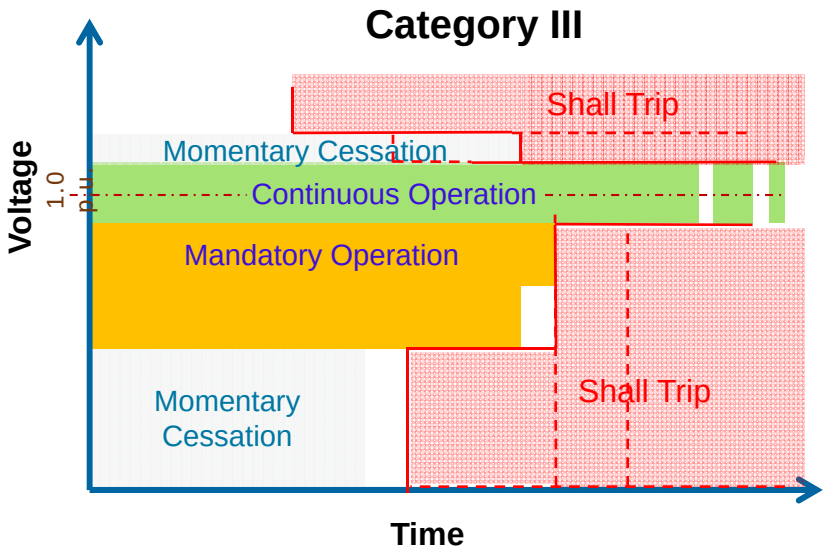
Structure of voltage ride-through and tripping – Categories I and II



Dashed lines indicate permissible range of trip adjustment

Structure of voltage ride-through and tripping – Category III

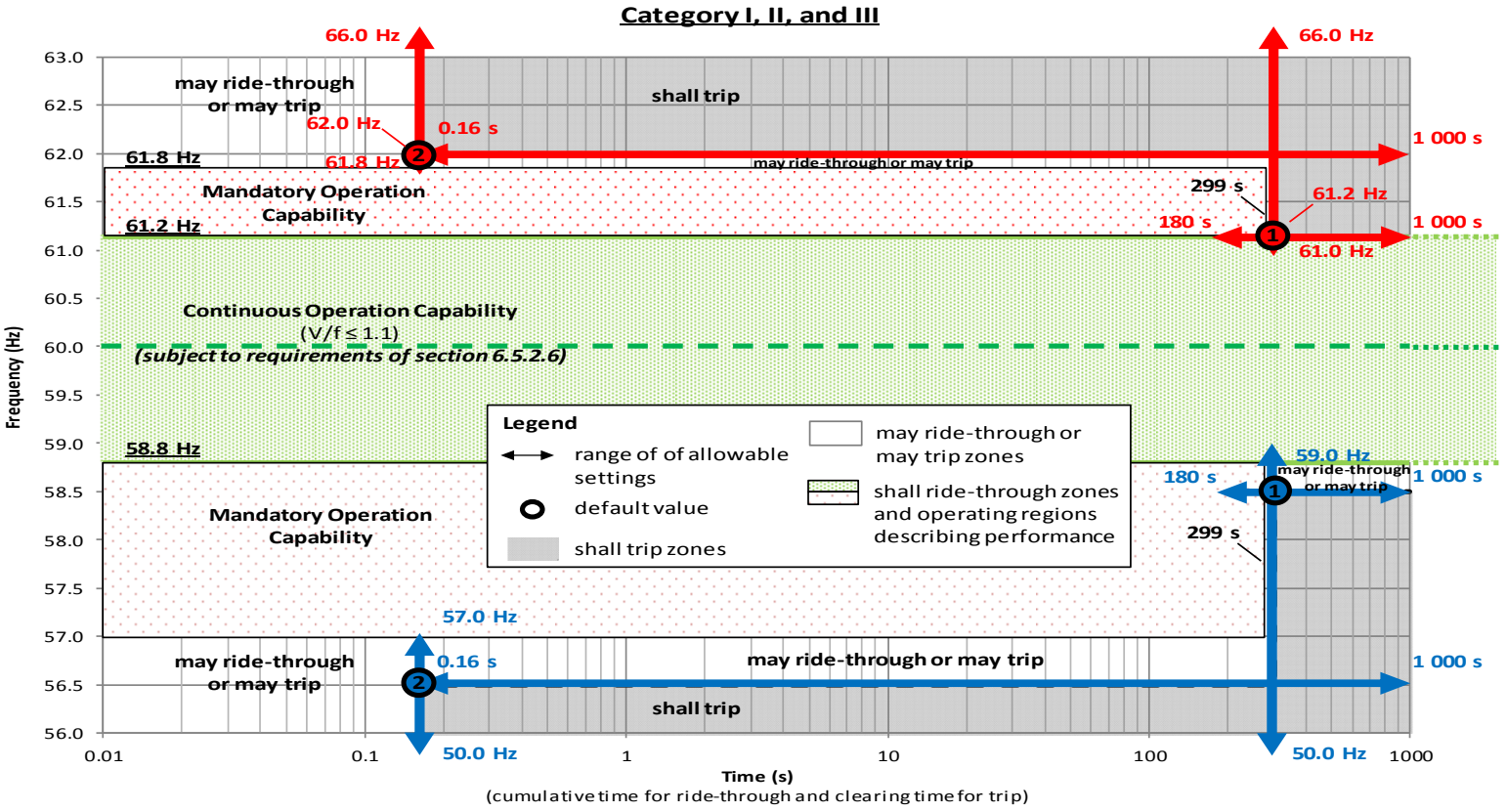
- Category III introduces *momentary cessation* requirement
- Requires a relatively long zero voltage ride-through requirement (in *momentary cessation* mode)
- If feeder is faulted then tripped, DER in *momentary cessation* mode will not energize the islanded feeder
  - Voltage will remain zero and DER will eventually trip off



Voltage disturbances within continuous operating range

- DER must remain in operation for any voltage disturbances in which voltage magnitude remains within C84.1 Range B.
  - E.g., abrupt steps of voltage up or down could be such a disturbance
- DER must deliver available active power as great as the pre-disturbance level (prorated by per-unit voltage if voltage is less than nominal)
  - Temporary deviations of active power < 0.5 seconds allowed
- Exceptions for unbalance:
  - Negative sequence voltage (V2) > 5% for duration > 60 s.
  - Negative sequence voltage (V2) > 3% for duration > 300 s.

Frequency ride-through and tripping requirements



Other ride-through requirements

- Consecutive voltage disturbances, e.g.:
  - Voltage dips caused by multiple unsuccessful reclosing attempts on another circuit
  - Dynamic voltage swings in and out of normal range following bulk system fault
  - Repetitive faults
- Rate-of-change of frequency (ROCOF)
  - Severe bulk grid dynamic events
- Phase angle jumps, e.g.:
  - Unbalanced faults
  - Bulk system switching events (generator trip, line switching, etc.)

Frequency response

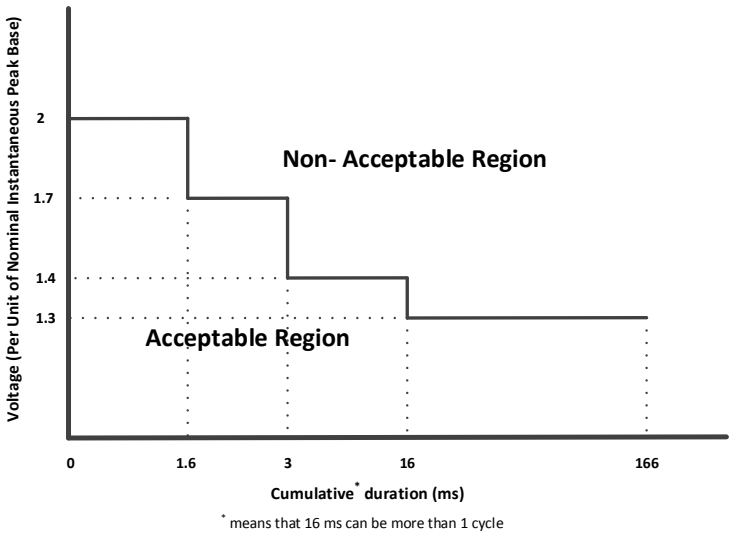
- Increasing penetration of unconventional generation is reducing system inertia which can degrade system frequency stability
- Frequency droop (governor-like) response required of all DER
  - Active power output is modulated in response to frequency deviation
  - No mandate to maintain headroom to increase active power to provide under-frequency response
- Frequency response parameters:
  - Default droop 0.05 p.u. frequency for one p.u. active power change
  - Default deadband ± 36 mHz
  - Other parameter settings allowed as approved by the regional reliability coordinator

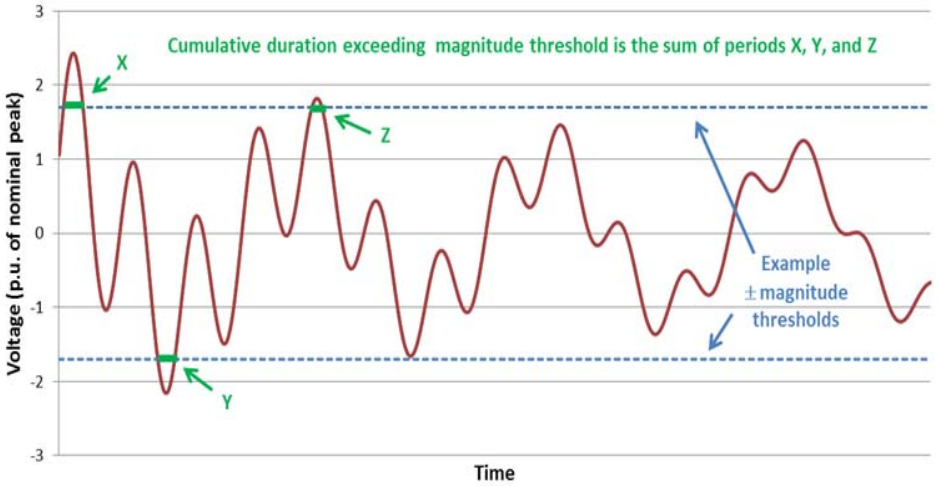
Power Quality

Summary of key power quality requirement changes

- Flicker limitations are more definitive
  - Specific P_{ST} and P_{LT} emission limits (as defined in IEEE 1453)
- Separate rapid voltage change (RVC) limits
  - E.g., frequent transformer or capacitor switching
- Harmonic emission limits based on IEEE 519 with some modifications
  - Interharmonics are now limited
  - Even-order harmonic limits less restrictive for higher harmonic orders
- Definitive transient and temporary overvoltage limitations

Transient overvoltage limitations





Example illustrating cumulative duration definition

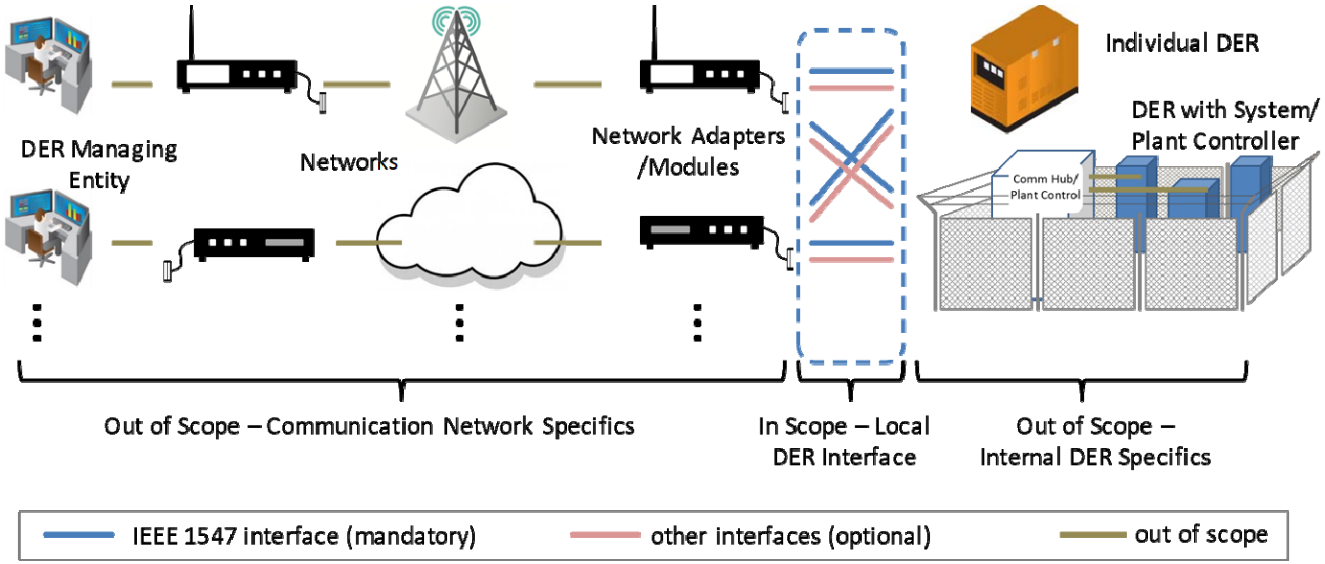
Islanding

DER islands in 1547-2018

- Island: Condition in which a portion of an Area EPS is energized solely by one or more DER – i.e., utility source is disconnected
- Unintentional island: one that is not planned
  - DER must detect, trip, and clear within 2 seconds –same as IEEE 1547-2003
  - Area EPS Operator (utility) can extend this to 5 seconds
  - Ride through requirements do not nullify this requirement
  - False detection of an island does not justify non-compliance with ride-through
- Intentional island: one that is planned such that DER can carry a specific load (e.g., microgrid, emergency/standby power supply)
  - 1547-2018 now addresses intentional islands
  - For *Local EPS Islands* (facility islands), standard only covers conditions of connection and disconnection
  - For Area EPS Islands (includes utility system assets), connection, disconnection, and changes to DER settings required during islanding condition

Interoperability

Interoperability requirements



IEEE 1547-2018 defines communication interface

Categories of information to be exchanged

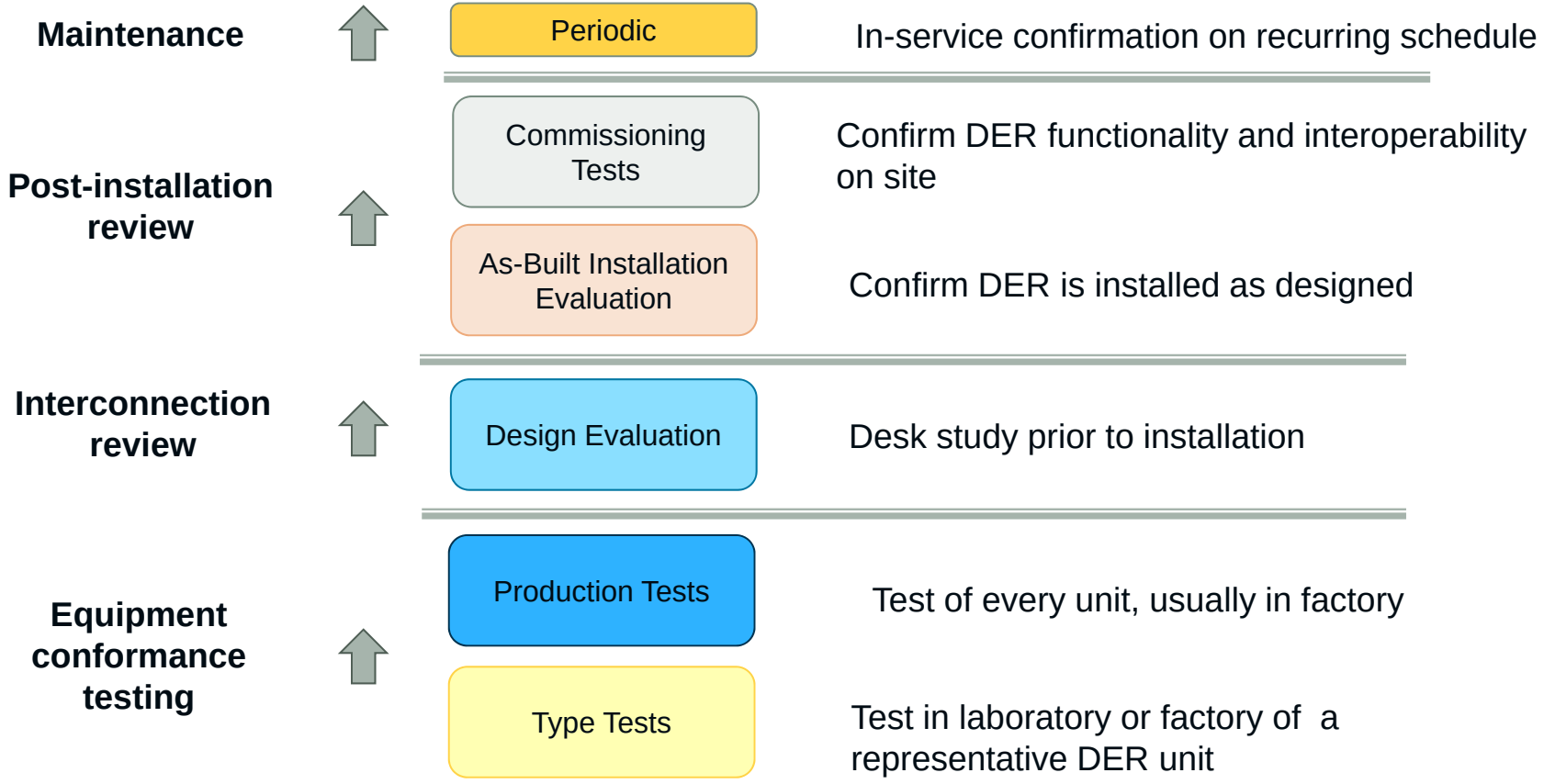
- Nameplate Data – As-built characteristics of the DER, e.g.:
  - Manufacturer/model
  - Active and reactive power rating, etc.
- Configuration Information – alternative nameplate ratings
- Monitoring Information –Measured values of:
  - Active and reactive power
  - Voltage, etc.
- Management information –update functional and mode settings for the DER.

List of eligible protocols

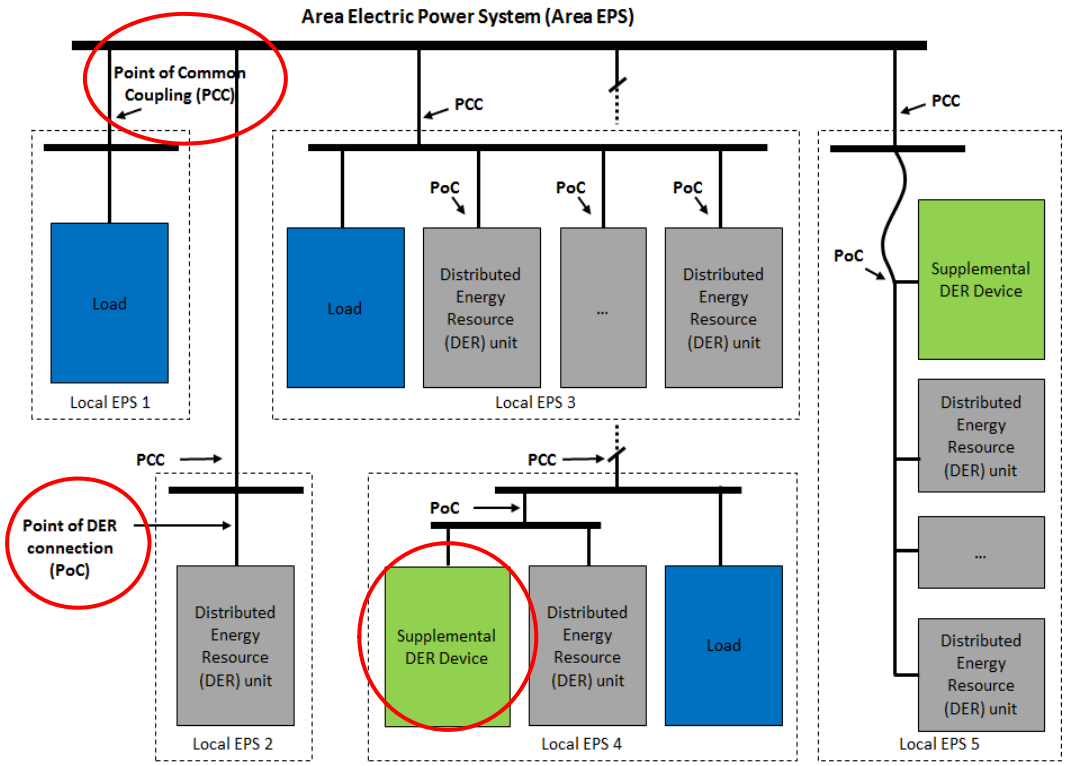
Protocol	Transport	Physical Layer
IEEE Std 2030.5™ (SEP2)	TCP/IP	Ethernet
IEEE Std 1815™ (DNP3)	TCP/IP	Ethernet
SunSpec Modbus	TCP/IP	Ethernet
	N/A	RS-485

Testing and Verification

High-Level Test and Verification Process

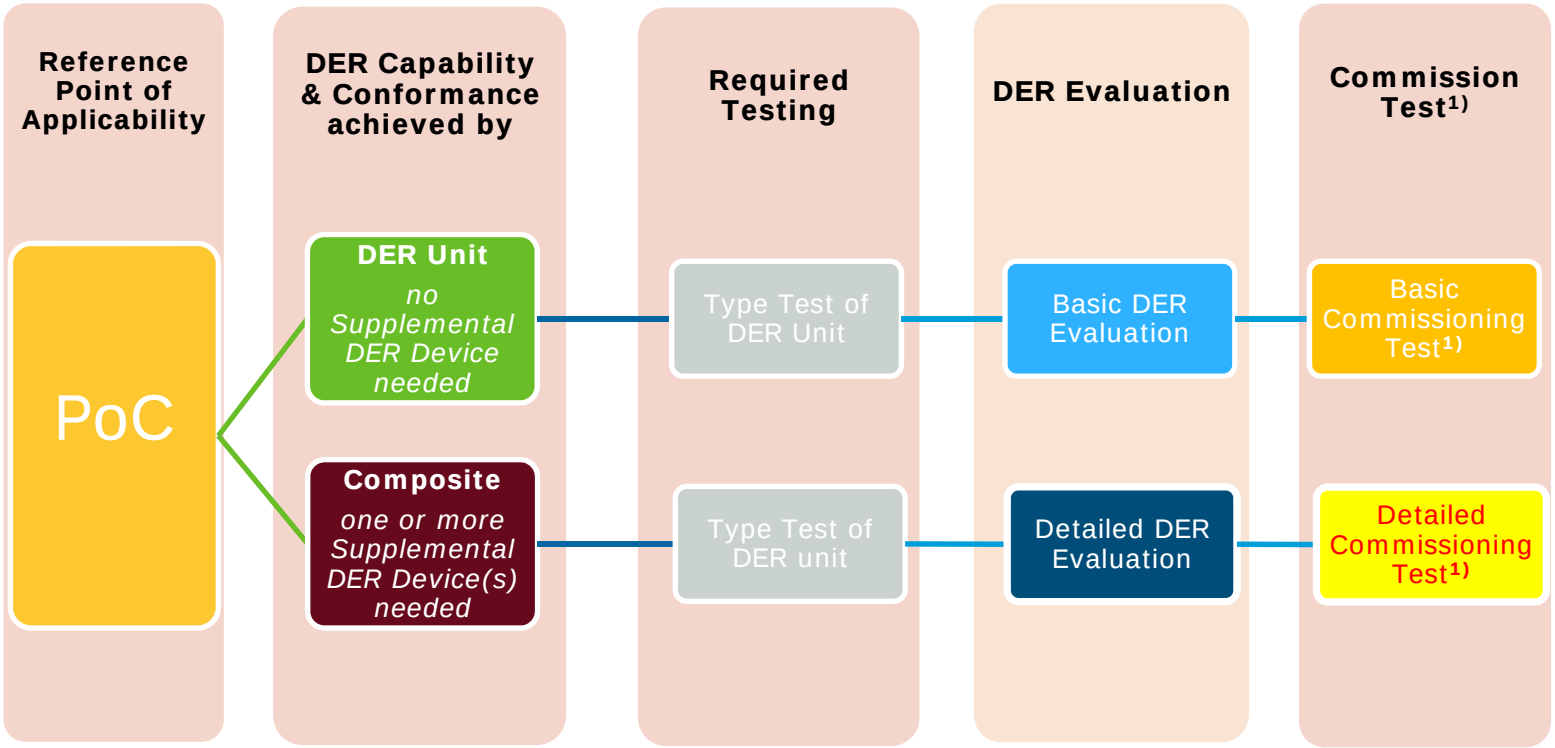


Reference Point of Applicability



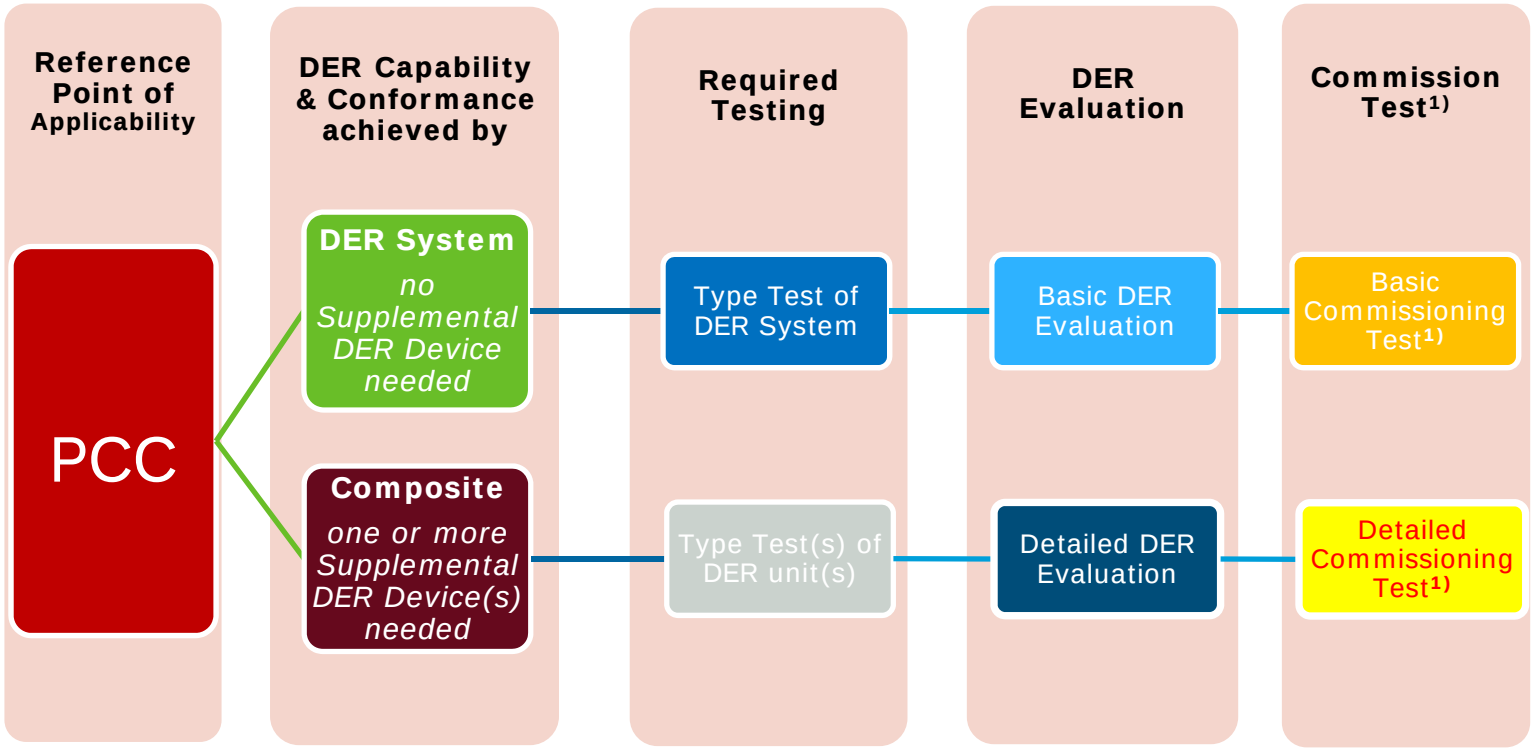
- **RPA is where performance requirements apply**
- **Point of Connection**
  DER terminals
- **Point of Common Coupling**
  Ownership interface

High-level test and verification process - PoC



[1)] As applicable, may depend on DER Design Evaluation.

High-level test and verification process - PCC



1) As applicable, may depend on DER Design Evaluation.

Review Questions

1. What are the major drivers of changes in the 2018 version of IEEE 1547?
2. True/False: Ride-through requirements can be important for DER connected to a feeder having only a small amount of DER capacity relative to the load.
3. If the utility requires a 2 MW PV farm to invoke the (voltage – reactive power (volt-var) mode, the voltage regulated is:
   a. The individual inverter terminal voltages
   b. The feeder-voltage side of the inverter step-up transformer
   c. The point where the farm is connected to the utility system
4. True/False: IEEE 1547-2018 requires DER owners to install a communication system linking the DER to the utility's control center.
5. True/False: A 2 MW PV farm uses certified, type-tested inverters. Therefore, compliance with IEEE-1547

Contact Information

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Backup Slides

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