GMLC Technical Assistance to States

DER Interconnection Workshop

NREL Team: Michael Ingram, David Narang, and Xiang Li
Guest Speakers: Caitlin Marquis, Debbie Lew, and Sydney Forrester

Presented on December 15, 2022
Revised for publication on January 4, 2023

Agenda

- Introduction & Background (David Narang)
- **Caitlin Marquis**: FERC Order 2222 Overview & Implications for PUCs
- **Debbie Lew**: DER Aggregation & Integration Into Wholesale Markets & Operations
- **Sydney Forrester**: Allowing Aggregations & FERC Order 719
- **David Narang**: Adoption of DER Performance Standards to Support DER Aggregation
- Conclusion & Next Steps

Workshop Goals

1. Increase awareness of existing materials and support to help state public utility commissions (PUCs) move forward on distributed energy resource (DER) interconnection activities.

2. Help participants make connections to colleagues with similar challenges (and solutions!).

3. Help the GMLC/NREL project team understand context and implementation challenges.

Workshop Origin: GMLC Technical Assistance to State Public Utility Commissions

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

Purpose: Provide customized support on issues specific to state's needs and unique situations.
Approach: Work with awardees on content and delivery method to maximize the efficacy of the TA
Budget/scope: $2.25M across 37 different technical engagements in more than 20 states.

Equity & Justice

- Grid Planning
- Utility Ratemaking

DER Adoption & Integration

- DER Adoption
- Interconnection Process
- Hosting Capacity
- Utility Regulation

Grid Planning

- Integrated Resource
- Comprehensive System
- Load Forecasting

Resilience

- Microgrids
- Regulation & Policy

Utility Regulation

- Performance-Based Ratemaking

NREL at a Glance

2,926

Workforce, including

219 postdoctoral researchers,
60 graduate students,
81 undergraduate students

World-class

facilities, renowned technology experts

More than 900

Partnerships

with industry, academia, and government

Campus

operates as a living laboratory

Renewable Power

Solar

Wind

Water

Geothermal

Sustainable Transportation

Bioenergy

Vehicle Technologies

Hydrogen

Energy Efficiency

Buildings

Advanced Manufacturing

Government Energy Management

Energy Systems Integration

Grid Integration

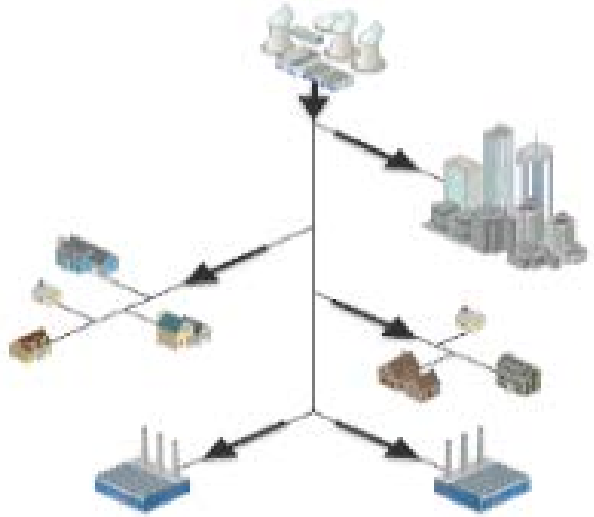
Hybrid Systems

Security and Resilience

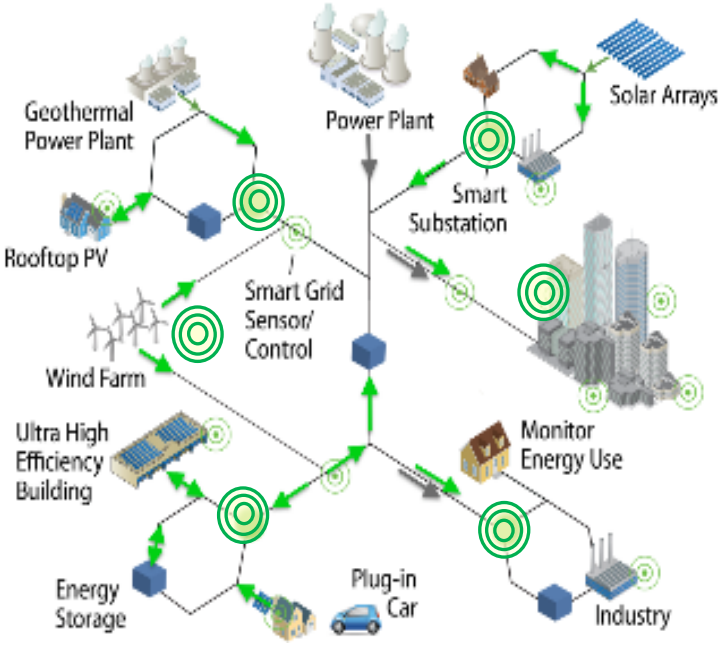
As we go through the discussion today, consider your own context.

What is your (state's) vision for your future power system?

Current Power System



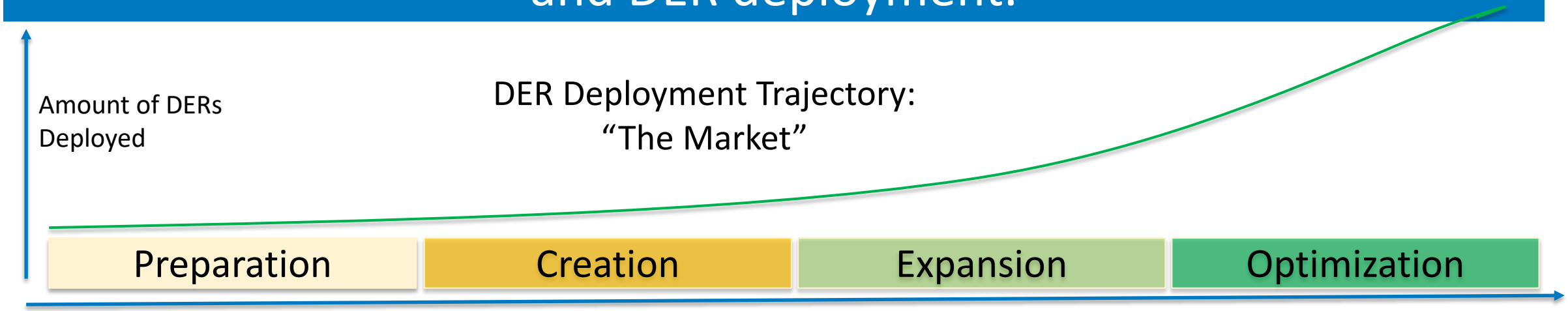
Future Power System



Potential new capabilities and elements:

- Improved resiliency to weather events
- New energy technologies (e.g., energy storage)
- **New markets and services**
- Improved communications and controls (e.g., AMI, ADMS)
- Electrification of other sectors (e.g., transportation).

Consider your own coordination needs between policy/regulation and DER deployment.



Example Policy Stack

Preparation	Creation	Expansion	Optimization
• Address institutional barriers. • Establish market access (e.g., enabling legislation/regulation for third-party ownership). • Increase transparency in permitting process and fees. • Establish legislative/regulatory rules for compensation (e.g., net metering). • Revise building energy codes to support DER deployment. • Revise interconnection rules?	• Establish legislative/regulatory mandates (e.g., renewable portfolio standards). • Establish financing mechanisms and funding sources. • Encourage pilot and demonstration projects ("regulatory sandbox"?). • Revise interconnection rules?	• Direct monetary incentives for specific projects (e.g., rebates, grants, tax incentives, production incentives for DER energy, feed-in tariffs). • Remove siting restrictions. • Ensure broad market access (legislative action needed?). • Streamline permitting. • Revise interconnection rules?	• New types of DERs or new applications of existing DERs? • New actors or new roles for existing actors? • Revise interconnection rules?

References:
Strategic Sequencing for State Distributed PV Policies: A Quantitative Analysis of Policy Impacts and Interactions, V. A. Krasko and E. Doris, 2012, http://www.osti.gov/servlets/purl/1054826/.
"Policy Building Blocks: Helping Policymakers Determine Policy Staging for the Development of Distributed PV Markets," E. Doris, 2012, https://www.nrel.gov/docs/fy12osti/54801.pdf.

Basis of this discussion: DER performance capabilities have advanced beyond traditional self-serve use.

Modern DER assets could provide a range of grid services that may improve system flexibility and reliability and reduce capital and operating costs.

Market-Level Functions (Bulk System)
Examples: system events, market orders/requests
Grid services—energy-related, regulation, reserve, ramping, frequency response

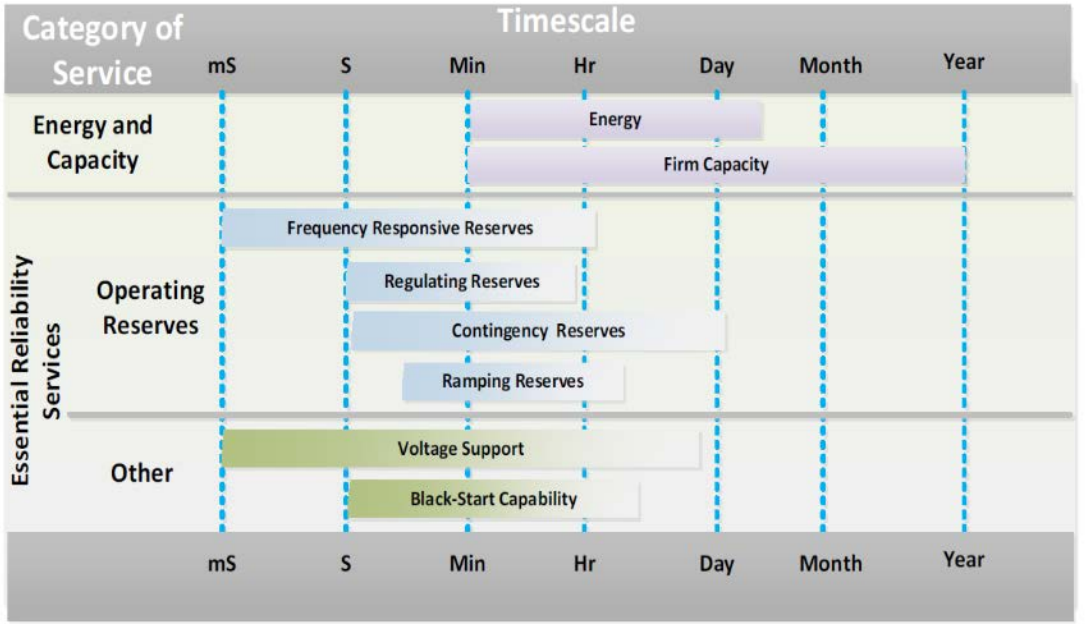
Operation-Level Functions (Distribution Grid)
Examples: local events, dispatch/aggregation
Grid services—energy-related, distribution voltage management

Electrical interface (interconnection)

Communications interface (interoperability)

Grid-Edge Functions (Local Facility / Devices)
Examples: voltage/frequency control, device specifications
Grid services—distribution voltage management

Reference:
"GMLC Survey of Distributed Energy Resource Interconnection and Interoperability Standards," D. Narang et al., 2021, https://www.nrel.gov/docs/fy21osti/77497.pdf.



Reference:
An Introduction to Grid Services: Concepts, Technical Requirements, and Provision from Wind, P. Denholm, Y. Sun, and T. Mai, 2019, https://www.nrel.gov/docs/fy19osti/72578.pdf.

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Content under separate cover

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Adoption of DER Performance Standards to Support DER Aggregation

Michael Ingram, Xiangkun Li, and David Narang
NREL Power Systems Engineering Center

DER Interconnection Workshop

Note: These slides were originally presented in part at the NARUC-NASEO Distributed Energy Resources Integration & Compensation Initiative Workshop in Washington D.C. on September 21, 2022

Key DER Capabilities That Support Aggregation

Topic Highlight

Complementing North American Reliability Standards

		Performance	Test & Verification & Model Validation
FERC/NERC?	**Transmission**	• FERC orders • NERC reliability standards & guidelines	• NERC compliance monitoring & enforcement
NARUC/State PUCs?	**Sub-Transmission**	• IEEE Std 2800-2022	• IEEE P2800.2 (in process)
NARUC/State PUCs?	**Distribution** (for DERs)	• IEEE Std 1547-2018 • IEEE Std 1547a-2020 ✓	• IEEE 1547.1-2020 • UL 1741 (SB) • IEEE ICAP ✓

Only when <u>adopted</u> by the appropriate authorities, IEEE standards become mandatory

Slide courtesy of EPRI/IEEE Std 2800 leadership team

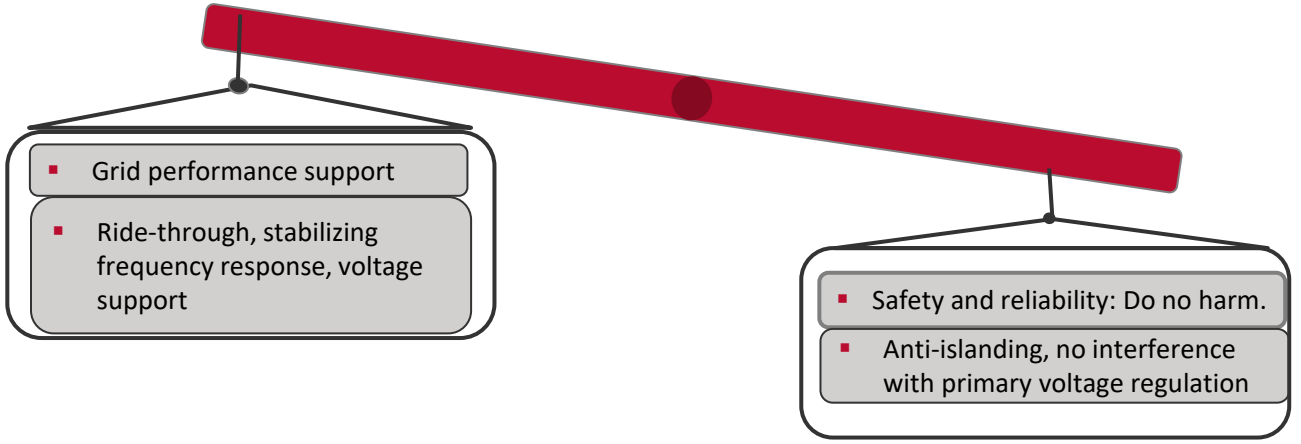
Grid Support Under Abnormal Grid Conditions

(Support for Bulk Power System Reliability)

How can DERs affect bulk power system reliability?

Aggregate performance:

- DER inverters are software-controlled systems.
- Unlike conventional rotating generators, software-controlled DERs can exhibit an "orchestral" response to abnormal conditions.
- At higher penetrations, computer models indicated that the aggregate DER response to abnormal voltage or frequency can contribute to the (in)stability of the bulk power system.
- This possibility prompted inclusion of ride-through requirements in IEEE Std 1547-2018.



Stakeholders for ride-through settings include "regional reliability coordinators" and the local utilities.

Grid Support Under Normal Grid Conditions

IEEE Std 1547-2018 Active Voltage Regulation Capability Requirements

Category A

Meets minimum performance capabilities needed for area electric power system (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.

Mandatory Voltage Regulation Capabilities	Cat A	Cat B
Constant Power Factor Mode	✓	✓
Constant Reactive Power Mode ("reactive power priority")	✓	✓
Voltage-Reactive Power Mode ("Volt-VAR"): • In this mode, the DER **actively controls its reactive power output as a function of voltage**. • Intended to supply VAR only when needed, push local voltage back toward nominal.	✓	✓
Active Power-Reactive Power Mode ("Watt-VAR," "P-Q") • In this mode, the DER actively controls the reactive power output as a function of the active power output. • Not widely discussed/deployed to date.	not required	✓
Voltage-Active Power Mode ("Volt-Watt") • In this mode, the DER actively ***limits*** the DER maximum ***active power*** as a function of the ***voltage***. • This mode can reduce the prevalence of very high voltages.	not required	✓

- *IEEE Std 1547-2018: "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 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 (min 44% injecting, 25% absorption (low), 44% (high)).
- Settings can be adjusted locally or remotely.

DER Interoperability

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

(IEEE Std 1547-2018 by reference to IEEE 2030)

Value of interoperability:

- Improves situational awareness/monitoring
- Provides more data for modeling and simulation
- Enables standardized control and advanced control
- Provides data for modeling and simulation.
- **Enables "orchestrated response," e.g., aggregation.**

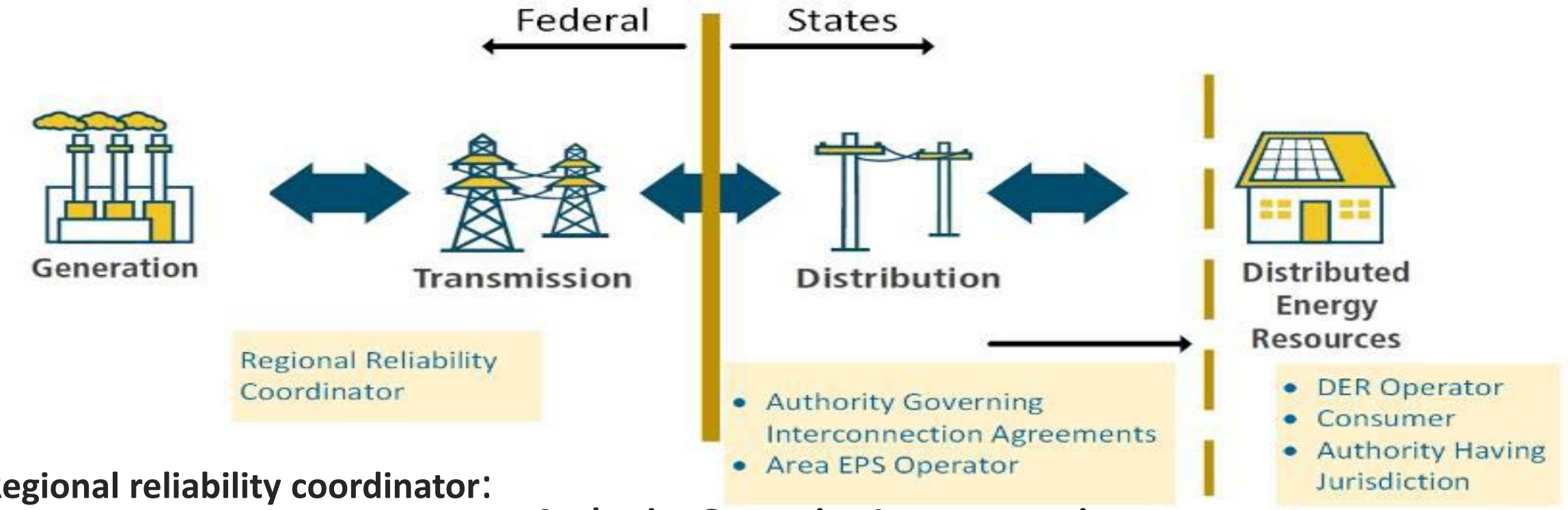
IEEE Std 1547-2018 support/ requirements for interoperability:

- Communications requirements
- Identified functions to communicate
- Scope of interoperability
- Protocols.

Increased Capabilities Come With Increased Complexity

Topic Highlight

IEEE Std 1547 Context—Key Terms and Entity Jurisdictional Boundaries



Regional reliability coordinator:
Maintains real-time operating reliability of bulk power system within a reliability coordinator area

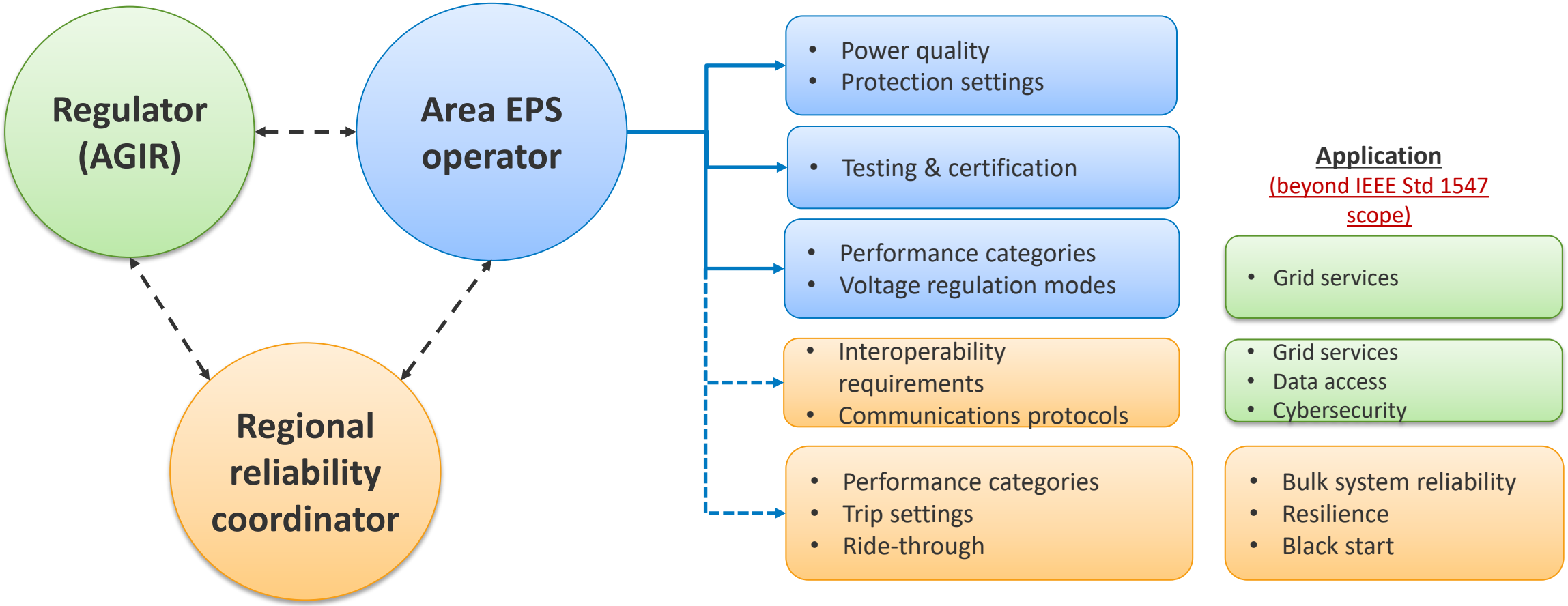
Authority Governing Interconnection Requirements (AGIR):
Codifies, communicates, administers, and enforces policies and procedures for allowing electrical interconnection of DERs to the grid.
Examples: State regulatory agency, public utility commission, municipality, cooperative board of directors

Authority having jurisdiction: Has rights to inspect and approve of the design and construction.
Examples: City or county inspectors

Images from DOE

Note: For a good discussion on bulk power system reliability, see the Federal Energy Regulatory Commission's (FERC's) *Reliability Primer*, https://www.ferc.gov/media/2135.

DER Capabilities Required in IEEE Std 1547 Cross Jurisdictional Boundaries



Education and Support Resources

Topic Highlight

NREL's IEEE Std 1547-2018 Resources Website

nrel.gov/grid/ieee-standard-1547

An online platform with educational resources to aid stakeholders in the successful adoption and implementation of IEEE Std 1547-2018.

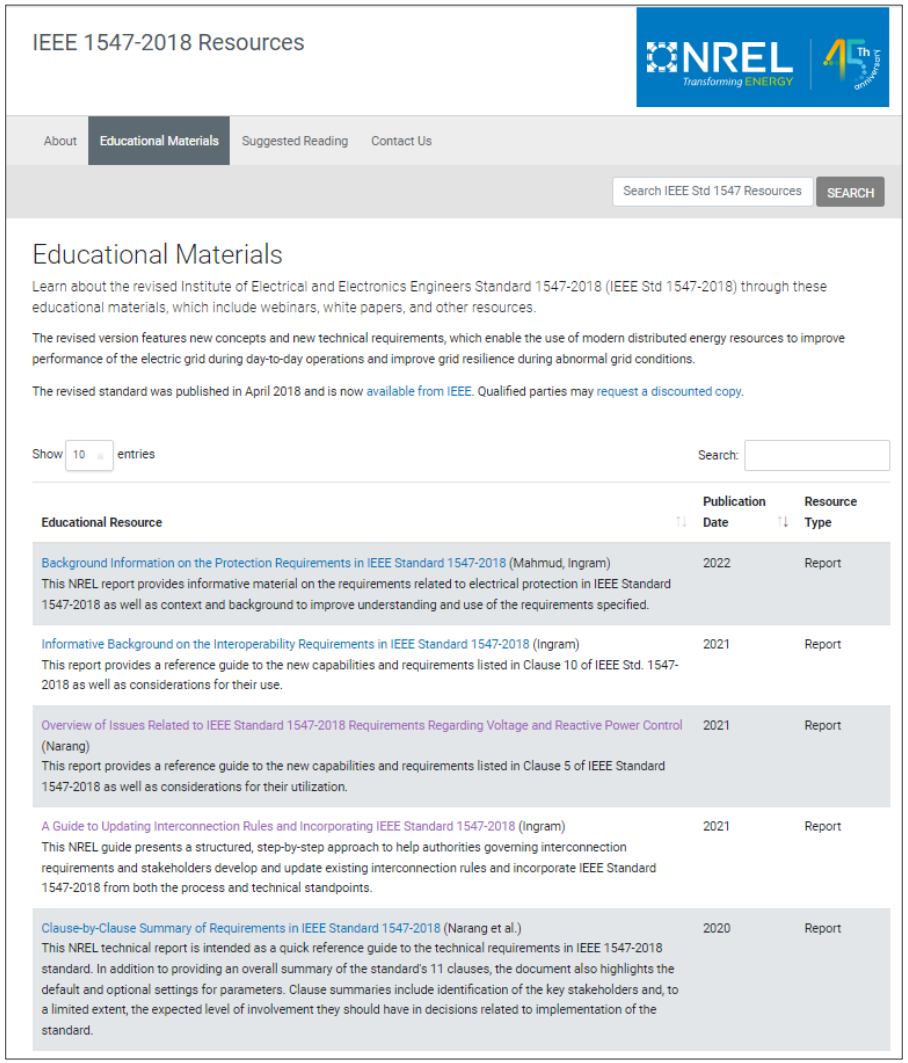
Sponsored by:
Solar Energy Technologies Office

Partners and advisors:
- Sandia National Laboratories
- Institute of Electrical and Electronics Engineers
- Electric Power Research Institute
- National Association of Regulatory Utility Commissioners
- National Rural Electric Cooperative Association
- Interstate Renewable Energy Council
- Regulatory Assistance Project
- Western Interstate Energy Board


Illustration by Fred Zietz, NREL

NREL's well-catalogued and publicly accessible online platform includes **presentations, industry white papers, and topic-specific NREL technical reports for utilities, states, solar developers, transmission operators, and other stakeholders.**

Resources on the Site



nrel.gov/grid/ieee-standard-1547

NREL's Guide for Updating Interconnection Rules

A Guide to Updating Interconnection Rules and Incorporating IEEE Standard 1547-2018 presents a structured, step-by-step approach to help government authorities that oversee interconnection requirements and other stakeholders develop and update interconnection rules. The NREL-published report considers the incorporation of the new standard from both process and technical standpoints.

- There are three main sections of the report:

- Key considerations include:
  - Has the governing authority sufficiently identified motivations for updating the interconnection rule? How do the identified technical requirements relate to the desired outcome?
  - Has the governing authority allowed for the use of DER capabilities (even if they are to be used in the future)?

Any state or local jurisdictions that are interested in adopting IEEE Std 1547-2018 should consult this resource!

Find the full report on NREL's IEEE Std 1547-2018 resources website or at nrel.gov/docs/fy22osti/75290.pdf.

IEEE Standards Committee 21 (SC21) Resources and Outreach

- **Public website on IEEE Std 1547**: http://sites.ieee.org/sagroups-scc21/standards/1547rev/.
  - Discount/free copies of the standard for select stakeholders (e.g., regulators)
  - Education and training/reading material—papers, webinars
  - "Approved" presentation content for subject matter experts
  - Catalog of ISO/RTO T&D coordination activities
  - State activity map (maintained approx. quarterly)
  - Inverter rollout timeline ("regularly" maintained).
- **Informal industry/stakeholder coordination calls (quarterly)**
- **Coordination with other IEEE societies, committees, and related standards (constant).**

Additional Resources

National Association of Regulatory Utility Commissioners (NARUC):

- Home page: https://www.naruc.org/
- Publications: https://www.naruc.org/cpi-1/publications/

Interstate Renewable Energy Council (IREC):

- Blog: https://irecusa.org/blog/tag/ieee-1547/
- "Decisions Options Matrix for IEEE 1547-2018 Adoption": https://irecusa.org/resources/decision-options-matrix-for-ieee-1547-2018-adoption-3/

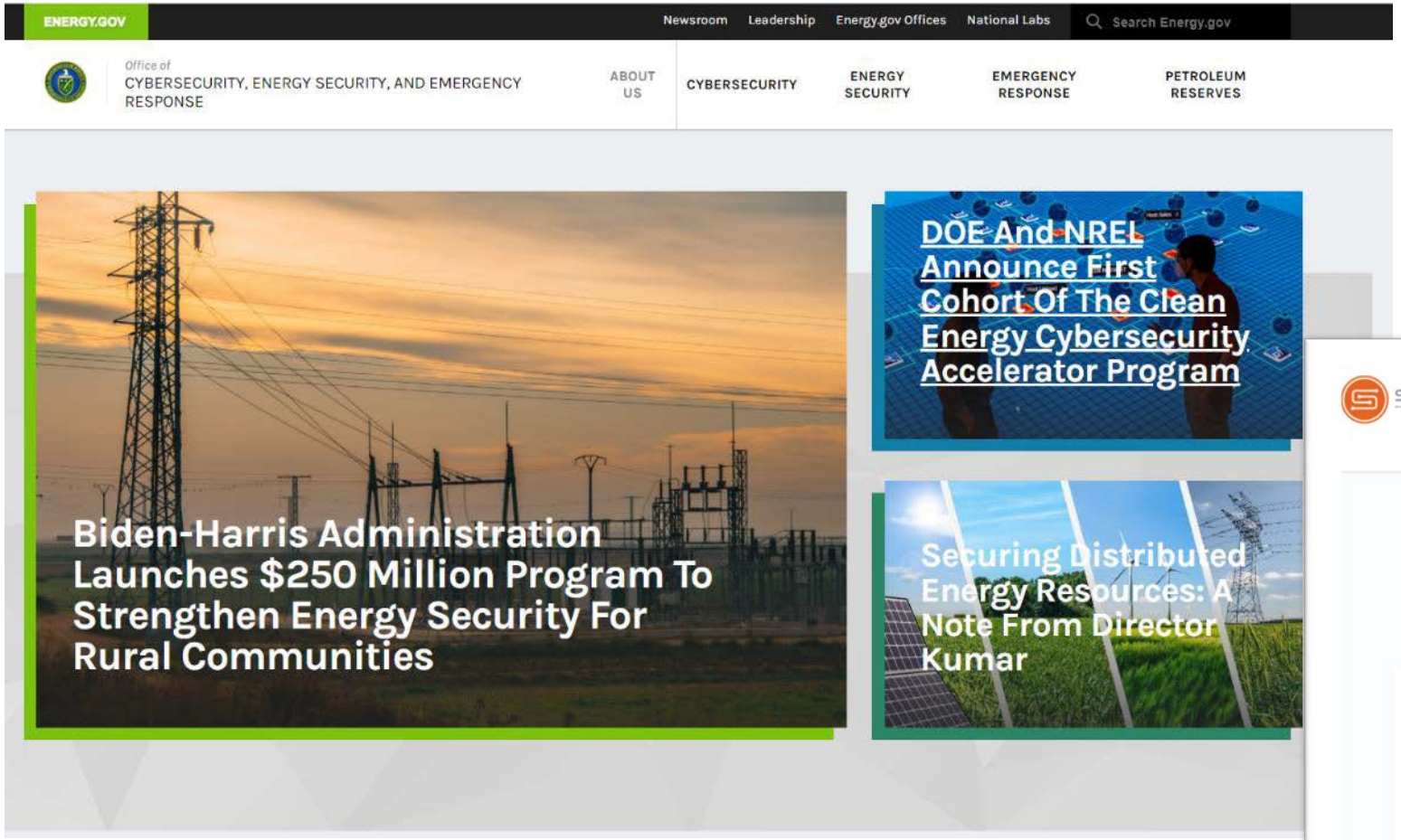
Electric Power Research Institute (EPRI):

- Training by EPRI U: https://www.epri.com/epri-u
- *DER Aggregation Participation in Electricity Markets: EPRI Collaborative Forum Final Report and FERC Order 2222 Roadmap*: https://www.epri.com/research/products/000000003002020599

North American Electric Reliability Corporation (NERC):

- "Quick Reference Guide: Distributed Energy Resource Activities": https://www.nerc.com/pa/Documents/DER_Quick%20Reference%20Guide.pdf
- *Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018*: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Guideline_IEEE_1547-2018_BPS_Perspectives.pdf
- *Distributed Energy Resources: Connection Modeling and Reliability Considerations*: https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report.pdf

Cybersecurity



https://www.energy.gov/ceser/office-cybersecurity-energy-security-and-emergency-response

Other activities:
https://www.nist.gov/programs-projects/cybersecurity-smart-grid-systems

https://sunspec.org/cybersecurity-work-group/

INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

Website:
energy.gov/i2X

An EERE collaboration between SETO and WETO

i2X Technical Assistance

Goal: To provide access to various interconnection technical assistance opportunities to support our partners in their implementation of developed reforms.

- **Interconnection office hours—Fridays:**
  - Direct access to i2X leadership
  - **"Consultation" phone calls available to any interconnection stakeholder.**

- **Preliminary i2X working groups:**
  - Energy Justice Working Group
  - **IEEE Std 1547-2018 Adoption Support Working Group**
  - Experienced peer learning webinar series.

- **Additional topics for consideration:**
  - Implementing queue management methods
  - Accelerated tool development and deployment
  - Best practices and training.

- **Others? Suggest a topic!**

National Renewable Energy Laboratory – Golden, Colorado
Photo: Dennis Schroder

Thank You

David Narang | David.Narang@NREL.gov
Michael Ingram | Michael.Ingram@NREL.gov
Xiang Li | Xiangkun.Li@nrel.gov

www.nrel.gov

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NREL
Transforming ENERGY

Next for us

- Continued collaboration with our GMLC interconnection cohort for the next workshop
- Continued collaborative efforts with partners on all the topics discussed.

Discussion

www.nrel.gov