IEEE 1547 – 2018 Impacts / Implementation

Jens Boemer, jboemer@epri.com

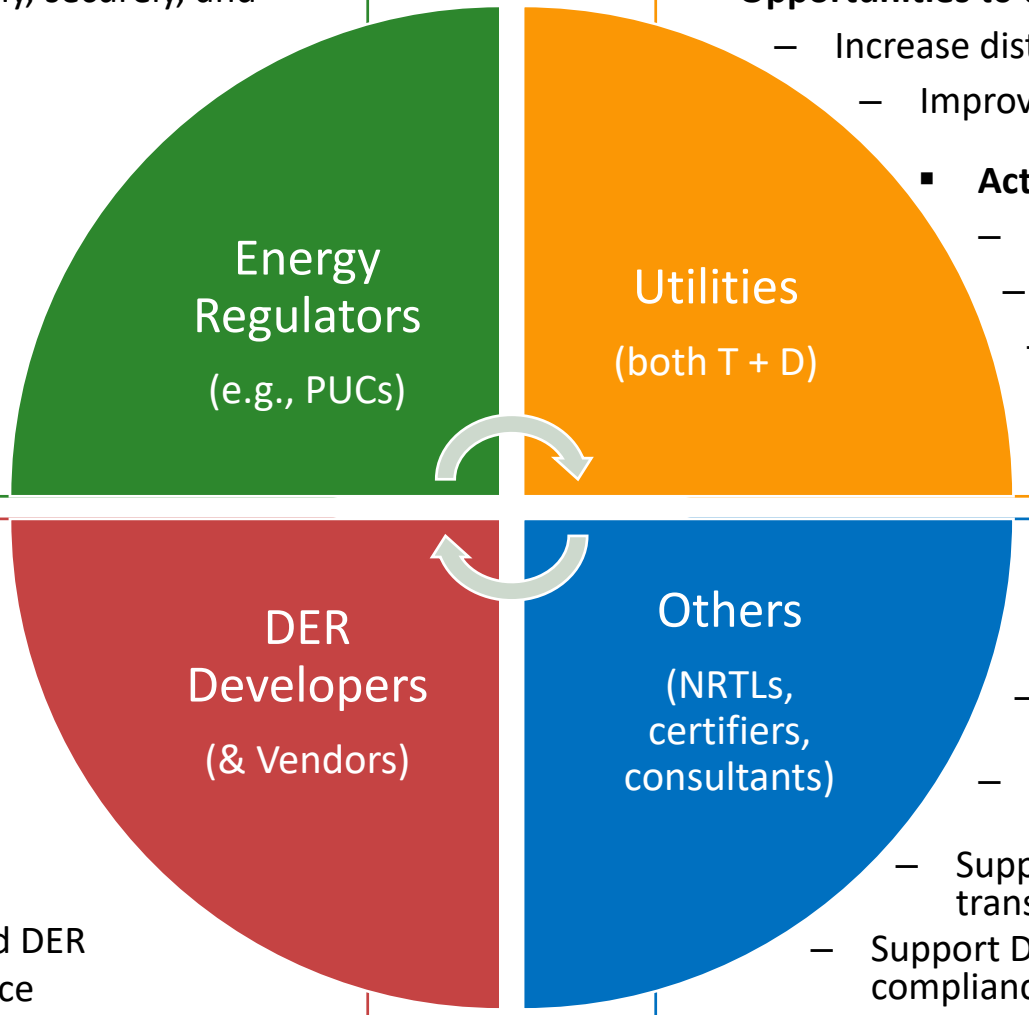
Jose Cordova, jcordova@epri.com

New York State
Interconnection Technical Working Group Meeting

August 26, 2020

This presentation is, in part, supported by the U.S. Department of Energy, Solar Energy Technologies Office under Award Number DE-EE0009019 *Adaptive Protection and Validated MODels to Enable Deployment of High Penetrations of Solar PV (PV-MOD)*.

Summary: IEEE 1547-2018 — What Does It Mean for Me?



- **Opportunities** to integrate DER reliably, securely, and efficiently into the grid
- **Actions required** to
  - Assign performance categories per DER technology and use case
  - Specify "preferred" utility-required profiles for DER functional settings
  - Specify certification for DER equipment and possibly verification for DER facilities

- **Opportunities** to utilize advanced DER capabilities
  - Increase distribution hosting capacity
  - Improve bulk system reliability
- **Actions required** to specify
  - Functional settings ≠ "preferred"
  - Performance categories
  - Communication interface
- **Coordinate across T&D**

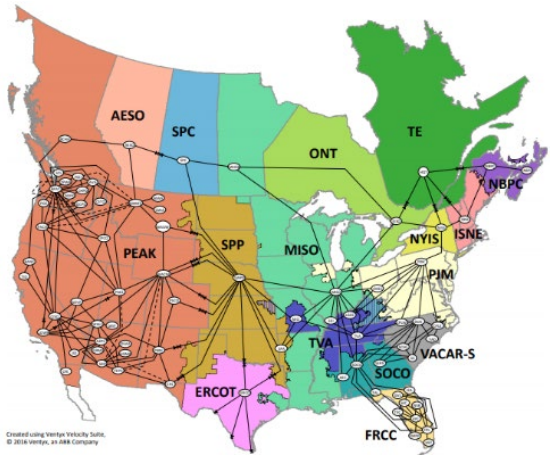
- **Opportunities** to interconnect larger amounts of DER
- **Clarity** regarding
  - Interconnection capabilities
  - Reference point of applicability
  - Functional settings
- **Potential need** for more sophisticated DER facility evaluations to verify compliance

- **Opportunities** for new business
  - Testing and certification of advanced DER units
  - Evaluation and verification of DER facilities
  - Support utilities in distribution planning with advanced DER functions
  - Support reliability coordinators in transmission planning with DER
  - Support DER developers in verification / compliance through DER evaluations

Aggregate DER Impacts on Bulk Power System

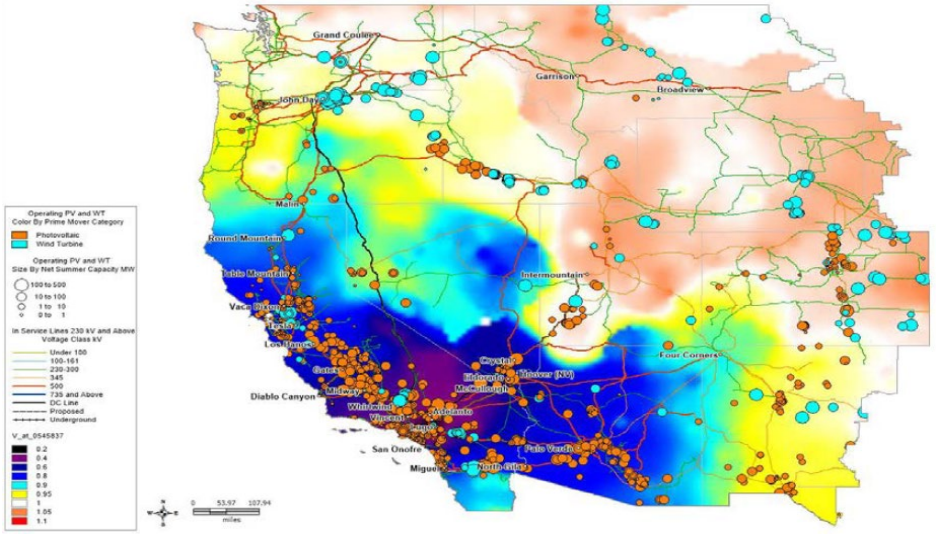
DER Frequency Tripping versus Ride-Through

- System frequency is defined by balance between load and generation
- Frequency is similar across entire interconnection
  - any DER exposed to large frequency deviations may trip simultaneously;
  - special concerns for system-split conditions
- Impact the same whether or not DER is on a high-penetration feeder
- NERC Reliability Coordinators
  - Colored entities in the map to the right



Source: NERC

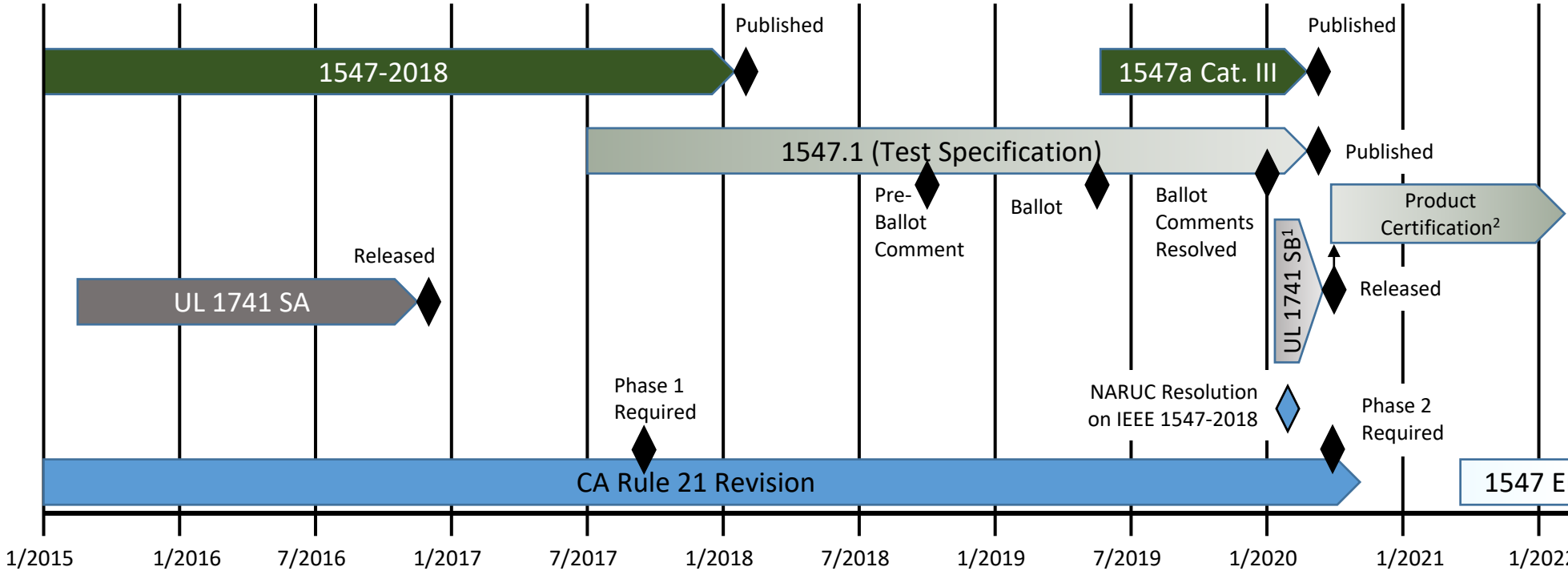
DER Voltage Tripping versus Ride-Through



Source: SCE

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

Timeline for Rollout of IEEE Std 1547™-2018 Compliant DER



Notes

[1] The new UL 1741 Supplement SB will directly refer to IEEE 1547.1-2020 and will be the only test procedure to certify IEEE 1547-2018 compliance. The existing Supplement SA will remain for the time being for those codes that continue to reference UL 1741 SA.

[2] Products to market not generally available until 18 months after release of IEEE 1547.1-2020 and UL 1741 SB.

Example Enforcement Dates

- MN: at "Commission Notice"
- MD: Jan 1, 2022

See also: https://site.ieee.org/sagroups-scc21/standards/1547rev/

Adoption of CA Rule 21 and Hawai'ian Rule 14H by inverter certification per UL 1741 SA.

Stopgap solution for **adoption of parts of IEEE Std 1547-2018** by inverter certification per UL 1741 SA.

Full adoption of IEEE Std 1547™-2018 by inverter certification per UL 1741 SB

Question from **distribution** perspective:

Need to increase DER Integration?

Question from **transmission** perspective:

Need to address bulk system reliability?

The time to prepare for integration of IEEE 1547-2018 compliant inverters is now.

Evolution of Technical Interconnection Capability, Test, & Verification Requirements

Common Practices

Leading Practices

Low DER Volume / Penetration

IEEE Std 1547™-2003/ UL 1741

- No voltage/reactive power exchange (power factor =1)
- No frequency response
- No voltage or frequency ride-through requirements
- No standardized communications capability or requirements
- Only DER equipment certification required, e.g., UL 1741 for inverters

Growing DER Volume / Penetration

IEEE Std 1547a™-2014/ UL 1741 SA

- No voltage/reactive power exchange (power factor =1)
- No frequency response
- Some voltage and frequency ride-through requirements
- No standardized communications capability or requirements
- Only DER equipment certification required, e.g., UL 1741 SA for inverters

Sustained DER Volume / High Pen.

IEEE Std 1547™-2018/ UL 1741 SB

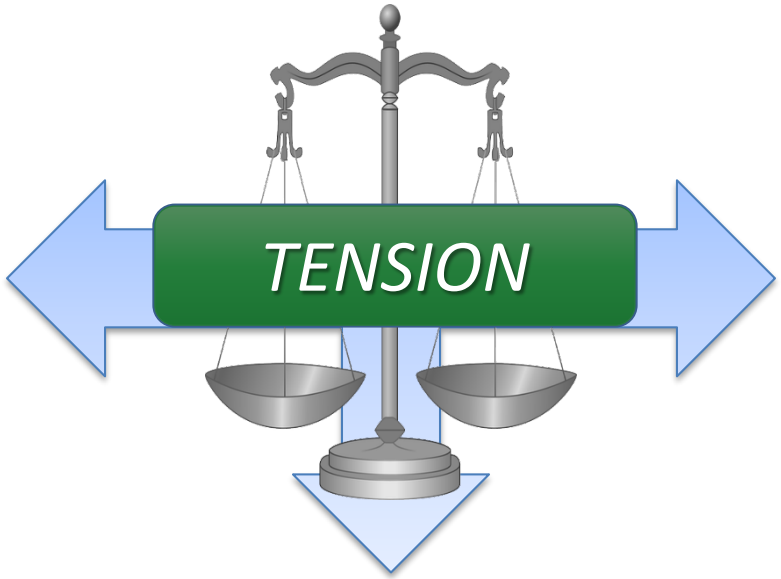
- Some voltage/reactive & active power exchange (power factor ≠1, volt/var, volt/watt)
- Mandatory frequency response
- Mandatory voltage and frequency, ROCOF, voltage phase jump ride-through requirements
- Mandatory communications capability requirements with one out of three standardized protocols (DNP3, 2030.5, SunSpec)
- Both DER equipment certification, e.g., UL 1741 SB, and some DER facility / system verification required, updated IEEE 1547.1 design and as-built evaluations and updated UL 1741 certification for inverters

Balancing Bulk & Distribution Grid Needs

Public EPRI-U Webinars
3002014545
3002014546
3002014547

Distribution Grid Side

- Short trip times
- Ride-through *with momentary cessation*
- Voltage rise concerns
- Islanding concerns
- Protection coordination
- Safety of line workers

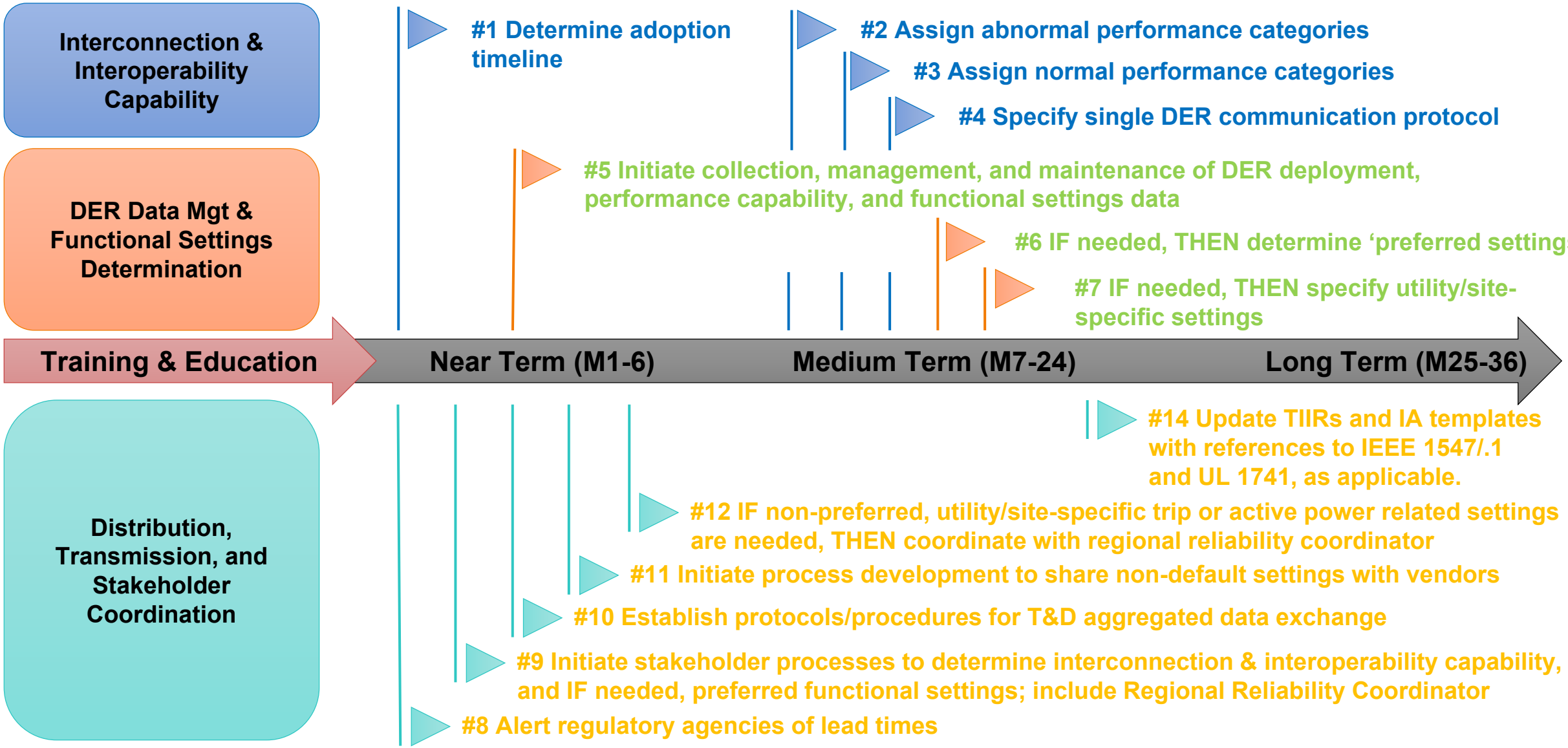


Increasing need for T&D Coordination

Bulk System Side

- Long trip times
- Ride-through *without* momentary cessation
- Reactive power support
- Dynamic voltage support during abnormal voltage
- Frequency support

Recommendations on IEEE Std. 1547-2018 Adoption for DER



Common Performance Category / Capability Assignments

Normal Performance Categories

Power Conversion	Prime Mover / Energy Source	Category
Inverter	Solar PV, Battery Energy Storage	Category B
	Wind	Category B
	Hydrogen Fuel Cell	Mutual Agreement
Synchronous generator	Bio-/landfill gas, fossil fuel, hydro, combined heat & power	Category A
Induction generator	Hydro	Mutual Agreement

Not in scope of NPCC guidance?

Abnormal Performance Categories

Power Conversion	Prime Mover / Energy Source	Category
Inverter	Solar PV, Battery Energy Storage	Category III [1] (amended)
	Wind	Category II
	Hydrogen Fuel Cell	Mutual Agreement
Synchronous generator	Bio-/landfill gas, fossil fuel, hydro, combined heat & power	Category I
Induction generator	Hydro	Mutual Agreement

[1] was Category II prior to Amendment

Regional Smart Inverter Settings To Address Bulk System Reliability

IA-URP
(site specific)

Utility-Required Profile (URP) for Specific Site
- Included in site-specific interconnection agreement (IA)
- May result from site-specific interconnection screenings

DU-URP
(distribution utility specific)

Utility-Required Profile for Distribution Service Area
- Included in interconnection agreement template
- Specific to Distribution Utility's practices, e.g., automatic re-closing, distribution circuit characteristics, operating practices

Regional-URP[1]
(state-wide or similar)

Utility-Required Profile for Region and/or ISO/RTO Reliability Region
- Consideration of distribution and bulk system impacts.
- May include some settings other than the SRD's default values

Adopted SRD[1] with Default Values
(state-wide or similar)

Source Requirements Document
- Preferably IEEE Std 1547-2018
- Otherwise: CAR21, HR14H, etc.

Database Scope

https://dersettings.epri.com/

[1] Based on decision by Authority Governing Interconnection Requirements (AGIR), may be a public utilities commission or similar

RTOs/ISOs Guidelines for IEEE Std 1547™-2018 Adoption

ISO New England

June 1, 2018

- Coordination between ISO-NE and the MA's utilities in the Massachusetts Technical Standards Review Group
- Reference to UL 1741 SA as a stopgap to verify DER ride-through capability in the interim
  - Harmonization of voltage & frequency trip settings with IEEE Std 1547-2018 ranges of allowable settings (Link)

PJM Interconnection

Jan 1, 2022

- Initiation of formal stakeholder proceedings in 2019
- Published PJM *Guideline for Ride Through Performance of Distribution-Connected Generators* for voluntary DER ride-through in Oct 2019 (PJM Website)
- Established minimum Ride-through requirements and trip time settings

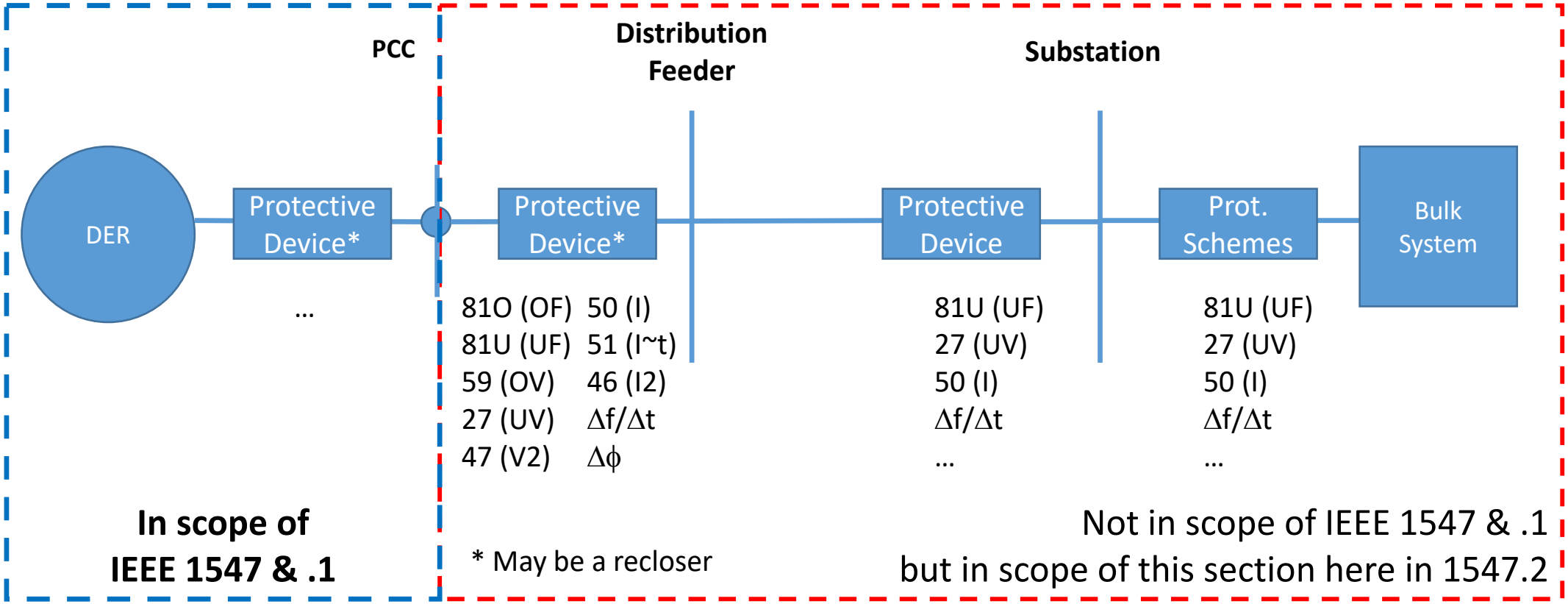
Midcontinent Independent System Operator (MISO)

date not specified

- MN PUC requested stakeholder process, see MISO's IEEE 1547 website
- Published the MISO Guideline for IEEE Std 1547-2018 Implementation (Link)
- Established the preferred regional Ride-through capabilities and trip time settings

See also NERC's Reliability Guideline
Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 (March 2020)

Coordination of Distribution Protection Practices with DER Ride-Through



Dynamic Voltage Support during Abnormal Voltage Conditions is not a Standardized Function

Steady State / Normal Conditions
(Inside Continuous Operating Region)

- Clause 5.3.3
  (Voltage-reactive power mode)
  - V reference: absolute or moving average
  - P-control, no integrator as in BPS IBR
  - Slower response, default open-loop response time: Category A: 5 s [1-90 s], Category B (inverters): 5 s [1-90 s]
- Industry Terms
  - “Dynamic Reactive Current”
  - “Dynamic VAr Support”
- Main purpose(s)
  - Power flow voltage profile at D & T
  - Post-contingency voltage collapse

Dynamic / Abnormal Conditions
(Outside Continuous Operating Region)

- Clause 6.4.2.6 (Dynamic voltage support)
  - V reference: moving average
  - P-control, no integrator
  - Faster response, within cycles
- Clause 6.4.2.7.2 (Restore output with dynamic voltage support) – continue 5 s post-fault
- Industry Terms
  - “Reactive current injection”
  - “Full dynamic grid support” (BDEW)
- Main purpose(s)
  - Improve voltage recovery, mitigate FIDVR
  - Prevent (legacy) DER or load from tripping

ITWG Specific Discussion

- ITWG to work with NYISO to create a regional guideline as recommended by NERC Reliability Guideline *Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018*?
  - *Abnormal performance category assignment*
  - *Functional settings impacting BPS (trip, frequency droop, etc.)*

- Work with distribution utilities regarding feeder & substation protection DER to coordinate with ride-through?

- Other Topics
  - Value of DER steady-state voltage/reactive power control?
  - Potential benefits & challenges of DER fault-related dynamic voltage support?

NYISO Reliability Guideline Could Provide Guidance to Distribution Providers

Together…Shaping the Future of Electricity

Jens Boemer
+1 206.471.1180
jboemer@epri.com

Jose Cordova
859-285922
jcordova@epri.com

Devin Van Zandt
+1 518.281.4341
dvanzandt@epri.com

Tom Key
(865) 218-8082
tkey@epri.com

Backup

Roadmap to Unlock Benefits of Advanced DER

This Activity

Specify **DER** Performance and Functional **Capabilities**

- e.g., adopt IEEE Std 1547-2018

Update interconnection agreements

- e.g., allow for **utilization** of DER capabilities

Design architecture and deploy DER **communication infrastructure**

- e.g., start with utility-scale DER before integrating retail-scale DER

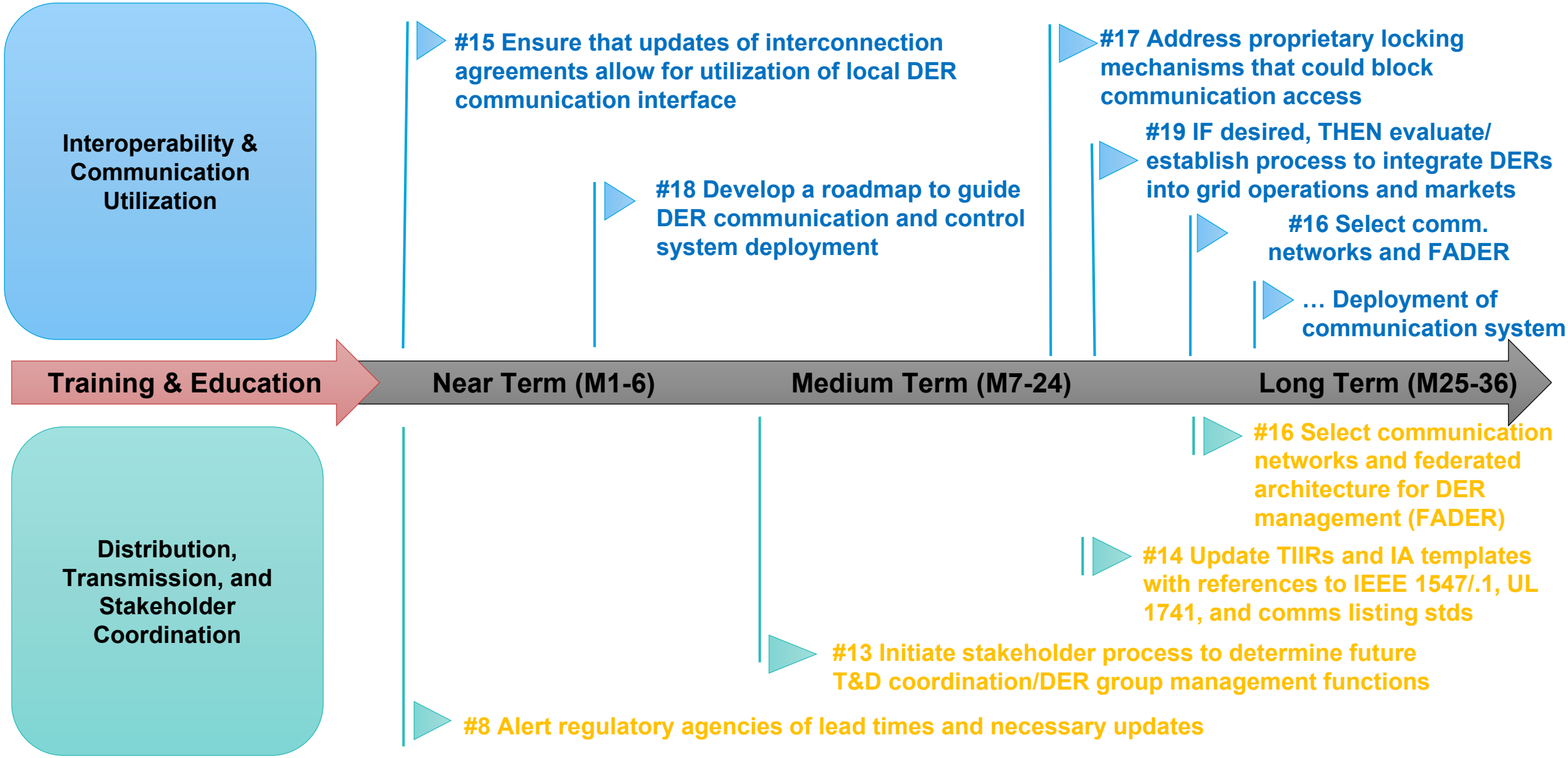
Specify DER Management System and select **DER Aggregations/Group Management** Functions

- e.g., codify messages to be exchanged across the T&D interface

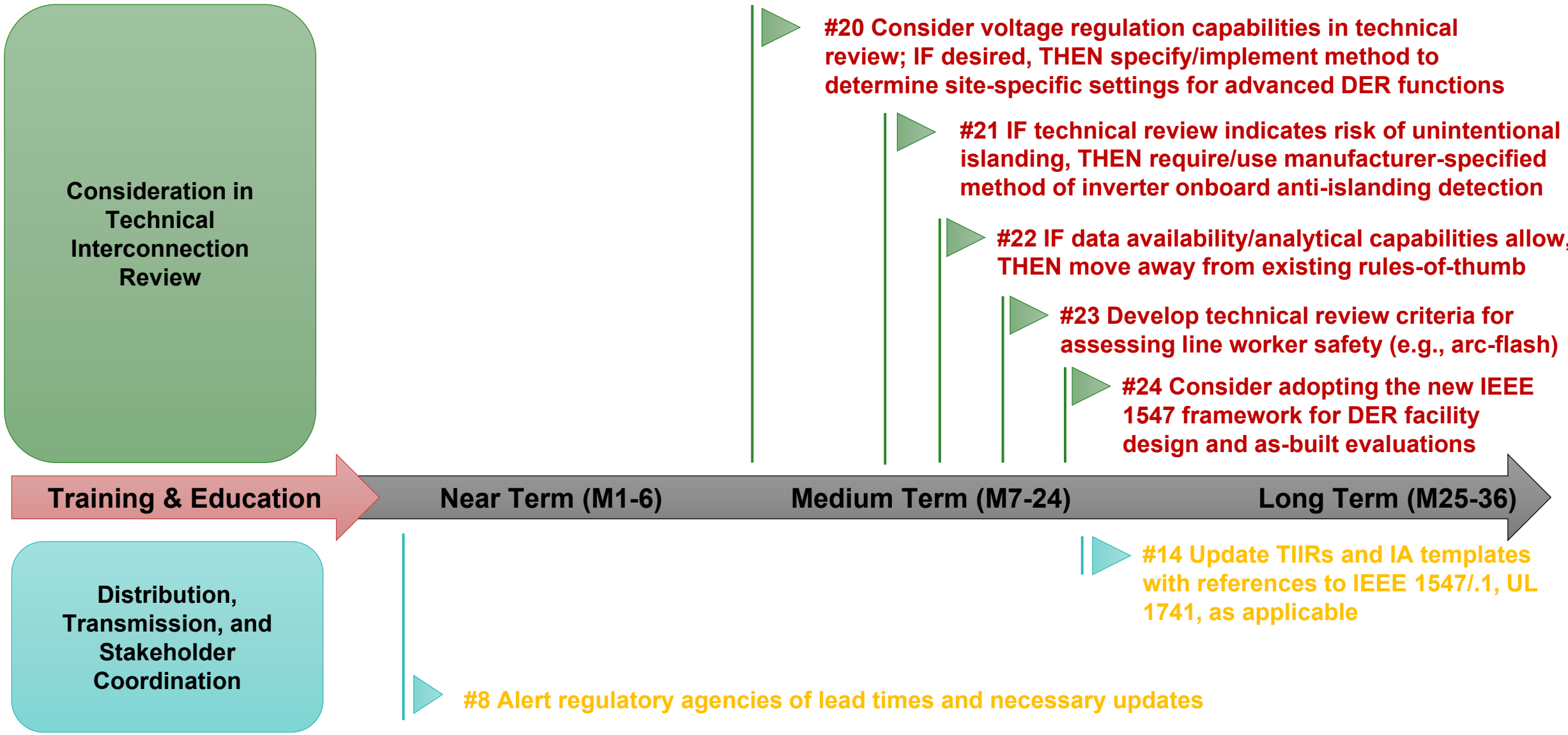
Design **market** and integrate DER into **grid operations**

- e.g., energy products, capacity products, re-dispatch, regulating reserves

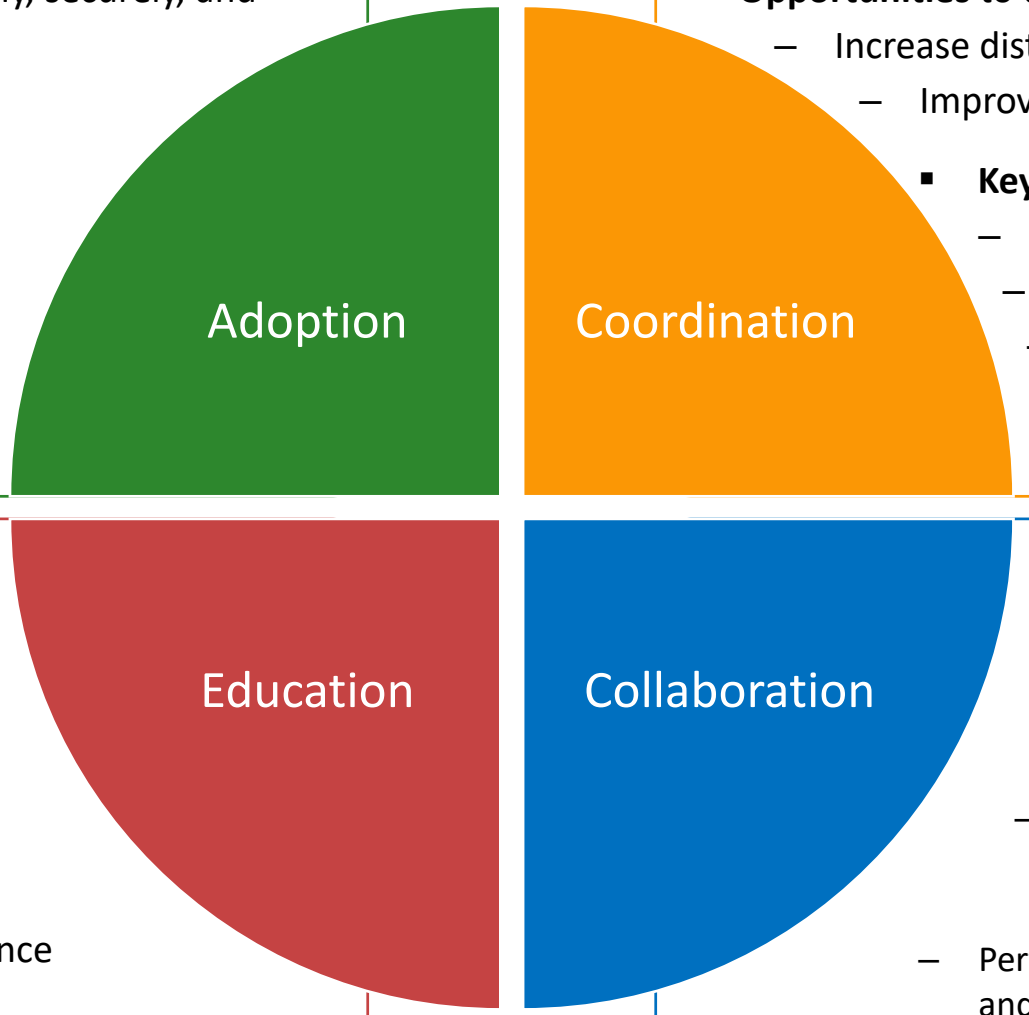
Recommendations on IEEE Std. 1547-2018 Utilization for DER



Recommendations on IEEE Std. 1547-2018 Utilization for DER



EPRI DER Integration Engagement



- **Opportunities** to integrate DER reliably, securely, and efficiently into the grid
- **Key Considerations**
  - Consider adoption of standard at state-level
  - Specify "preferred" utility-required DER functional settings
  - Specify certification for DER equipment and potentially verification for DER facilities

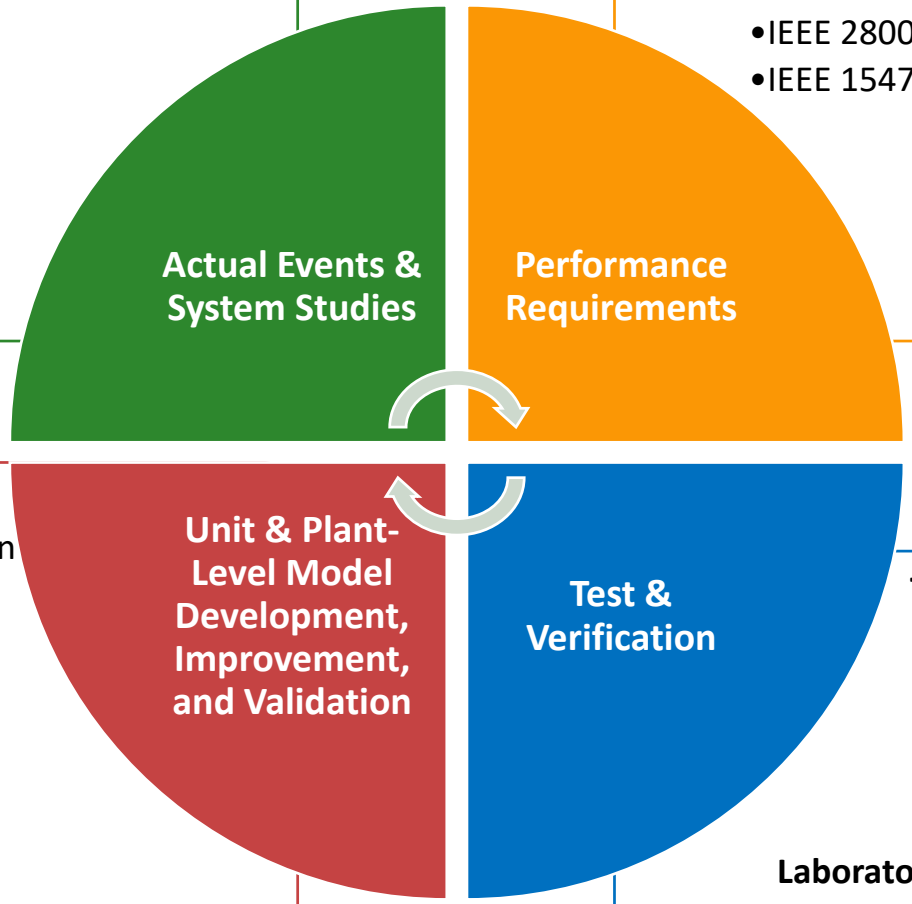
- **Opportunities** to utilize advanced DER capabilities
  - Increase distribution hosting capacity
  - Improve bulk system reliability
- **Key Considerations**
  - Functional settings
  - Performance categories
  - Communication interface
- **Coordinate across T&D**

- **Opportunities** to engage a broad set of stakeholders
- **Key Considerations**
  - Understand the key implications of the changes to the standard
  - Engage all parties in the education process
  - Learn how the standard may influence past regulatory decisions

- **Opportunities** to work collaboratively to solve issues
- **Key Considerations**
  - Engage state and federal agencies to advance understanding
  - Developers, utilities, and regulators collaborating to solve interconnection challenges
  - Perform research to understand best practices and develop policy objectives

Continuation Model Development, Improvement, and Validation of Inverter-Based Resources (Generating & Storage)

- **Actual Events / Field Measurements**
  - Blue Cut, Canyon fire events
  - Duke event
  - Plant-level performance
- **Modeling Case studies**
  - Utilities –Duke, Entergy, CenterPoint
  - ISOs - CAISO, SPP



Interconnection standards
- IEEE 2800
- IEEE 1547

Technical Interconnection Requirements
- Transmission
- Distribution

Objectives
- Plant-level verification for interconnection
- Plant-level model for integration studies

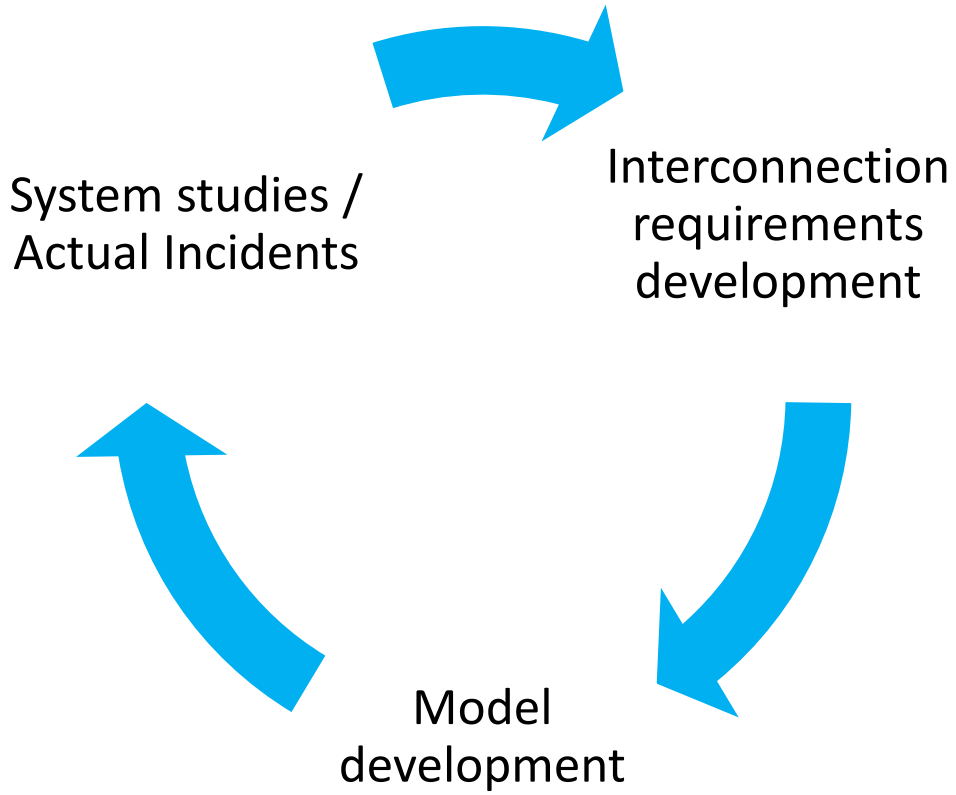
Features
- Existing/required features
- New/optional features

Stakeholder Engagement
- EPRI transmission & distribution members
- Industry engagement: WECC, NERC, IEEE
- Software vendor engagement

Test & Verification Standards
- IEEE 2800.1
- IEEE 1547.1 / UL 1741 SB
- UL 1741 CRD Power Control Systems
- MOD-032

Laboratory Type/Unit Testing
- Smaller scale units
- Larger scale units

EPRI Transmission Research Related to DER



IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

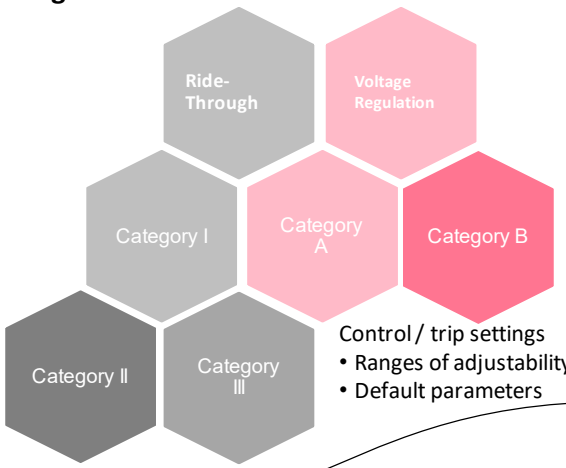
Available

IEEE Standards Coordinating Committee 21

Sponsored by the
IEEE Standards Coordinating Committee 21 on Fuel Cells, Pl
Generation, and Energy Storage

Also refer to supplemental project notice on "Navigating DER Interconnection Standards and Practices" (3002012048)

Normal and abnormal operating performance categories



Control / trip settings
- Ranges of adjustability
- Default parameters

Provide guidelines and tools to create a technical basis for assignment of `abnormal performance categories' specified by IEEE Std 1547-2018.

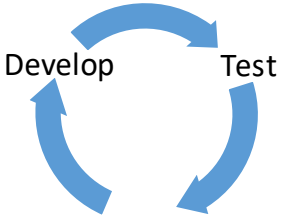
DOE PV-MOD: Project Overview

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

1 Resource Characterization

- Existing Models
- Lab Tests
- Field Data

2 Model Development



- Unit, Plant & Aggr. Feeder/BTM

3 Model Commercialization

- **Stability** (PSS/E, PSLF, …)
- **Protection** (CAPE, CYME, …)
- **EMT** (EMTDC, EMTP-RV, …)
- **QSTS** (CYME, Synergi,…)

4 Adaptive Protection Application

- Design
- HIL Testing

5 Demonstration

2020

- Field data collection
- Smaller kW inverter characterization (lab testing)
- Gap analysis of PV models (dynamic, short-circuit, EMT/HIL, PQ)
- Inverter models for quasi-static time series (QSTS)

2021

- Grid scale inverter characterization (NREL)
- Develop initial versions of refined or newly developed models
- Provide model specs to vendors
- Model validation using the newly developed models

2022

- Complete model validation
- Refine models based on validation
- Finalize specs for models & work with vendors

Validated; publicly available models for various types of studies, reports detailing the work, close collaboration with industry stakeholders (NERC, WECC, IEEE etc.)

Dynamic Voltage Support is Only an Optional Requirement in IEEE 1547-2018

Function Set	Advanced Functions Capability	IEEE 1547-2003	IEEE 1547a-2014	IEEE 1547-2018	Rule 21 (Phases)	Rule 14H & UL SRDv1.1
All	**Adjustability in Ranges of Allowable Settings**	X	√	‡		
Monitoring & Control	**Ramp Rate Control**				‡ (P1)	‡
	Communication Interface			‡	‡ (P2)	‡
	Disable Permit Service (Remote Shut-Off, Remote Disconnect/Reconnect)			‡	‡ (P3)	‡
	Limit Active Power			‡	‡ (P3)	
	Monitor Key DER Data			‡	‡ (P3)	
Bulk System Reliability & Frequency Support	**Frequency Ride-Through (FRT)**	X	√	‡	‡ (P1)	‡
	Rate-of-Change-of-Frequency Ride-Through			‡	!!!	!!!
	Voltage Ride-Through (VRT)	X	√	‡	‡ (P1)	‡
	VRT of Consecutive Voltage Disturbances			‡	!!!	!!!
	Voltage Phase Angle Jump Ride-Through			‡ [23]	!!!	!!!
	Dynamic Voltage Support during VRT			√	[‡ (P3)]	
	Frequency-Watt	X	√	‡	‡ (P3)	‡
Legend:	X Prohibited, √ Allowed by Mutual Agreement, ‡ Capability Required					
	[…] Subject to clarification of the technical requirements and use cases, !!! Important Gap					

The DER Performance Capability & Functional Settings Challenge

- Central database(s)
  - Includes only public, non-proprietary information otherwise available in utility interconnection documents
  - EPRI: https://dersettings.epri.com
- EPRI Phase 1 (2019):
  - Storage of *.csv files + metadata, search functionality
  - Need for external DER Settings Form (Excel) to validate settings and create *.csv files
- EPRI Phase 2 (2020+):
  - Verification of uploaded settings
  - Data mining, visualization