# Be Prepared for IEEE 1547-2018 – Standard for Interconnection and Interoperability

ComRent®
LOAD BANK SOLUTIONS

Mark Siira

July 19, 2018

# GOALS OF THIS SESSION

Review changes in IEEE 1547-2018 Interconnection Standard

**01**

ComRent Background

**02**

Why Changes are Needed

**03**

IEEE 1547 Requirements

**04**

Takeaway

# 01

## ComRent Background

# Introduction – ComRent Utility Solutions Commissioning, Grid Emulation, Witness Testing

**ComRent is a short-term solutions company providing the energy and technology industries the opportunity to commission, test and maintain systems faster and with absolute precision.**

- Simulate grid connection/substation
- Meet anti-islanding protection requirements
- Simulate startup and power generation and protection for each collection point
- Witness testing frees up engineering resources

- Substations up to 230kV can be commissioned quickly and safely
- Turnkey support streamlines planning, logistics, and execution

## Experience & Expertise

Turnkey partnership: product, design, engineering, on-site support

## Control Schedule, Safety

Largest fleet of load banks, available with the shortest lead time

# TRACK RECORD STRETCHING 20 YEARS

We understand mission critical testing. We deliver a custom solution.

**1997**
Company founded. Entered load bank rental market

**2003**
Entered medium voltage market

**2005**
Leader in data center commissioning

**2009**
Performed 1st substation test
Started Canada operations – Montreal, Toronto, Edmonton

**2011**
Entered Latin America

**2013**
Performed test at 200kV

**2015**
Performed 62MVA resistive/reactive test
Commissioned 50MW project

# KNOWN BY THE COMPANY WE KEEP

Our success is just a reflection of our customers success

DUKE ENERGY
Microsoft
YAHOO!
Xcel Energy
Chevron
SIEMENS
Cummins
E LIGHT WIND AND SOLAR
SOUTHERN CALIFORNIA EDISON An EDISON INTERNATIONAL Company
EMERSON
ROLLS ROYCE

## Recognition

| CHAIR MEMBER | BOARD MEMBER | 7 CONSECUTIVE YEARS |
|---|---|---|
| IEEE Advancing Technology for Humanity | 24 7 XChange International The end-to-end reliability forum. | Inc. 5000 America's Fastest Growing Private Companies |

# MOST TRUSTED LOAD BANK SOLUTION

Trusted for safety, availability, performance, precision and support

**Safety**

**Reliable**

**Fleet**

**Available Product**

**Performance At All Scales**

| 2017 OSHA Recordable Events | Product Uptime | Fleet Size (Units) | Average Availability (hrs.) | Completed Systems From 1kW to 50 MW |
|---|---|---|---|---|
| 0 | 99% | 3,500 | 24 | 75,000 |

# 02

## Why Change is Needed

# Note on Presentation Content

## Author Background

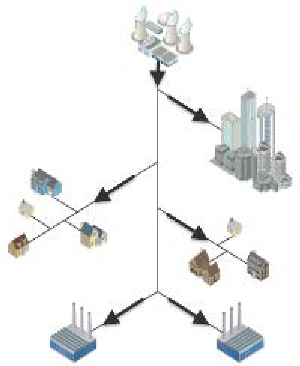
- Vice-Chair for IEEE1547-2018 Interconnection Standard
- Sub-group chair of IEEE P1547.1 Test Procedures
  - installation evaluation and commissioning.

## Disclaimer

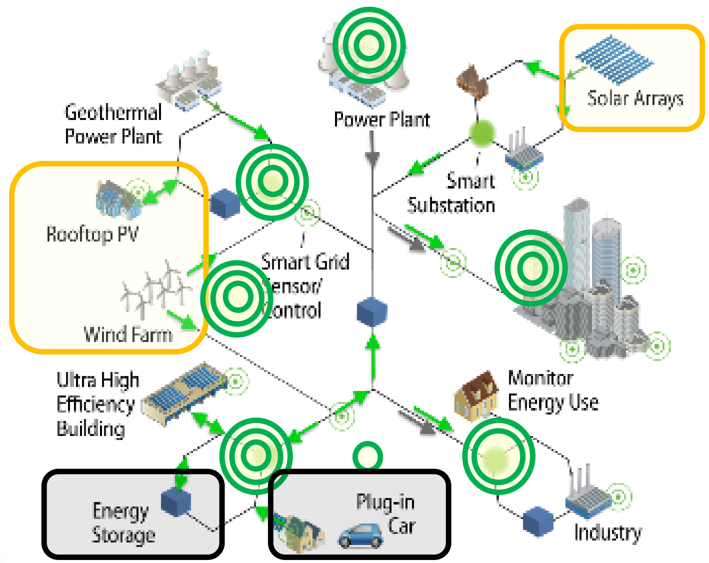
- This presentation on IEEE 1547-2018 are the author's views and are not the formal position, explanation or position of the IEEE or ComRent
- The author acknowledges the contribution of the IEEE 1547-2018 Working Group, Balloters and Officers

# Background- Evolution of the Grid

## Current Power System



## Future Power Systems

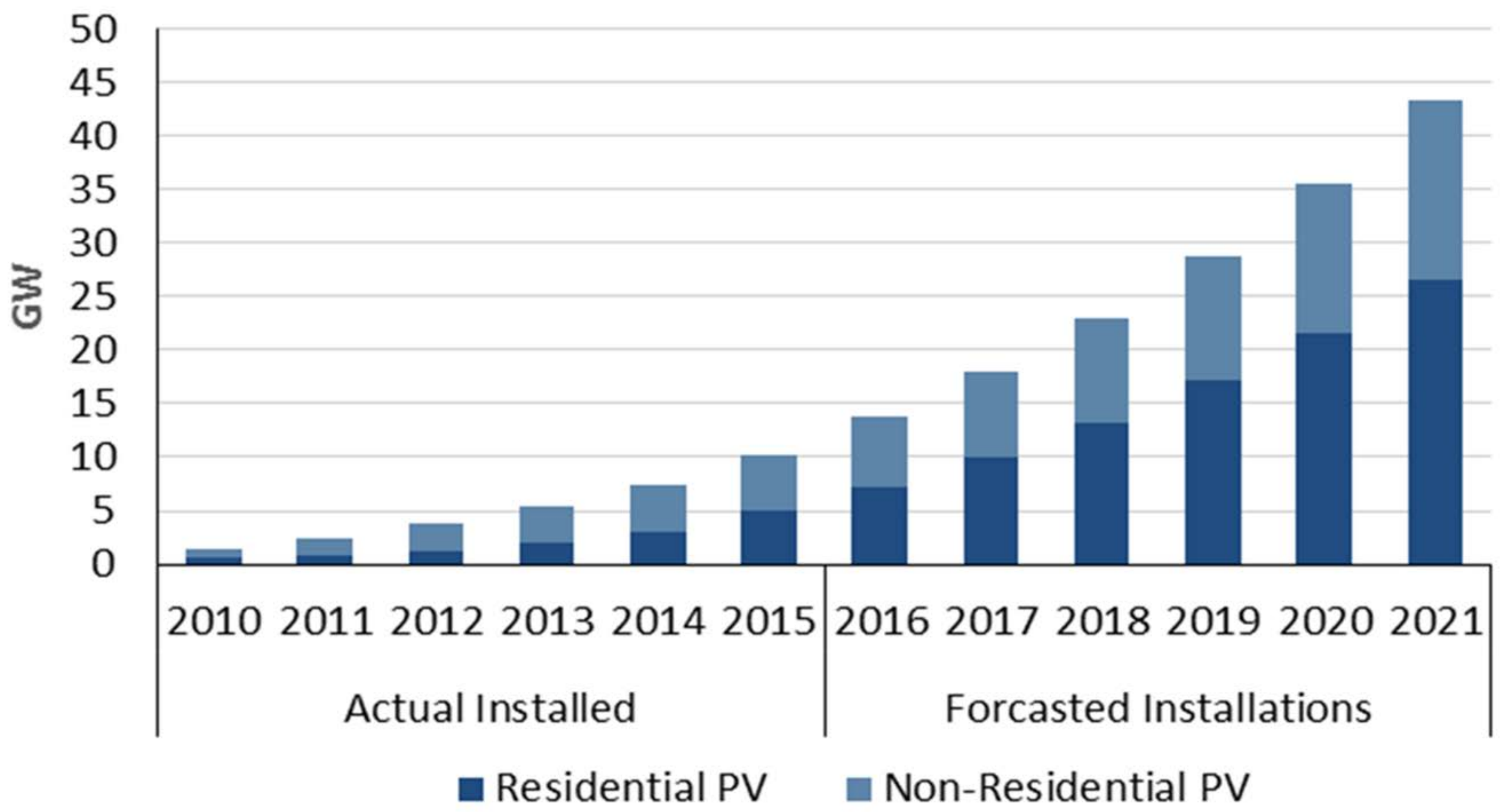



## New Challenges

- 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


Source:. NREL

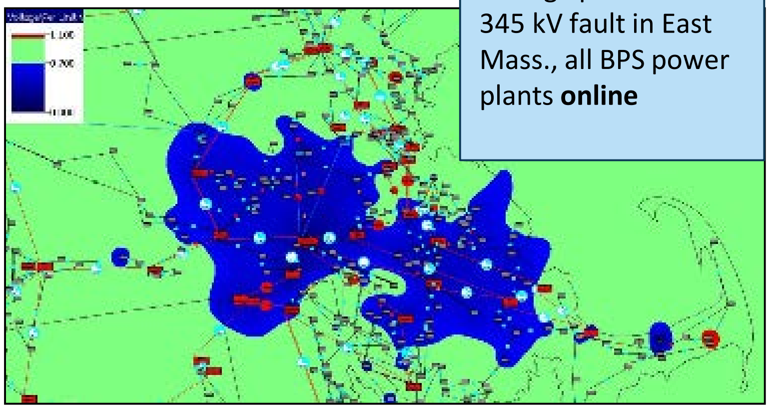
# Solar PV Penetration Growth




**Source: GTM Research**

# Driver for new ride-through requirements - Potential for widespread DER tripping (Cont)

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



**Source: ISO-New England**

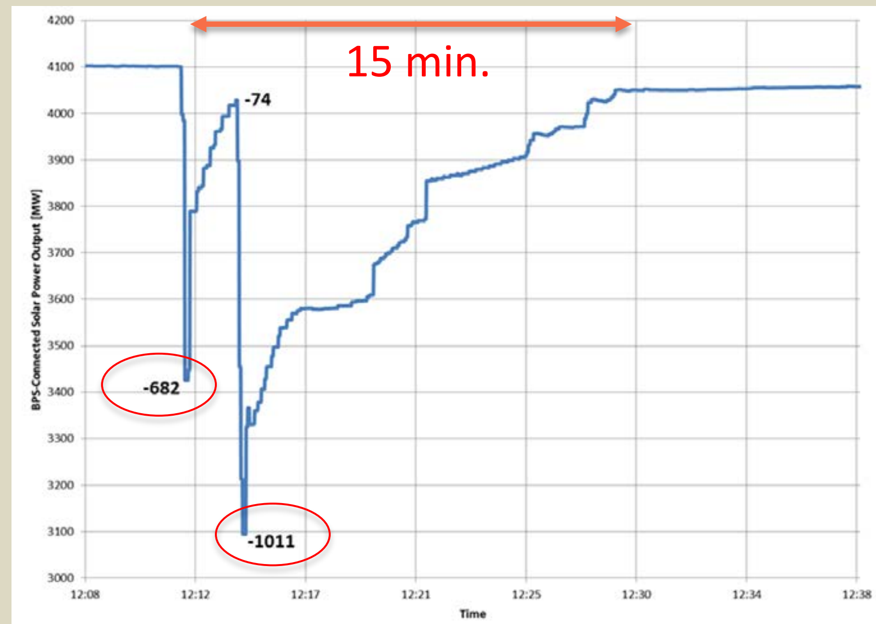
## Voltage and Frequency Across Large area Affected by DER Resource Trip

- Transmission faults can depress distribution voltage over very large areas
- Sensitive voltage tripping can cause massive loss of DER generation

## Southern California Event – October 9, 2017

- 900 MW Solar PV Resource Interruption

## Loss of Solar PV Resource




**Source: NERC**

# Standards Development - Distributed Energy Resources

## IEEE Standards Coordinating Committee 21

Fuel Cells, Photovoltaics, Energy Storage and Dispersed Generation

- Interconnection Series — 1547 Series
- Smart Grid Interoperability — 2030 Series
- Solar PV — Energy Storage

## Standards Development Flow

**IEEE 1547**
Interconnection Technical Requirements

**IEEE 1547.1**
Inter-connection Verification and Test Procedures

Full Revision Late 2017

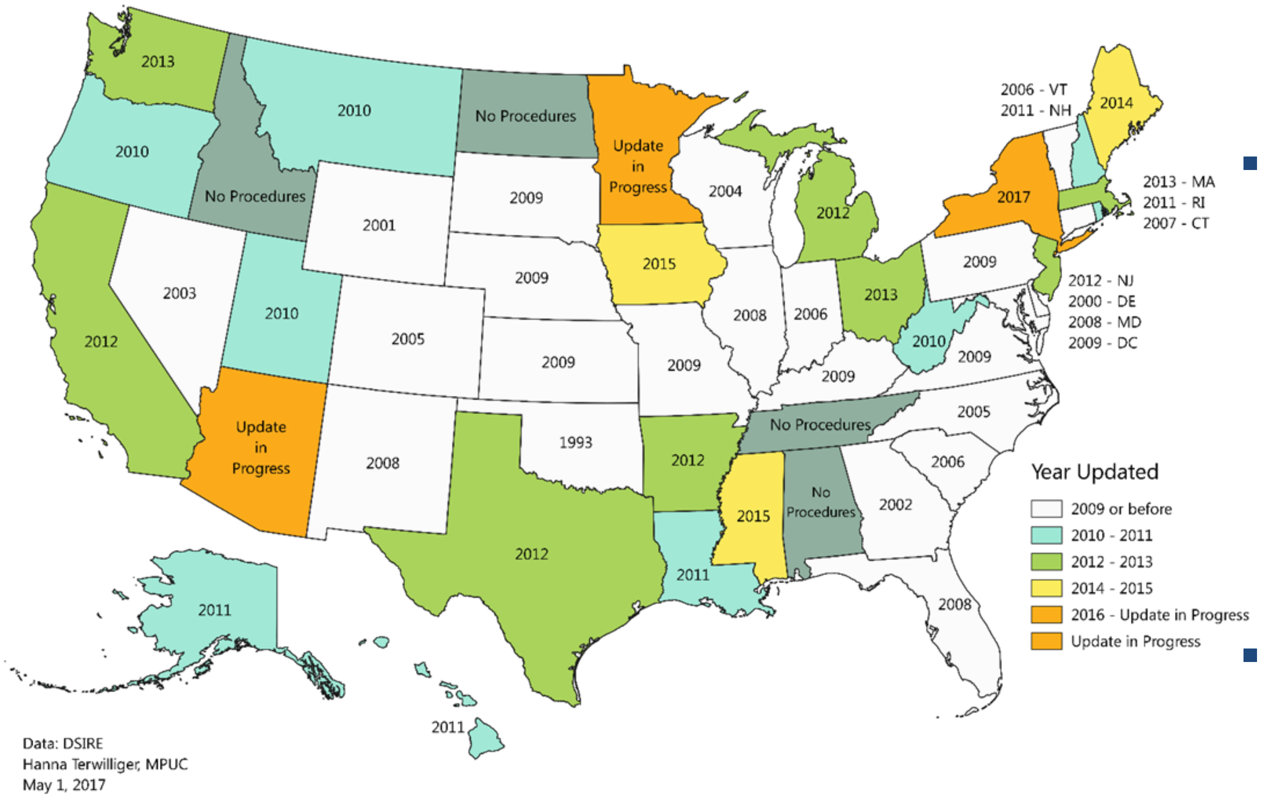
**UL 1741**
Inverters and Converters

**IEC 62109**
Inverters and Converters

**NEC**
NFPA 70e Articles:
- 690 PV Systems
- 705 Interconnection
- 480 Storage Batteries
- 692 Fuel Cell
- 694 Wind Electric

IEEE UL IEC NFPA NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

# Recent State- and Utility-Level Activities in U.S.




Recent Updates to State Interconnection Standards

- State initiatives
  - Standards updates
    - ✓ NY REV
    - ✓ MN proceedings
    - ✓ CA Interconnection
  - Grid modernization efforts underway in 35+ states
- Utility activities
  - Employing new standards
  - Preparing staff
  - Improving processes

# IEEE 1547-2018 Impact

- Defines and standardizes "**smart DERs**" across the industry.
- Attempts to specify **safe, reliable,** and **cost-effective** new interconnection and interoperability **requirements** for DERs.
- Provides a widely-accepted **technical basis** for regulatory proceedings and Interconnection Agreements that can be **flexibly** adjusted to regional differences.
- Value provided to PUCs and Utilities:
  - ✓ avoid lengthy discussions with various stakeholders;
  - ✓ avoid necessity to specify technical requirements;
  - ✓ mitigate technical risks.

# 03

## IEEE 1547 Requirements

# Comparison of IEEE 1547-2003 to IEEE P1547 - 2018

## Old Standard

- **IEEE 1547-2003**
  - No voltage regulation
  - Disconnect for grid disturbance
  - 10 MW capacity limitation

## IEEE 1547-2018

- **Requirements**
  - Voltage Regulation capabilities
  - Ride through prior to anti-islanding limits
  - No limitation
- **New Requirements**
  - Interoperability requirements
  - Intentional Islands (Microgrid)
  - Verification
    - Site Assessment
    - Commissioning

## Other Benefits

- Technology-neutral
- Harmonize with FERC/NERC standards
- Introduces DER Categorization

# IEEE 1547-2018 Document Outline

## Clause Headings

1. Overview
2. Normative references
3. Definitions and acronyms
4. General specifications and requirements
5. **Reactive power, voltage/power control [normal conditions]**
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)

**Bold Text indicates clauses with significant change from 2003 standard**

# General remarks and limitations

- Applicable to all DERs connected at typical primary or secondary distribution voltage levels
- Specifies performance and not design of DER
- Specifies capabilities and functions
- 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.

# New Requirements

General Provisions Are Specified

- Measurement accuracy (RMS voltage, frequency, active power, reactive power)
- Cease to energize capability
- Enter service criteria
- Control capability - Limit active power
- Permit service disable (within 2 seconds, primarily for bulk)


Source: IEEE Std. 1547-2018

# Categories For Grid Support – Normal Operation Conditions

## Voltage Regulation Capabilities

**Category A**

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

**Category B**

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

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

# Active Voltage Regulation Requirements – Normal Operation Conditions

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

## Capability required for all DER – (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")

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


Source: IEEE Std. 1547-2018

# Abnormal Operating Conditions - Categories

## Ride Through Capabilities

**Category I**

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

**Category II**

- Full coordination with all bulk system power system stability/ reliability needs
- Coordinated with existing reliability standards to avoid tripping for a wider range of disturbances ( more robust than Category I)

**Category III**

- Designed for all bulk system needs and distribution system reliability/power quality needs
- Coordinated with existing requirements for very high DER levels


Source: IEEE Std. 1547-2018

# Grid Support Requirements - Abnormal Operating Conditions

***Ride-through***

*ability to withstand voltage or frequency disturbances*

**Required**

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

**Other allowed capabilities**

- Inertial response[3]

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

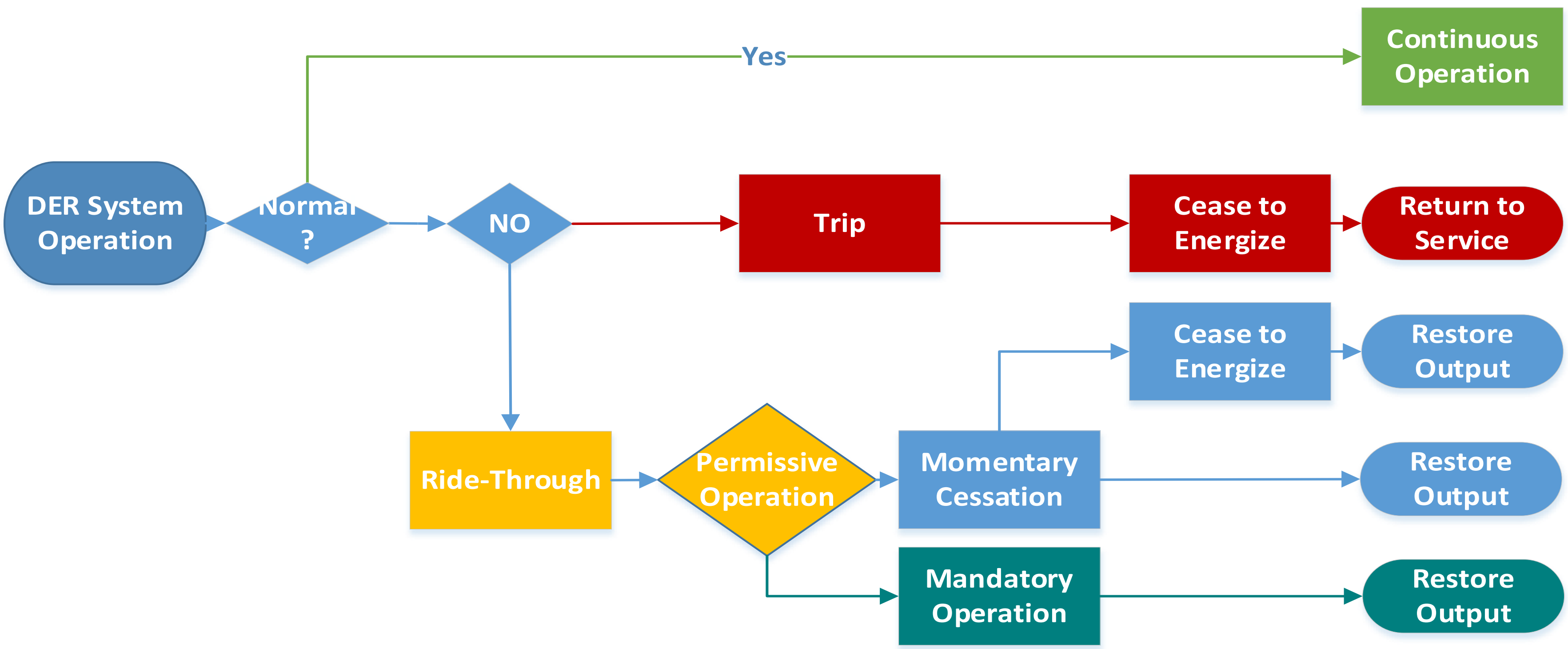

Source: IEEE Std. 1547-2018

# Specific Performance Terminology

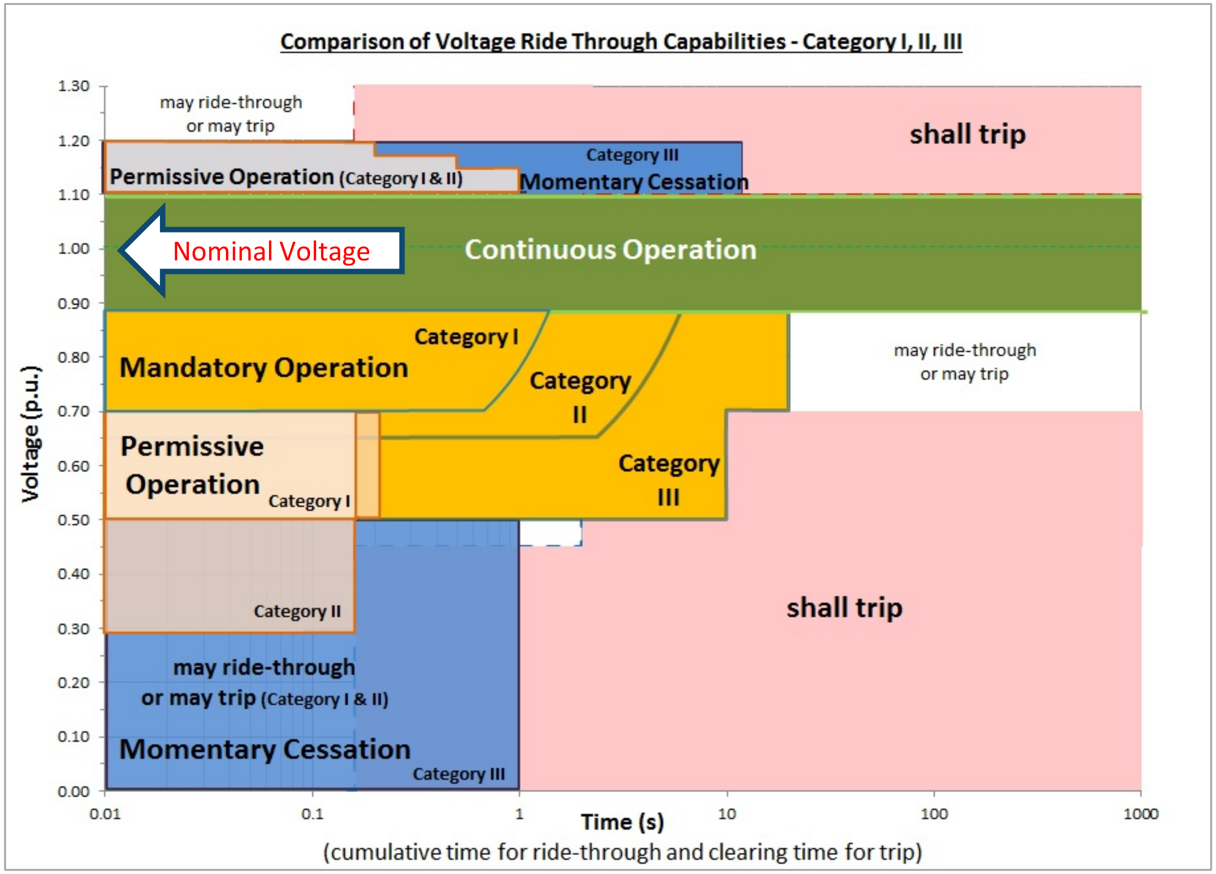
- **Trip** – cessation of output without immediate return to service; not necessarily disconnection
- **Cease to energize** – no active power delivery, limitations to reactive power exchange; Does not necessarily mean physical disconnection. Can be either a *momentary cessation* or a *trip*
- **Permissive 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***.


Source: IEEE Std. 1547-2018

# Specific Performance Terminology



# Voltage Ride-Through

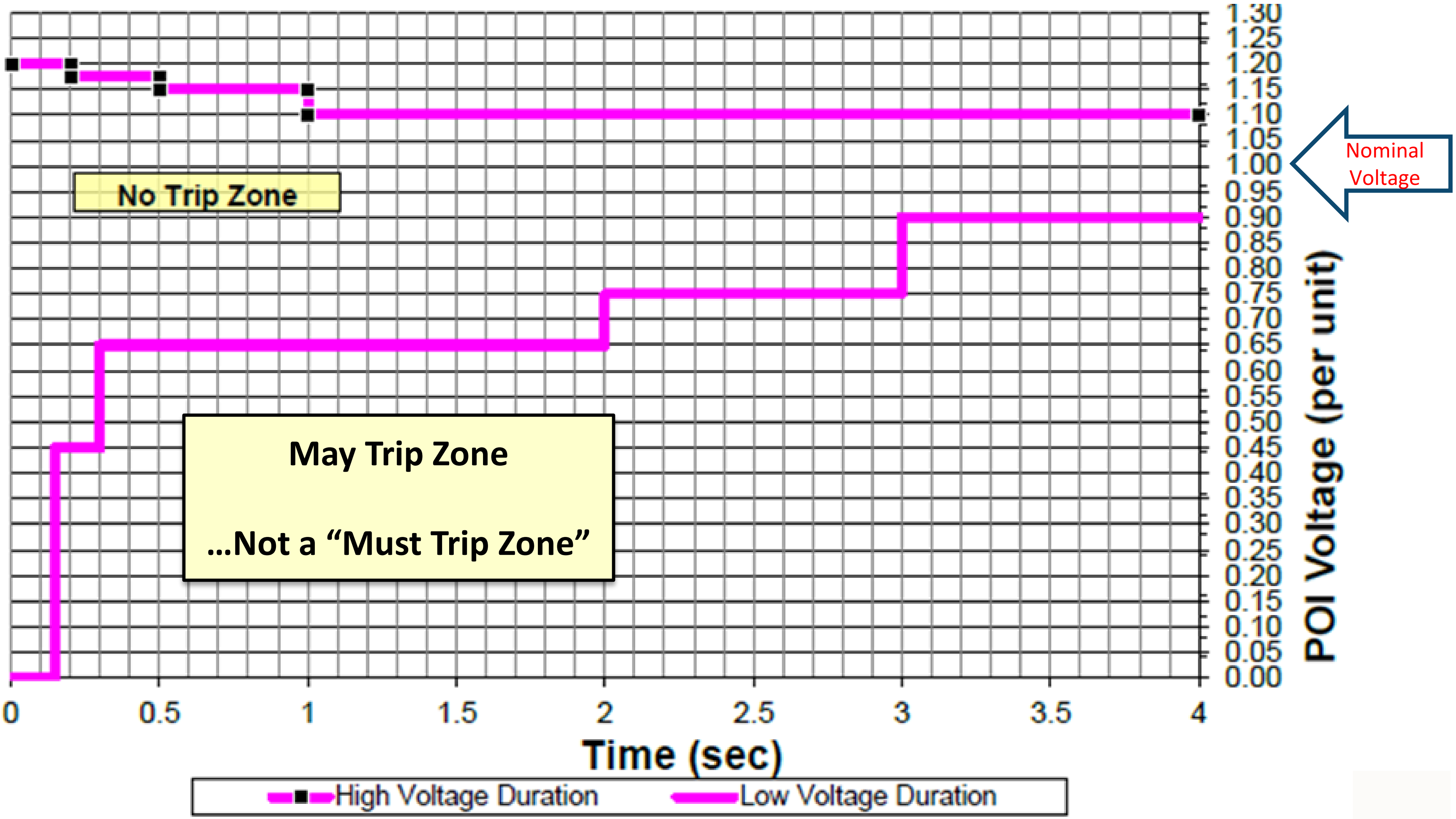



*"The Area EPS Operator, as guided by the AGIR who determined applicability of the performance categories as outlined in 4.3, shall specify which of abnormal operating performance category I, category II, or category III performance is required.*"*

*based on IEEE 1547-2018 DER Device Behavior/Operation Regions Comparison for Voltage Ride Through Categories I, II, III*

**This may be subject to regulatory requirements that are outside the scope of this standard and may consider DER type, application purpose, future regional DER penetration, and the Area EPS characteristics.*

# Voltage Ride-Through (Simplified)




Source: NERC PRC-024-2

# Islanding definitions in IEEE 1547-2018

## Unintentional Island

**An unplanned island.**

- DER must detect the island and trip within 2 seconds of the formation of an unplanned island (adjustable if needed up to 5 seconds)

## Intentional island

**A planned electrical island that is capable of being energized by one or more Local EPSs**. These:

(1) have DER(s) and load,

(2) have the ability to disconnect from and to parallel with the Area EPS,

(3) include one or more Local EPS(s), and

(4) are intentionally planned.

## Intentional island systems can transition to an islanded condition in two ways:

**Scheduled:** Formed through DER operator or area EPS operator manual action or other operating dispatch means that triggers the transition to an islanded system.
**Unscheduled:** Formed autonomously from local detection of abnormal conditions at the interface(s) with the area EPS

# Interoperability Requirements

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

## Mandatory communications capability

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

## Information to be exchanged:

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

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

**Monitoring**: present operating conditions of the DERs (read)

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

## Communication performance requirements:

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

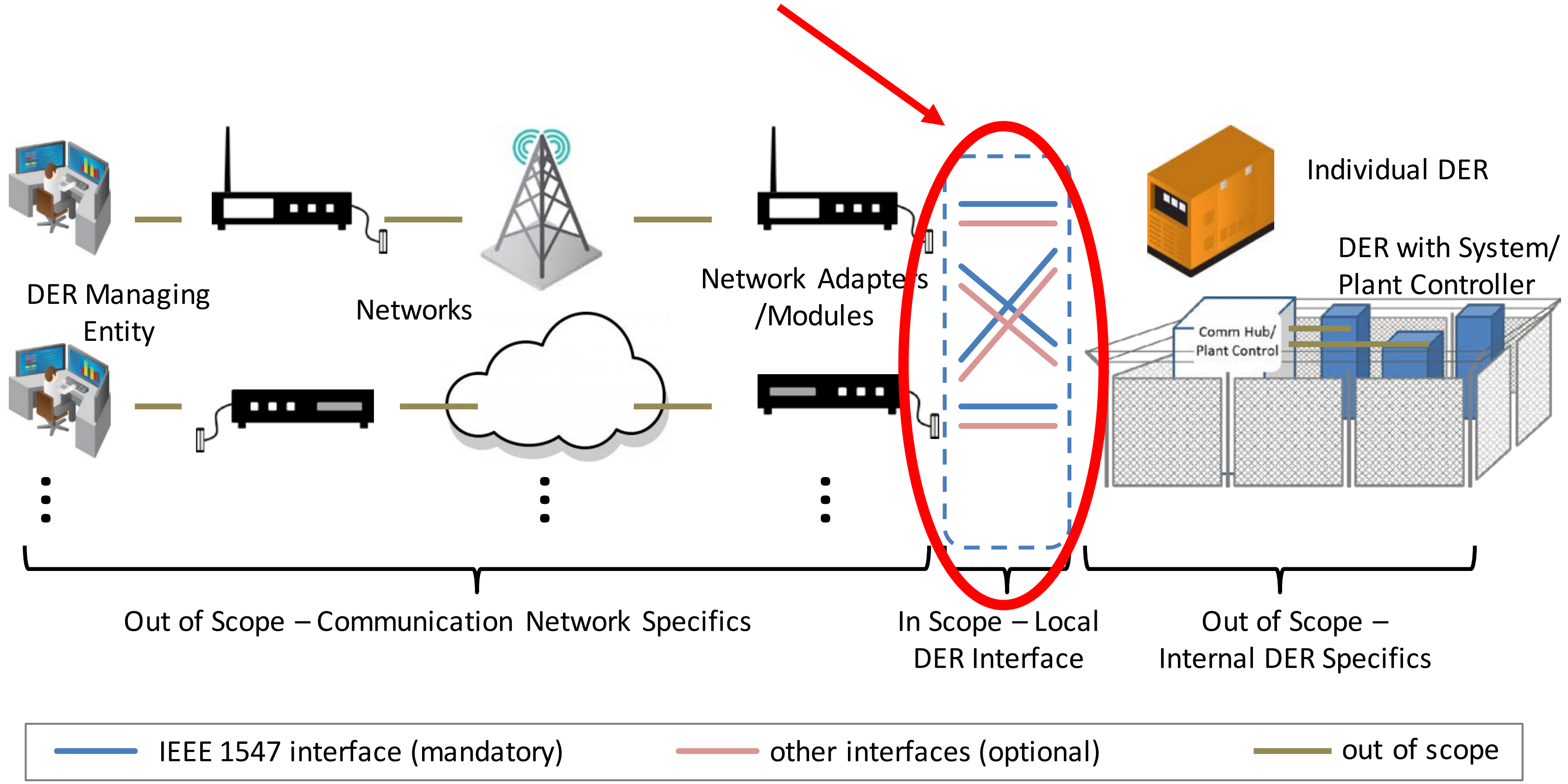
**Information read response times** (≤ 30 s, maximum amount of time to respond to read requests)

## Communication protocol requirements:

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

# Interoperability

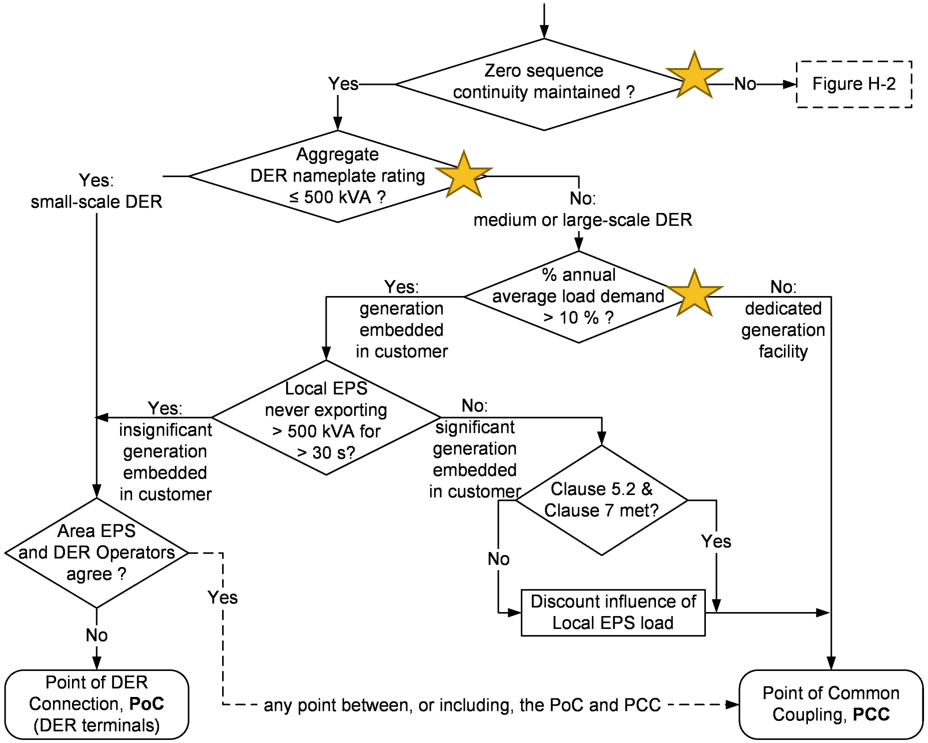
## Scope of IEEE 1547-2018 Interoperability Requirements




*Source: 1547-2018 Approved Draft*

# Verification: Determination of Reference Point of Applicability (RPA)

The reference point of applicability (RPA) has implications for testing & conformance requirements in IEEE 1547-2018 & P1547.1 !




## RPA depends on

- Zero-sequence continuity (or not)
- Aggregate DER nameplate rating (500kVA)
- Annual average load demand (10%)

*Source: IEEE 1547 D7.3 H-1 (informative)*

**zero-sequence continuity**: Circuit topology providing continuity between two defined points in the zero sequence network representation.

NOTE—A transformer having a delta or ungrounded-wye winding in the topological path between the defined points produces discontinuity of the zero-sequence network.

# Verification: DER versus Composite Compliance

- For DER system that shall meet requirements at RPA
  - **DER System** – DER system is fully compliant
    - *No supplemental DER device needed*
  - **Composite** – Composite of partially compliant DER that is fully compliant at RPA
    - May need one or more supplemental DER devices
- Supplemental DER devices may include:
  - Capacitor banks, STATCOMs, harmonic filters that are not part of a DER unit, protection devices, plant controllers, etc.

# High-Level Test and Verification Process

**Maintenance**

**Periodic**
- Scheduled or other criteria
- **Reverification** needed on important system changes

**Post-installation review**

**Commissioning Tests**
- Performed **on site** at the time of commissioning
- **Basic**: visual check equipment, isolation device
- **Detailed**: check functionality and interoperability as a system

**As-Built Installation Evaluation**
- Performed **on site** at the time of commissioning
- **Basic**: check components and connections
- **Detailed**: engineering verification of components, may do modeling and simulation

**Interconnection review**

**Design Evaluation**
- **Desk study**
- Check equipment together meet requirements
- Typically done off-site before equipment is delivered and installed, may include analysis and modeling/simulation

**Equipment conformance testing**

**Production Tests**
- Done in **factory**, or on equipment in **field**
- Tests on **every unit** of DER and interconnection
- **Verify** operability and **document** default function settings

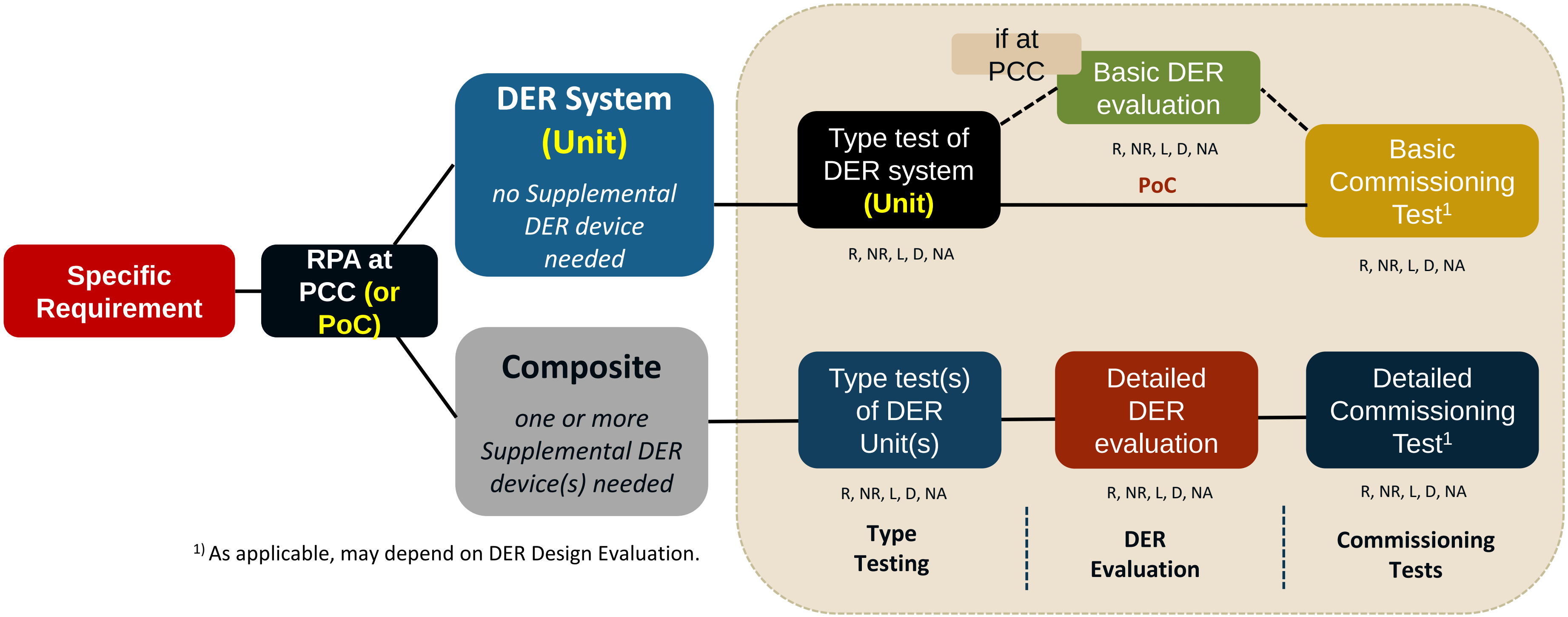
**Type Tests**
- typically done in **test lab** or **factory**
- Tests on **representative** DER Unit or DER system
- Type test from a DER within a product family of the same design


Source: IEEE Std. 1547-2018

# Determination of Requirements Verification and Testing

What's the requirement? → Where's the reference point of applicability? → Are supplemental DER device(s) needed? → Category of test and verification needed

- **R:** Required
- **NR:** Not required
- **L:** Limited
- **D:** Depends on DER design evaluation.
- **NA:** Not applicable




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

The type of evaluation or testing needed for each requirement depends on the reference point of applicability and whether there are any supplemental DER devices

-help in Annex F (informative) Discussion of Testing and Verification Requirements at PCC or PoC

# SCC 21 Active Projects/Standards

Status as of June2018

| Standard | Status |
|---|---|
| 1. IEEE P1547.1 | 1. Active Project – Ballot in late 2018 |
| 2. IEEE P1547.2 – "Application Guide" | 2. Active Project - First Meeting March 8,<br>• Monthly calls to continue progress<br>• Meeting adjacent to IEEE P1547.1 in October |
| 3. IEEE P1547.9 - "Guide for Interconnection of Energy Storage Distributed Energy Resources with Power Systems" | 3. Approved in May 2018 –<br>• First Meeting in October, 2018 |
| 4. IEEE P1013 "Recommended Practice for Sizing Lead-Acid Batteries for Stand-Alone Photovoltaic (PV) Systems"<br><br>IEEE P1562 "Guide for Array and Battery Sizing in Stand-Alone Photovoltaic (PV) Systems" | 4. Ballot Closed May 15, met minimum Requirements (>75% Response Rate)<br>• Comment Resolution Underway<br>• Will incorporate reference to tools from Sandia and NREL |
| 5. IEEE P1561, P1661, P937 – "Lead-acid Battery Guides.." | 5. Will ballot summer 2018 |





ComRent

# 04

## Takeaway

# Importance of IEEE Standards Changes

Industrial and Utility Scale Systems

## New Requirement

1. Changes to Interconnection, Interoperability and Relay Testing Standards
2. NERC and DOE Involved in New Standards Development
3. Many New Technical Requirements for DER integration
4. Commissioning Process Emphasis with Explicit Decision Making

## Implications

1. Awareness of new rules allows integration into project plans
2. All Requirements should be aligned – IEEE, UL, NERC, FERC
3. Less ambiguity on verification required means commissioning can be more predictable, maintaining schedule.
4. Explicit decision to make full system testing predicts performance, increases availability and reduces unplanned failures

# How ComRent Can Help

## Industrial and Utility Scale Systems

### ComRent Features

1. ComRent has Knowledge and Experience and has performed a wide variety of Commissioning tests

2. Our recommendations are required by Industry Code or Standards

3. We can provide Reference and Knowledge based on past experience.

### Benefit

1. ComRent can recommend the best approaches for you to consider for your project. Allows you to work with project developer and choose the most cost-effective solution for project - **maintaining schedule, reduced cost**

2. ComRent's knowledge can eliminate confusion during the latter stages of a project that can result in inefficient use of scarce resources. – **maintaining schedule**

3. Project Consultations, white papers, webinars

# Thank You

Any questions we can answer?


Mark Siira

Director, Utility Solutions

Msiira@ComRent.com

920-980-8426


Learn more at:

**www.ComRent.com**