GMLC Technical Assistance to States

DER Interconnection Workshop

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

12/15/2022

Agenda

- Introduction and background (Dave Narang - 5 min)
- FERC Order 2222 Overview and Implications for PUCs (Caitlin Marquis - 30 min)
- DER Aggregation and Integration into Wholesale Markets and Operations (Debbie Lew - 30 min)
- Allowing Aggregations and FERC Order 719 (Sydney Forrester - 30 min)
- Using the IEEE 1547 Standard to Support DER Aggregation (David Narang - 15 min)
- Conclusion and Next Steps (David Narang - 5 min)

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- **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 (David Narang)

Workshop Goals

1. Increase awareness of existing materials & support to help state PUCs move forward on DER interconnection activities

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

3. Help 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 situation
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 over 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

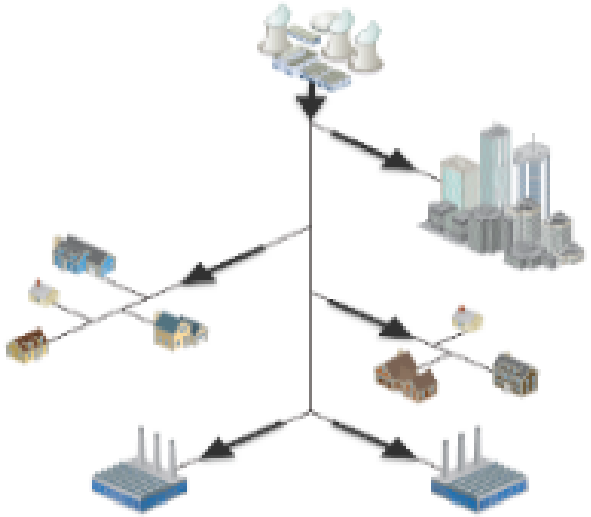
Hybrid Systems

Security and Resilience

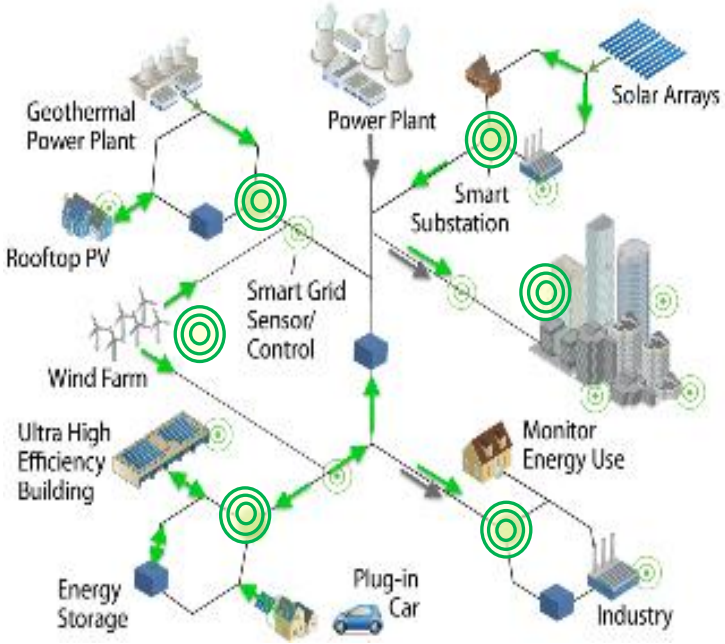
As we go through the discussion today, consider your own context.

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

Current Power System



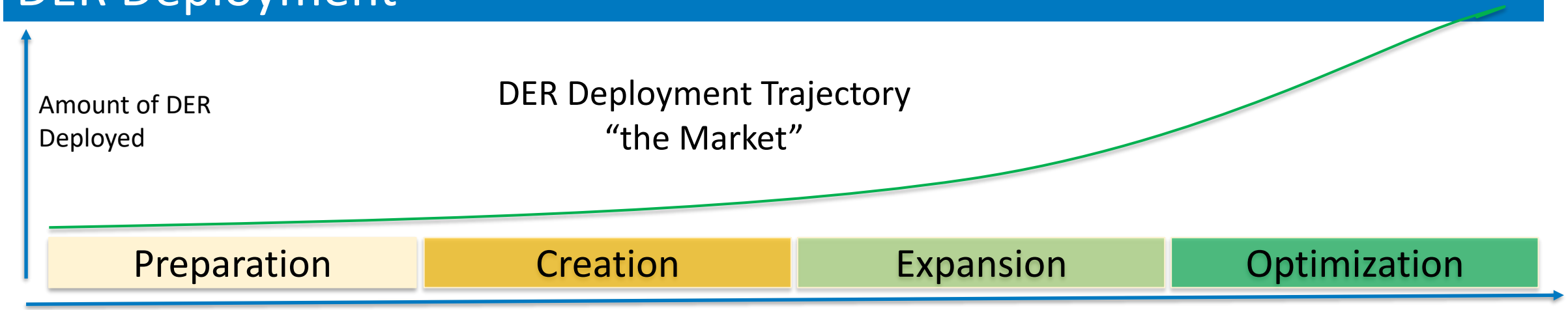
Future Power System



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 between policy/regulation and DER Deployment



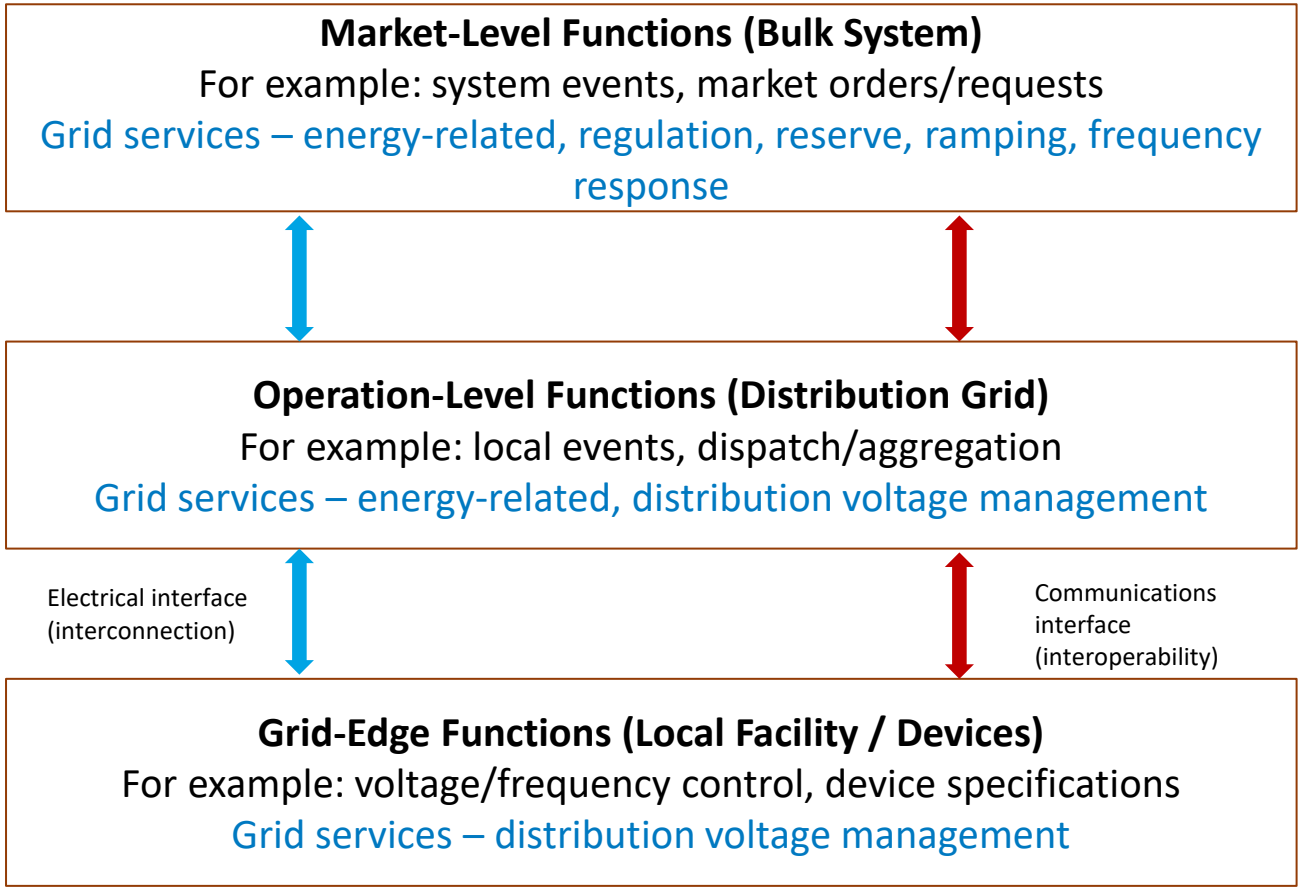
Example Policy Stack

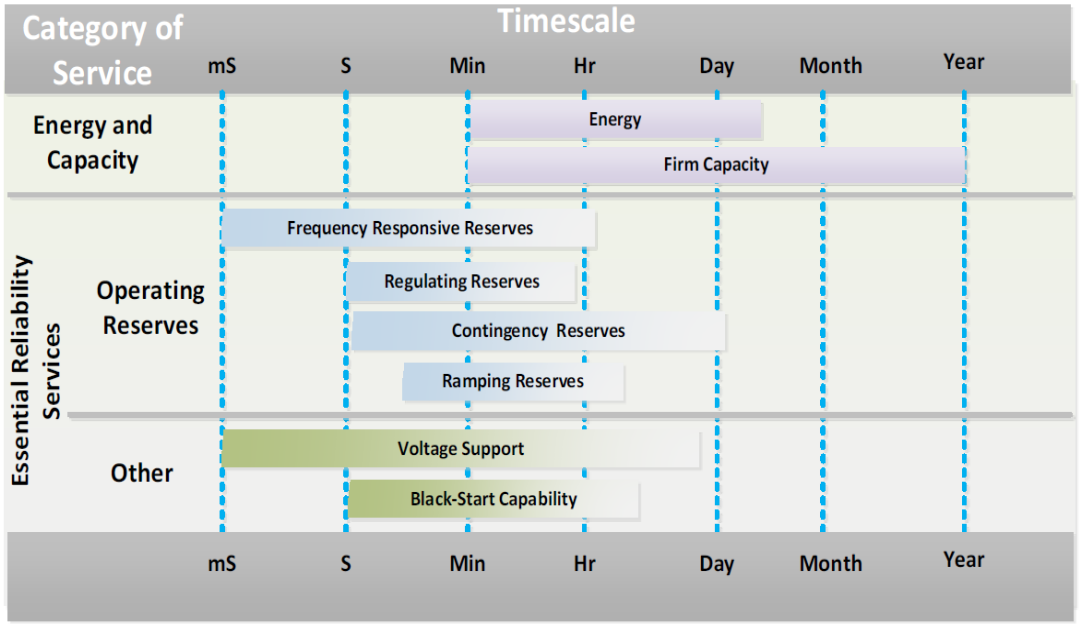
Preparation	Creation	Expansion	Optimization
• Address institutional barriers • Establish market access (e.g., enabling legislation/regulation for third-party ownership) • Increase transparency in permitting process and fees, • Establish legislative/regulatory rules for compensation (e.g., net metering) • Revise building energy codes to support DER deployment • Revise interconnection rules?	• Establish legislative/regulatory mandates (e.g., Renewable Portfolio Standards (RPS) • Establish financing mechanisms and funding sources. • Encourage pilots & 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, reliability, and reduce capital and operating costs.





Denholm, Sun, and Mai. "*An Introduction to Grid Services: Concepts, Technical Requirements, and Provision from Wind*"

Narang et al. "*GMLC Survey of Distributed Energy Resource Interconnection and Interoperability Standards*".

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Order No. 2222 – Preparing the Distribution Grid and Retail Programs to Maximize the Value of DERs for Customers

NREL DER Interconnection Workshop

December 15, 2022

About AEE

- Advanced Energy Economy (AEE) is a national association of businesses that are making the energy we use secure, clean, and affordable. We work to accelerate the move to 100% clean energy and electrified transportation in the U.S.
- Advanced energy encompasses a broad range of products and services that constitute the best available technologies for meeting energy needs today and tomorrow. These include energy efficiency, demand response, energy storage, solar, wind, hydro, nuclear, electric vehicles, biofuels and smart grid.
- AEE represents more than 100 companies in the $238 billion U.S. advanced energy industry, which employs 3.2 million U.S. workers.

Goals for today

- **Brief overview of FERC Order No. 2222 and Status Update**
- **Introduce AEE-GridLab Report and Summarize Recommendations**
  - "FERC Order 2222 Implementation: Preparing the Distribution System for DER Participation in Wholesale Markets" (January 2022)
- **Discuss Dual Participation in Retail and Wholesale Markets**

Note: "RERRA" = Relevant Electric Retail Regulatory Authority (i.e., states, municipalities, cooperative utility boards)

Overview of Order No. 2222, Issued Sept. 2020

- **Commission determination:** "we find that existing RTO/ISO market rules are unjust and unreasonable in light of barriers that they present to the participation of distributed energy resource aggregations in the RTO/ISO markets, which reduce competition and fail to ensure just and reasonable rates."
- **Commission directive:** that "each RTO/ISO… revise its tariff to ensure that its market rules facilitate the participation of distributed energy resource aggregations"
- **Definition of DER:** "any resource located on the distribution system, any subsystem thereof or behind a customer meter. These resources may include, but are not limited to, electric storage resources, distributed generation, demand response, energy efficiency, thermal storage, and electric vehicles and their supply equipment."

Order No. 2222 Overview: Key compliance requirements

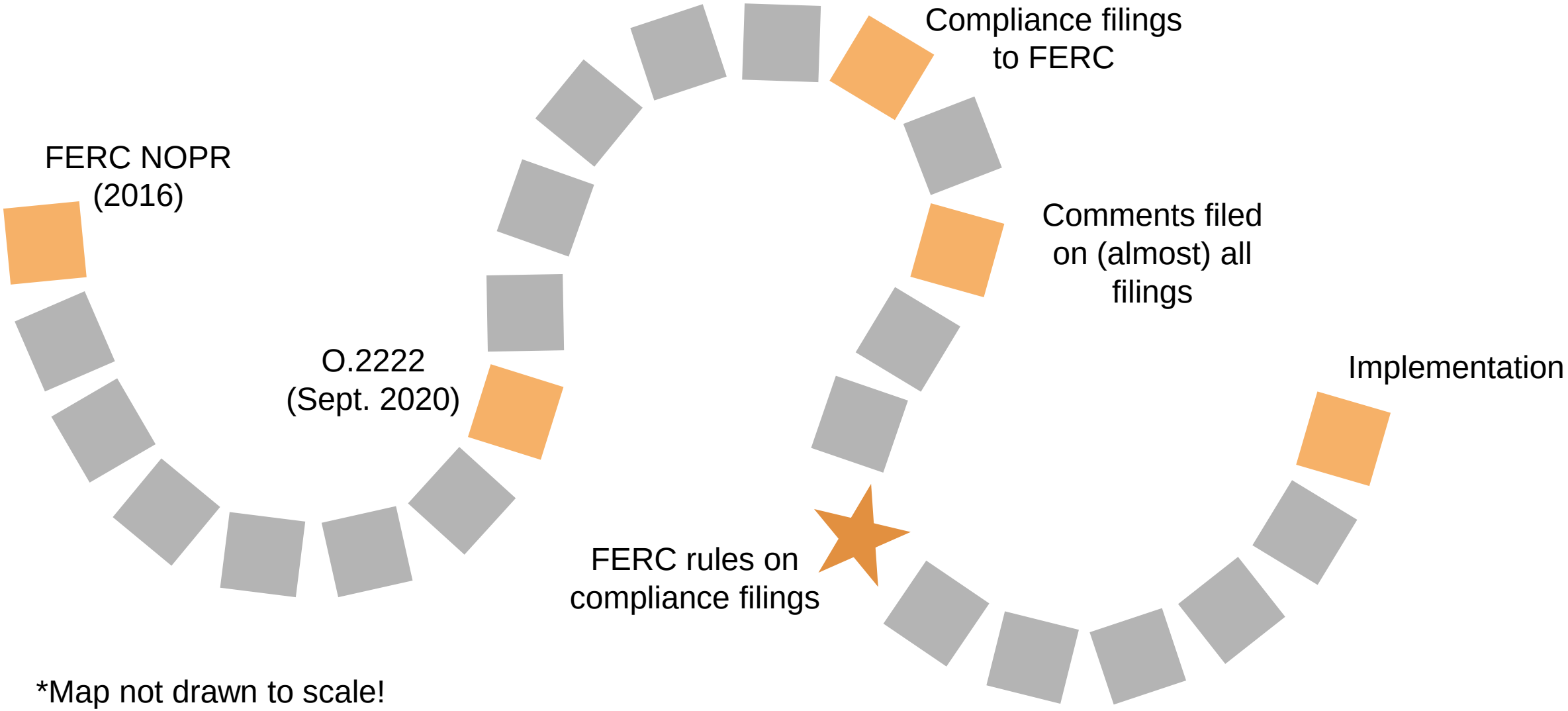
Parameter(s)	Key Requirement(s)
Eligibility of DER aggregators/DER types	DER aggregators must be an eligible market participant; RTOs/ISOs must allow all technology types and multi-technology combinations; rules must prevent "double counting" in retail and wholesale markets; no broad state "opt-out"
Geographic scope of aggregation	Encourages broad geographic scope of aggregation, but allows RTOs/ISOs to propose to limit aggregations to a single pricing node
Distribution factors and bidding parameters	Must account for physical and operational characteristics of DER aggregations and ensure they are able to fully offer their aggregations into RTO/ISO markets
Information and data requirements	RTOs/ISOs are required to transparently state the information and data that DER aggregators must provide them about the performance, physical parameters, and components of their aggregations
Metering and telemetry requirements	RTOs/ISOs have flexibility to set these requirements, including whether to require metering and telemetry of individual DERs; must justify why they are necessary and explain why they do not result in undue barriers to participation
Coordination	Requires RTOs/ISOs to establish procedures for coordination between RTOs/ISOs, DER aggregators, distribution utilities, and state and local regulators

AEE's Vision of Successful Order No. 2222 Implementation

Wholesale market participation/compensation *complements* other values and revenue streams that DERs currently access (e.g., customer benefits and retail programs). This means:

- **Customers can deploy DERs more affordably,** because DERs receive compensation for *all* the services they can provide
- **DERs already being deployed add more value to the grid** by offering all the services they are technically capable of providing
- **DERs are deployed more rapidly and more efficiently,** because they are responding to transparent market signals
- **Reliability improves,** because grid operators gain visibility and control as DERs participate in wholesale markets
- **Wholesale competition is enhanced** as DERs participate

You Are Here*



*Map not drawn to scale!

Status of RTO/ISO Compliance Filings

RTO/ISO	Date of filing	Implementation	Status
CAISO (ER21-2455)	7/19/21	2022	FERC Order issued XX
NYISO (ER21-2460)	7/19/21	2023 (2019 model), 2026 (O.2222 compliance)	FERC Order issued XX
PJM (ER22-962)	2/1/22	2026	Awaiting FERC Order
ISO-NE (ER22-983)	2/2/22	202? (capacity); 2026 (E&AS)	Awaiting FERC Order (requested by Nov. 1; 2022 capacity participation delayed)
MISO (ER22-1640)	4/14/22	2030	Awaiting FERC Order
SPP (ER22-1697)	4/28/22	Q3 2025 (targeted)	Awaiting FERC Order
ERCOT* (PUCT Project No. 51603)	N/A	2023 (applications accepted beginning Nov. 2022)	Pilot program approved by PUCT and ERCOT

*Not subject to O.2222

Introduction to AEE – GridLab Convening and Report

FERC Order 2222 Implementation: *Preparing the Distribution System for DER Participation in Wholesale Markets*

January 2022

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GridLAB

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Background

- AEE and GridLab brought together utilities and AEE members to build consensus around key distribution system issues to facilitate DER participation in wholesale markets
- This summary lists key recommendations to help educate state commissions; inform FERC and RTO/ISO processes; and support state policies that increase DER value
- Four working groups formed to discuss: Interconnection and aggregation review; communications, controls, and coordination; dual participation; and investment recovery and cost causation

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CAMPAIGN PARTICIPANTS

Microsoft, DTE, greenlots (A Member of the Shell Group), CLEAResult, ecobee, Dominion Energy, Google, Xcel Energy, RECURVE, CPower, Portland General Electric, sip, uplight, enel x, ORACLE, Walmart, GridLAB, Advanced Energy Economy

Other participants include: APS, Exelon, PECO, ComEd, Pepco, and BGE

Vision of Success

DER aggregators, distribution utilities, RTOs/ISOs, and utility customers may benefit from increased DER participation in wholesale markets, for example:

- **DER Aggregators**: Order 2222 opens new opportunities to earn revenue from wholesale markets; alongside distribution level compensation, this brings DERs closer to providing and being compensated for their full suite of benefits
- **Distribution Utilities**: Order 2222 creates an opportunity to play a role in enabling DER participation in wholesale markets while potentially deriving value from DERs at the distribution level
- **RTOs/ISOs**: Aggregated DER participation gives system operators access to more resources that increase grid flexibility and maintain reliability, particularly in the context of increasing renewables
- **Customers**: Utilization of DERs in wholesale/retail markets has the potential to lower overall customer costs by avoiding otherwise needed energy and capacity investments across the grid

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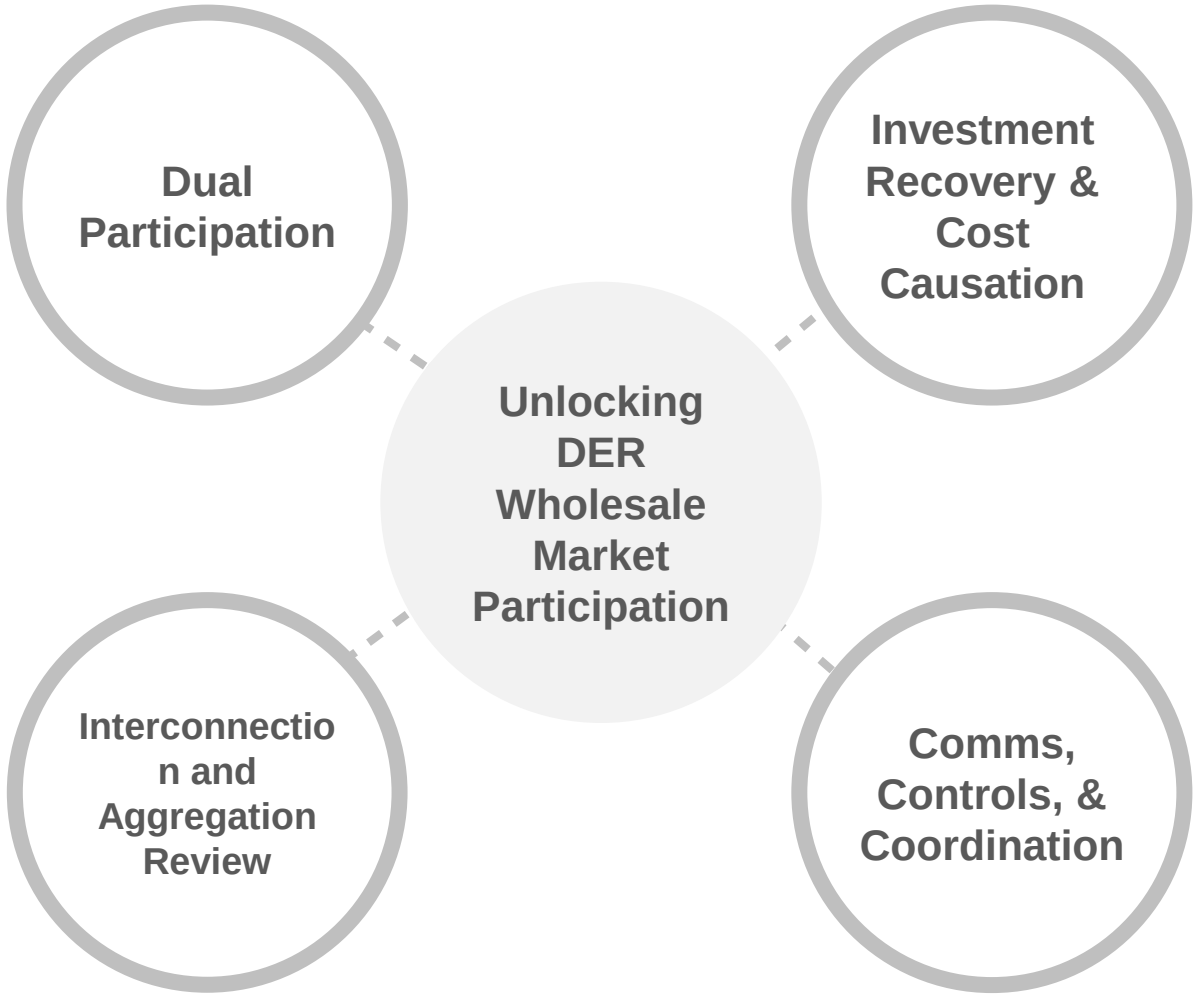
The collaborative prioritized four areas of focus and developed four Working Groups to address each



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Broad Conclusions

- DER aggregation in wholesale electricity markets under Order 2222 presents unique opportunities and challenges
- Order 2222 implementation will be most successful for customers and grid reliability with active engagement from state utility regulators
- Existing processes and tools developed by states, distribution utilities, and stakeholders to support DER integration should be built on to facilitate Order 2222 implementation
- In the future, processes and tools adopted by states and utilities related to DER adoption and integration should anticipate participation in wholesale aggregations
- New requirements and investments to support Order 2222 implementation should be aligned with the services provided and scaled as participation increases where possible
- Processes, tools, and policies enacted to support Order 2222 implementation must set clear expectations of all participants
- Equitably addressing the potential incremental distribution-level costs of Order 2222 implementation requires identification of a range of potential costs and benefits
- State regulators could consider establishing dedicated forums to examine and address the complex distribution system issues identified in this report

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Zoom In:

Dual Participation in Retail and Wholesale Programs

What is “dual participation?”

- *Ability to participate in both wholesale and retail programs, so long as DER is not receiving compensation for the same services as part of another program*.
- **Order No. 2222**: FERC required RTOs and ISOs to "allow [DERs] that participate in one or more retail programs to participate in its wholesale markets,” while allowing “appropriate restrictions” that are “narrowly designed to avoid counting more than once the services provided by distributed energy resources in RTO/ISO markets.”
- **Why does it matter**?
  - Dual participation is key to unlocking value given the operational and economic realities of DER aggregations; most are adopted for retail purposes first, but additional wholesale revenue streams can improve utilization and reduce costs (for DER owner and broader system)
  - Broad restrictions on DER participation that do not recognize reasonable operational limitations will diminish value and increase costs

Challenges of Dual Participation Identified by Working Group

- **Double Counting:** To the extent that a DER's wholesale participation coincides with the LSE/EDC peak demand and that participation impacts the amount of capacity for an ISO or LSE/EDC to procure, the DER's wholesale activities will need to be separately metered or added back to the peak load to ensure the ISO or LSE/EDC can accurately plan for system peak demand
- **Double Compensation:** Absent mechanisms to prevent duplicate payments, DERs engaged in dual participation may inappropriately receive compensation for the same service within the same time interval at both wholesale and retail levels
- **Operational Compatibility:** There could be instances when wholesale participation and retail obligations conflict with one another

Dual Participation

Opportunity

- Some states and RTOs/ISOs already have retail and wholesale constructs for dual participation while others may need to implement new constructs.
- States will have a key role, as recognized by FERC, particularly as it relates to oversight and design of retail programs. A thorough understanding by all parties of best practices and considerations will facilitate the regulatory decision-making process and pave the way for DER dual participation in a way that appropriately balances the interests of DER owners and aggregators, distribution utilities, and retail customers

Recommendations

- Load forecasting reconstitution practices exist today for wholesale demand response in markets such as NYISO and ISO-NE; other grid operators can leverage these existing practices for DERs
- States should establish a process through which the utility can identify where duplicate compensation may occur and RERRAs should develop appropriate mechanisms to prevent duplicate compensation (e.g., eligibility criteria in the aggregation enrollment and review, including ways to operationalize those criteria)
- Consideration of, and accounting for, instances of dual participation where a DER's capability may be split to provide more than one distinct wholesale or retail service in a given interval

Dual Participation Recommendations
(Continued)

- ISO/RTO participation models for joint ownership may be an example of how dual participation could be structured
- New York utilities' CSRP and DLRP tariffs provide useful models for preventing double compensation of energy
- DER Aggregators should update the DERA's operational status to the ISO/RTO to appropriately reflect any retail activities and/or obligations of DERs that comprise the DERA that impact resource availability for wholesale services and potential dual participation
- Retail tariffs and contracts should have guidelines for governing DER dual participation (such as identifying incompatible wholesale market services), with consideration for both normal and emergency operations at the bulk- and distribution-system levels
- States should proactively collaborate with utilities, DERs, Aggregators, and RTOs/ISOs to develop dual participation rules that are transparent and accommodate DER capabilities while preventing those issues outlined earlier in this document
- States should recognize that on-site metering will be necessary to facilitate wholesale participation and/or participation in retail programs

Thank you!

Caitlin Marquis

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Appendix: Summary of AEE-GridLab Working Group Recommendations:

Interconnection and Aggregation Review;

Communications, Controls, and Coordination;

Investment Recovery and Cost Causation

Interconnection and Aggregation Review

Problem Statement

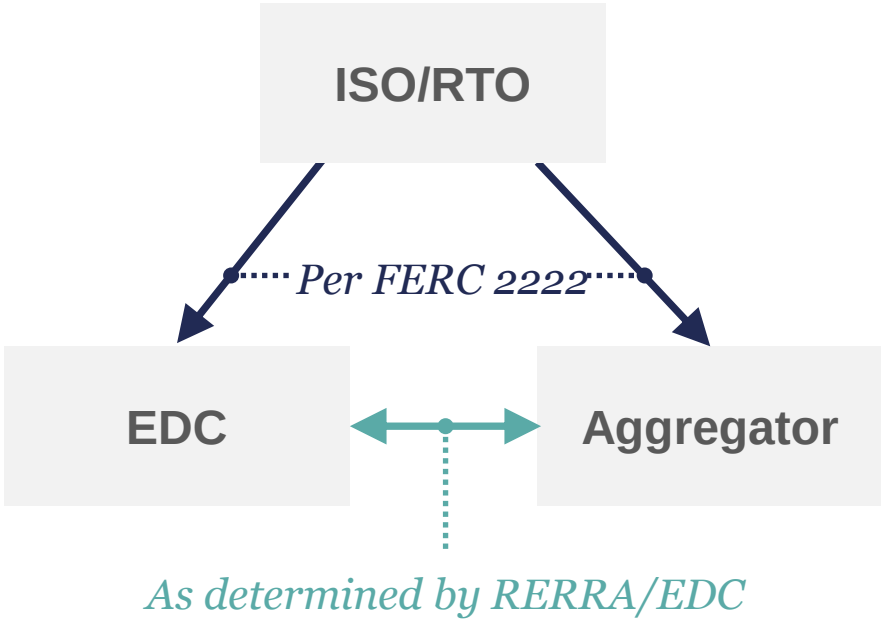
There appears to be a need for clarity around what an Aggregation Review process might be (and what, if any relationship it has to other processes)

Recommendations

- As EDCs establish an aggregation review process, they should utilize existing data from interconnection or ISO aggregation registration processes where possible to minimize the impact on all parties
- EDCs should work with RERRAs to modify existing distribution interconnection processes to include an option to indicate if a DER is intended to be included in an aggregation
- EDCs should distinguish aggregation review processes for different use cases and penetration levels
- DER aggregators should share ISO/RTO aggregation registration data with EDCs wherever possible and make best efforts to share any updates that take place on a regular basis
- ISO/RTOs should maintain up-to-date records accessible to EDCs on aggregations
- RERRA have an important role to play in approving tariffs, aggregation review processes, relevant cost recovery, adjustments to distribution interconnection, and potentially resolving any disputes that may arise

Interconnection and Aggregation Review Recommendations
(Continued)

- Requirements in the aggregation review process and any necessary impact studies should align with expected dispatch of the aggregation and any restrictions should be transparent for all parties
- Any new/modified processes need to be feasible for EDCs of varying degrees of sophistication
- All parties should expect that these processes will evolve as DER penetrations increase and/or EDC operations become more complex



Communications, Controls, and Coordination

Problem Statement

FERC order 2222 requires unprecedented coordination between the RTO/ISO, aggregator, and EDC. Existing tools and processes do not provide the functionality needed to enable the required coordination

Recommendations

- Do not assume a complete solution will be implemented immediately; follow a “crawl, walk, run” approach. Start with least regrets deployments
- At the early stage, scrutinize whether additional investments in communications, monitoring and controls above what the RTO/ISO and the interconnection procedures will require are necessary
- Consider if there are simple and lower cost approaches for fostering coordination, controls and visibility between EDCs and aggregators
- The functions of controls and monitoring are distinct, and these terms should not be used synonymously; distinct requirements should be developed.
- Requirements on controls, coordination, and monitoring for various types of DERs can be very different

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Communications, Controls, and Coordination Recommendations
(Continued)

- DER installations should leverage autonomous control features that have been adopted as standards, such as IEEE 1547.
- For distribution overrides, there may be two levels of overrides:
  - Soft override where aggregator can act based on early notice from EDC
  - Hard override where EDC directly curtails or interrupts DER for safety and/or reliability purposes
- The need for hard vs. soft overrides will depend on circumstances and degree of coordination between EDC and aggregator
  - Soft overrides will be the preferred option in non-real time applications and demand response
  - Hard overrides will be a last resort where system reliability or safety is at risk
- Level of automation (i.e., machine-to-machine) vs. manual communication will depend on level of complexity, existing tools at the EDC/aggregator, DER penetrations, and/or grid topology
- Setting clear expectations and open communications between EDCs and aggregators on drivers and likely conditions that lead to distribution overrides will benefit all parties

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Communications, Controls, and Coordination Recommendations
(Continued)

- EDCs alerting aggregators prior to bidding windows and aggregators adapting bidding behavior to expected conditions from EDC could help to alleviate the need for hard overrides
- Support foundational EDC actions that bring greater visibility into the distribution system (such as linking AMI with SCADA and/or ADMS); these can be part of broader grid modernization efforts
- The EDC functions of planning and operations are distinct. Any proposed hardware/software investment should be understood in the context of how they support these distinct functions, and how the EDC plans to institutionalize these new procedures and the feasibility of doing so vis-à-vis current planning and operations
- For small DER applications (especially residential demand response), access to AMI data has been a barrier; consider frameworks that reduce friction for aggregators to access AMI data and/or create systems that don't require aggregators to access AMI data by coordinating the data exchange between the EDC and ISO/RTO
- Low friction aggregator access to relevant meter data for settlement purposes and low friction utility access to relevant metering and controls data for planning, operation and settlement purposes need to be specified and mandated by applicable RTO/ISO tariffs and/or state jurisdictional tariffs in order to scale DERs in wholesale markets

Investment Recovery and Cost Causation

Problem Statement

Implementation of Order No. 2222 will result in incremental distribution level costs

Recommendations

Consider the following potential cost categories when evaluating utility investments that relate to Order No. 2222

1. **Interconnection Studies & Upgrade Costs**
2. **Utility Review of DERA Registration Requests**
3. **Day-to-Day Utility Management of DERs**
4. **Investments to Increase or Maintain Hosting Capacity**
5. **Wholesale Market Access Charge**

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Recommended Considerations by Which to Evaluate Proposed Investments[1]

1. Identify costs required to enable DERs sited on the distribution system to participate in wholesale markets
2. Identify relevant benefits of enabling DER penetration in wholesale markets
3. Avoid duplication of DER benefits in benefit cost analysis
4. Establish an objectively quantifiable basis for measuring, quantifying, and allocating relevant identified benefits and costs
5. Equitably allocate costs between retail customers, DERs, and aggregators, taking into consideration of applicable benefits and consideration of implications of any cost shifts to retail customers

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[1] These principles are focused on costs incurred at the distribution level; costs incurred by RTOs/ISOs are expected to be recovered through existing RTO/ISO cost recovery mechanisms.

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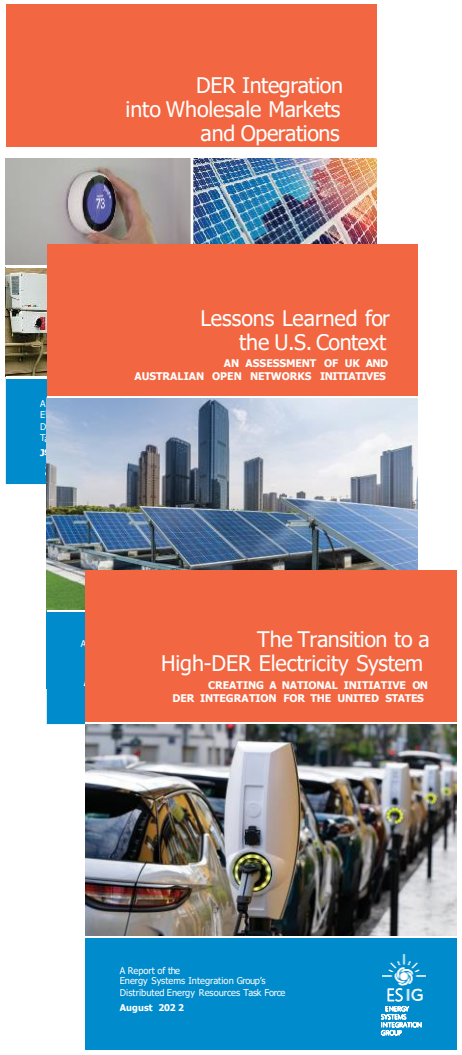
DER Integration into Markets and Operations

Debra Lew, Associate Director, ESIG

Speaking on behalf of DER Task Force including Priya Sreedharan, Matt McDonnell, Fritz Kahrl, Lorenzo Kristov, Josh Keeling, Jennifer Gorman, Jason Brogden, Obadiah Bartholomy

Dec 15, 2022

ESIG three-part series on DER integration



DER Integration into wholesale markets and operations.
Examines the changes in regulation, market rules, planning, and operating practices needed to better integrate DERs into U.S. wholesale markets and operations, addressing both near term opportunities and long-term needs.

Lessons Learned for the U.S. Context: An Assessment of UK and Australian Open Networks Initiatives. Reviews the UK and AU open networks initiatives and highlights elements that could be useful to incorporate in a US initiative on DER integration and characteristics from each initiative that should be avoided.

The Transition to a High-DER Electricity System: Creating A National Initiative for DER Integration for the United States. Leveraging the first two reports and inputs from the task force, this report clarifies the need, value and design of a potential US national initiative.

https://www.esig.energy/der-integration-series/

Key areas and actions for regulatory commissions and distribution utilities to support FERC Order 2222 compliance

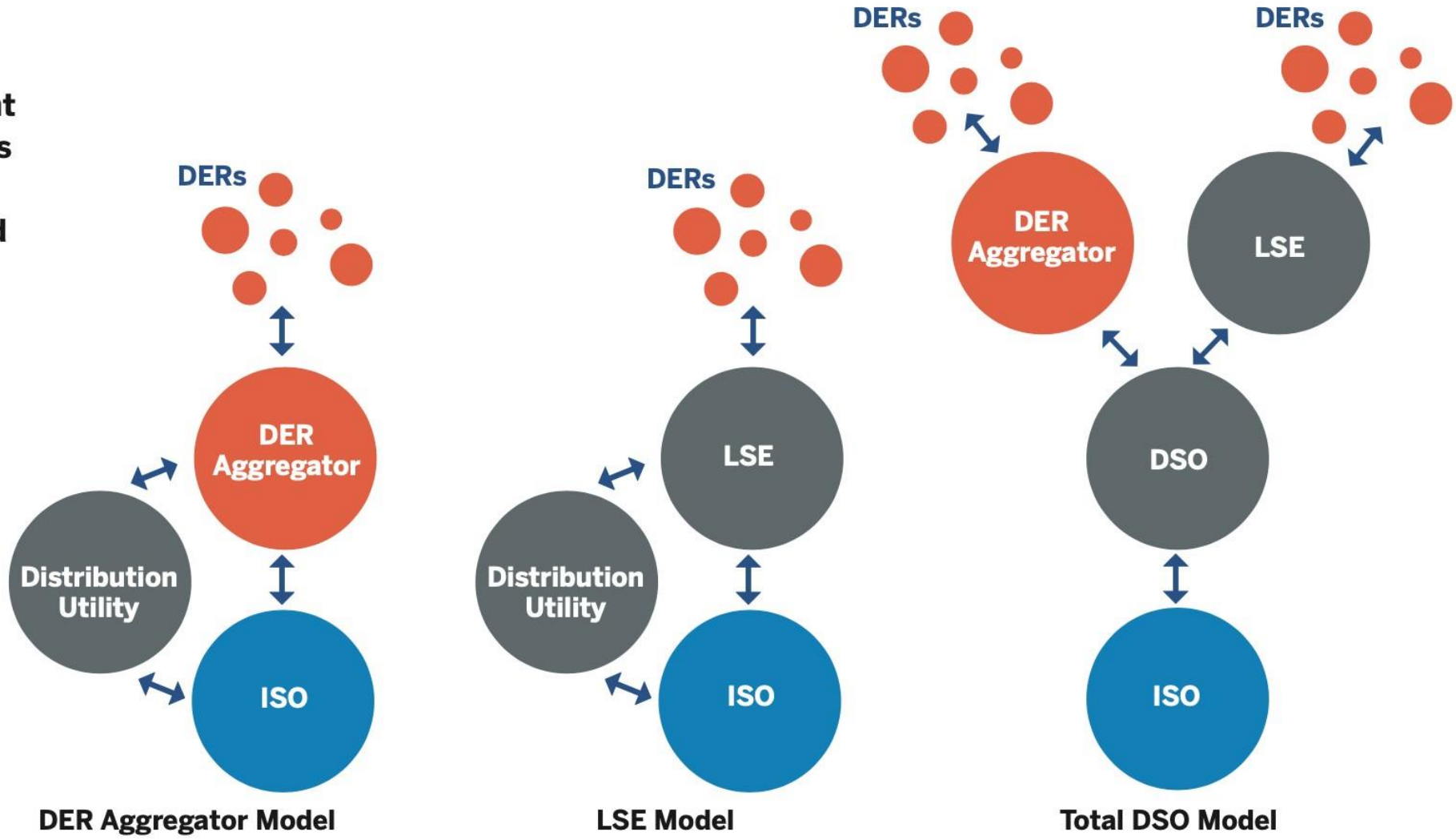
	Actions Needed by Commissions	Actions Needed by Distribution Utilities
Interconnection procedures	Ensure that interconnection procedures are transparent, are fair, and conform to predictable costs and time frames	Develop new or enhance existing DER interconnection procedures to establish DER performance parameters (e.g., maximum injection limits) and utilities' ability to curtail DER power injections for reliability purposes
DER aggregation review	Ensure that utility aggregation review is timely, fair, and flexible, avoiding the need for new interconnection studies	Develop transparent procedures for review within 60 days of an aggregator proposing a DER aggregation
Outage communication	Ensure that distribution utility outage communication is timely and fair, allowing DER providers to manage non-performance risks in the wholesale market	Develop new processes and capabilities for communicating distribution outages or constraints to DER aggregators
Utility overrides	Ensure that distribution utility overrides are transparent and non-discriminatory	Develop transparent, non-discriminatory procedures for overriding ISO/RTO scheduling and dispatch of DERs that align with expectations set within the aggregation review process

Focus in on market operations

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

We examined three structural participation models

Structural participation models describe different approaches for how DERs participate in wholesale markets; they vary based on the nature of the interactions among the ISO, distribution utility, and DER aggregator.

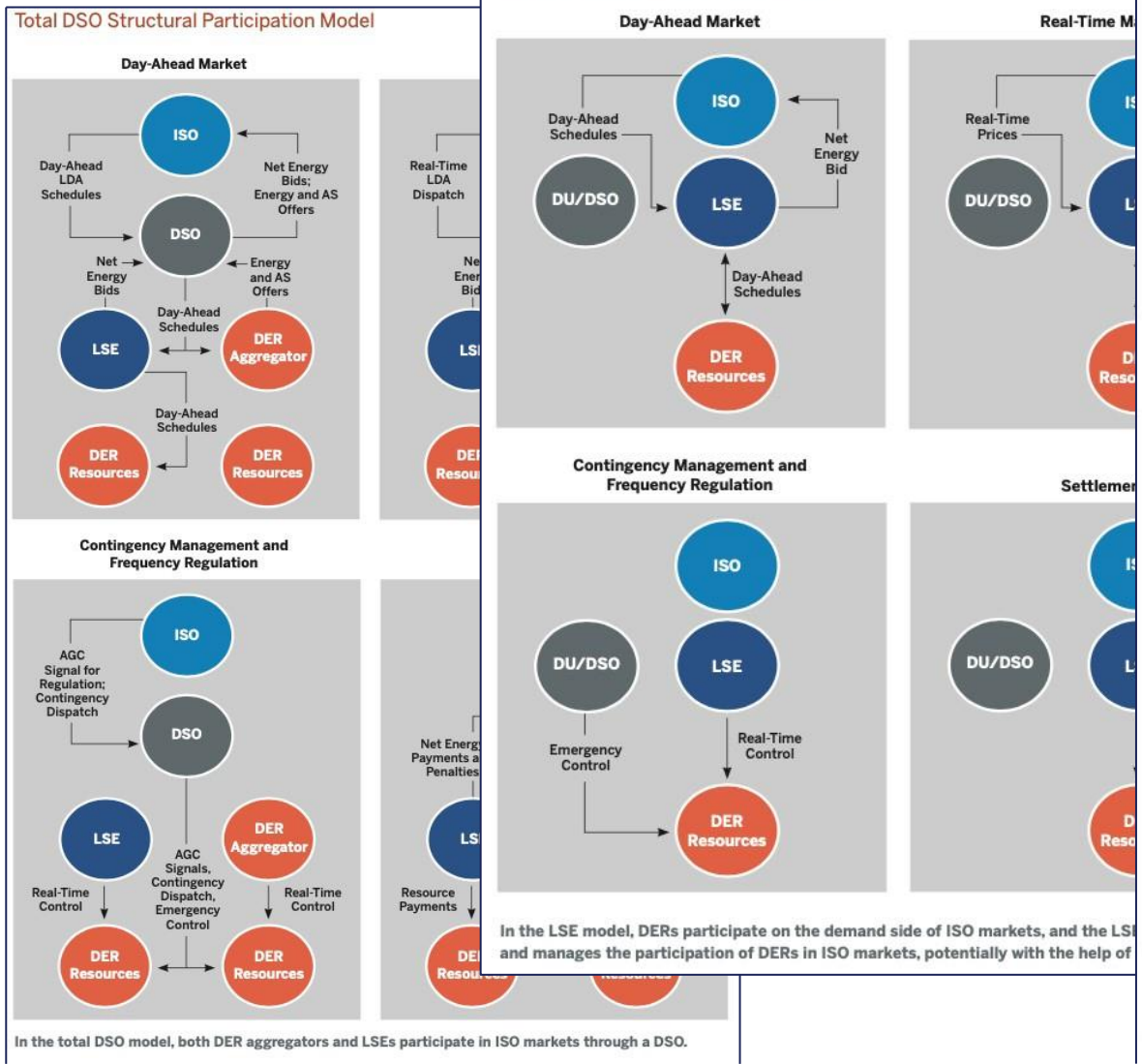


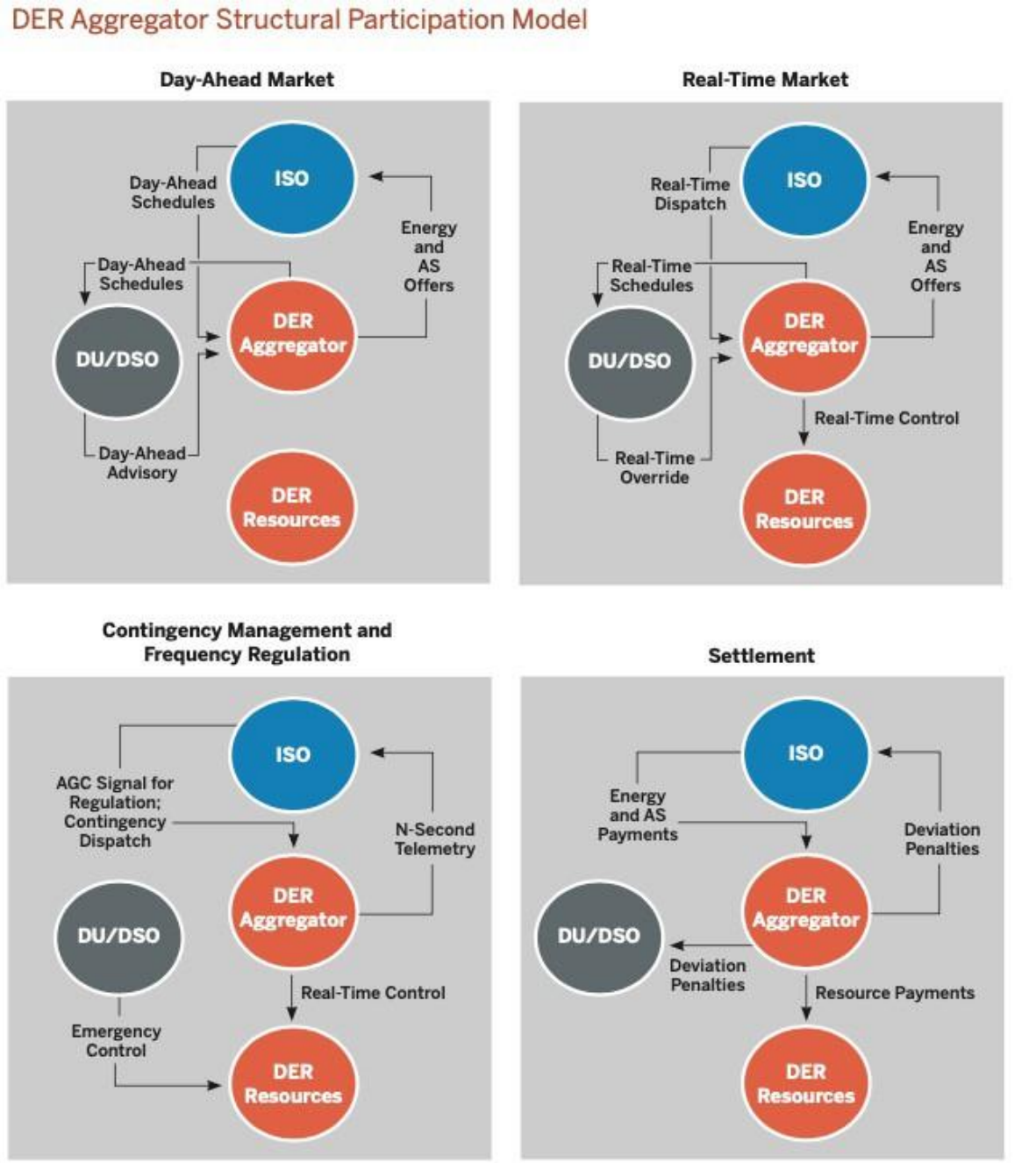
DER Aggregator Model

LSE Model

Total DSO Model

We examined market operations across the different models





Market Processes and Operator Functions

Pre-operations and Planning

Market Process	Operator Function	
	DU/DSO	ISO
Registration of market participants and resources	Register market participants (DER providers) and participating resources (DERs or DERAs)	Register market participants (DER providers) and participating resources (DERs or DERAs)
Distribution planning	Plan investments in distribution infrastructure and non-wires technologies	Provide DU/DSO with timely information on planned transmission expansion
Transmission planning	Provide ISO with i and DER forecasti	
DER interconnection	Set interconnecti screens and studi	
Resource verification	Review DERA; rev communications	
Resource adequacy	Verify deliverabilit	
Maintenance scheduling	Manage and repo equipment outag	

Market and System Operations

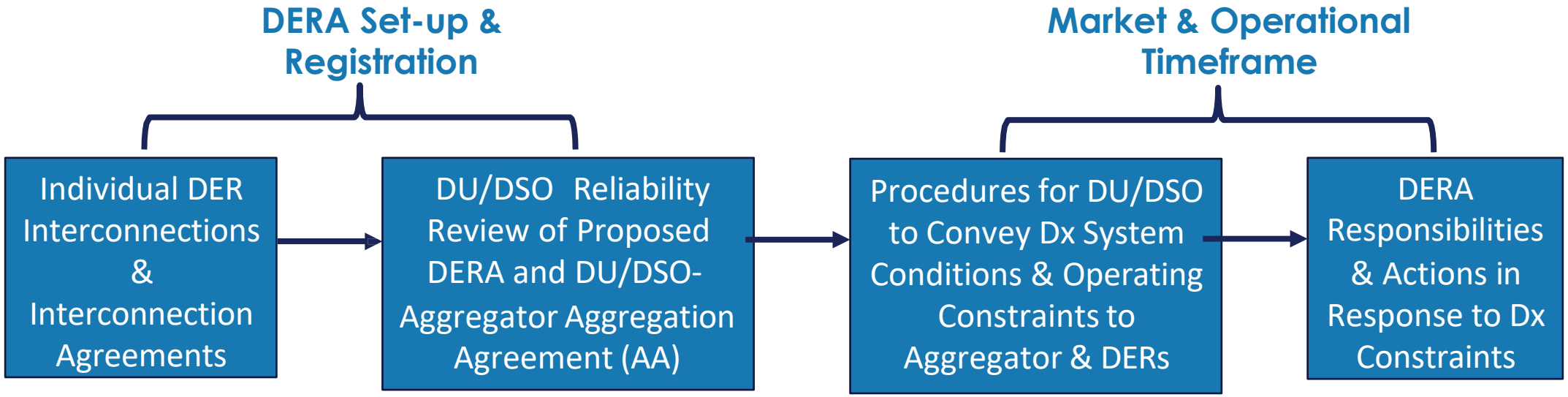
Market Process	Operator Function	
	DU/DSO	ISO
Day-ahead market	Schedule DERs that provide distribution grid services to the DU/DSO	Perform scheduling and unit commitment
Real-time market	Dispatch DERs that provide distribution grid services to the DU/DSO; ensure distribution system security and, in some models, perform economic dispatch	Perform security-constrained economic dispatch
Contingency management	Manage outages and provide emergency control	Manage outages and provide contingency dispatch
Frequency balancing		
Voltage regulation		

Market Settlement

Market Process	Operator Function	
	DU/DSO	ISO
Market settlement	Assess penalties for DERs' or DERAs' non-compliance with override instructions; perform market settlement in some models	Settle day-ahead energy, real-time energy, and ancillary service markets; assess imbalance penalties
Network tariffs and settlement	Settle non-wires resources; distribution tariffs; and tariffs for generation, storage, and demand response	Settle transmission tariffs

Operational Coordination Architecture

- Provide a framework for the distribution utility (DU) or distribution system operator (DSO) to manage reliability impacts to distribution resulting from aggregations of DERs (DERA) participation in the ISO market under changing distribution system conditions.
- Satisfy FERC 2222 requirements for DU/DSO to implement "transparent, non-discriminatory" procedures for over-riding ISO dispatches (para 310).
- Minimize real-time transaction complexity via effective Interconnection Agreement and Aggregation Agreement provisions



In the future, these agreements could include flexible interconnection (dynamic curtailment)

See example

Transparent, Non-Discriminatory Provisions for DU/DSO Curtailment of DERA Dispatch

- These procedures would probably live in a DU/DSO tariff, with references in the Interconnection Agreement and Aggregator Agreement.
- Transparency requires clear specification of the causes of curtailment, compliance requirements, penalties, etc.
- Non-discriminatory requires fair allocation of limited distribution capacity between multiple DERAs that may use some of the same capacity

DERA Curtailment Options

Simple Approaches

- Full curtailment of all net injecting DERs on a circuit in abnormal configuration
- Pro rata curtailment based on installed capacity
- "First-in-last-curtailed" (e.g., based on commissioning date)

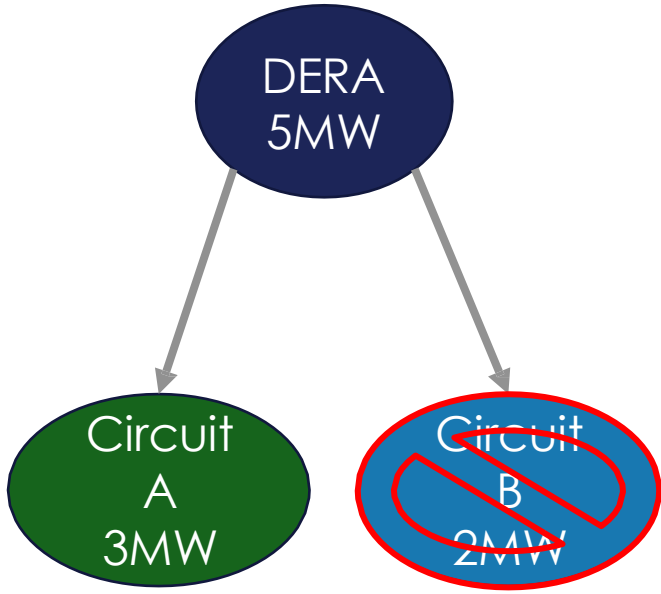
More Complex Approaches

- Physical rights for non-firm (flexible) access to the dist. system are curtailed first
- Economic curtailment
- Economic dispatch of a distribution-level energy market operated by the DU/DSO

Example: Day-to-Day ISO Market and Operational Coordination

DERA in CAISO with 5 MW capacity comprised of individual DERs over two distribution circuits within a single T-D interface. Circuit A hosts 3 MW and circuit B hosts 2 MW. At 9 am Monday the DU/DSO informs the Agg of a problem that has taken out distribution circuit B that will continue for the next 24 hours.

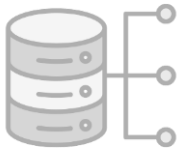
1. The Agg immediately submits an outage/derate card to CAISO indicating DERA capacity reduction from 5 MW to 3 MW for HE10 Monday through HE09 Tuesday
2. The Agg structures its DA market offers for the DERA for Tues to reflect maximum 3 MW for HE01-09 and maximum 5 MW for HE10-24 (based on the expected duration of the circuit B outage)
3. The Agg structures its RT market offers for Monday HE12-24 based on maximum 3 MW capacity; this may involve buying back portions of the DERA's DA schedules (which cleared in Sunday's DAM) for hours where they exceed 3 MWh.
4. The CAISO does not receive new RT offers for 5-minute intervals from 0910 until 1100, but the market optimization knows from the outage/derate card that the DERA's maximum output is 3 MW, so it will not dispatch the DERA for more than 3 MW capacity in any interval.
5. For the interval 0900-0910 the CAISO does not perform any new market optimization, so its previously issued dispatches to the DERA would reflect 5 MW capacity. Thus the DERA may fall short of its DA schedule or RT dispatch. The imbalance on the CAISO system is managed by Regulation (AGC) and will subject the DERA to imbalance energy charges and possibly uninstructed deviation penalties.



Broader gaps for DER market and system integration beyond Order 2222

TRANSMISSION AND DISTRIBUTION PLANNING

- Integrate approach to distribution planning, interconnection, and operations
- Increase coordination between distribution and transmission planning



DISTRIBUTION OPERATIONS

- Identify least-regrets enhancements in visibility, communications, DER operations, and real-time controls that will be needed
- Allocate responsibilities for active coordination of DER activity between the distribution system operator and the ISO/RTO

DISTRIBUTION INTERCONNECTION

- Determine setpoint guidance for smart inverters, given distribution systems' needs
- Define how utilities should determine minimum reliability upgrades versus upgrades that could be avoided through DER curtailment or re-dispatch
- Determine how utilities ensure that procedures for curtailing or re-dispatching flexible interconnections are transparent and non-discriminatory

Broader gaps for DER market and system integration beyond Order 2222 *(continued)*

COMMUNICATIONS AND DATA-SHARING

- Enable increased communication between distribution utilities or distribution system operators and ISOs/RTOs, including during day-ahead and intraday scheduling, real-time dispatch, automatic generation control signals, and emergency operations
- Increase available information on loads, anticipated load growth, and DERs in the interconnection queue

ISO/RTO MARKET DESIGN

- Implement market design changes to enable market-based approaches to load participation during the operating day

MARKET REGULATION

- Ensure that distribution operators' overrides of DER schedules and dispatch and dispatch of DERs are transparent and non-discriminatory
- Clarify issues around state-federal jurisdiction

UTILITY REGULATION AND BUSINESS MODELS

- Implement incentive frameworks that attempt to better align utility incentives with maximizing the system value of DERs
- Design tariffs to incentivize the flexibility that can be provided through energy storage and load management

Recommendations to enable DER integration in wholesale markets

For those at an early stage of DER integration, these strategies can help:

1. **START WITH MINOR CHANGES.** Begin from an assumption that relatively minor changes in distribution planning, distribution operations, and utility investments in monitoring and controls necessary to support them will be needed for near-term compliance with Order 2222 (commissions, utilities).

2. **LEVERAGE EXISTING DATA.** Leverage data from DER registration and interconnection in DER aggregation reviews to minimize the need for additional study during reviews; in most cases, DER aggregation review should not require redoing interconnection studies (commissions, utilities).

3. **USE EXISTING PROCESSES FOR COMMUNICATIONS AND DATA-SHARING.** Rather than create new processes and additional complexity, make use of existing protocols and processes for communications and data-sharing among utilities, aggregators, and ISOs/RTOs (utilities, DER aggregators, ISOs/RTOs).

4. **DEVELOP WORKABLE APPROACHES TO UTILITY OVERRIDES.** Focus initially on developing workable approaches to utility overrides, based on a foundation of efficient communication between utilities and aggregators, with terms and conditions that are clearly articulated in interconnection and aggregator agreements and can evolve over time (utilities, commissions, aggregators).

5. **PRIORITIZE ADOPTION AND IMPLEMENTATION OF IEEE 1547-2018.** Voltage support provided through compliance with interconnection standards may reduce the need for overrides and distribution upgrades (commissions, utilities).

National dialogue

PARTICIPATE IN NATIONAL, INDUSTRY-WIDE DIALOGUE.

6

- Build:
  - A **common vocabulary, framework, and vision** for thinking about DER integration across different jurisdictions
  - A common understanding around **shorter-term, least-regrets strategies for DER integration that are consistent across distribution utilities**, including strategies for enhancing distribution and transmission planning, data-sharing and communication, distribution operations, and DER interconnection and aggregation review
  - A **structured dialogue on solutions to longer-term issues around DER integration**, such as the design of distribution system operator (DSO) operations, markets, and regulation, federal-state jurisdictional overlap, independent system operator (ISO) market design, and incentive frameworks for regulated utilities
- Develop a general framework and terminology for considering distribution system operations, markets, and regulation with higher levels of DERs
- Identify nearer-term least-regrets DER integration enhancements and solutions that are grounded in power system engineering and economics and could be applicable to diverse jurisdictions
- Develop a portfolio of potential longer-term DSO models and TSO-DSO coordination arrangements that each jurisdiction could tailor to their individual needs, rather than develop a one-size-fits-all approach

THANK YOU

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Agenda

- Introduction and 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 (David Narang)

Aggregations in Opt-Out States

Sydney P. Forrester*

Additional Co-Authors: *Cole Triedman†, Sam Kozel†, Cameron Brooks†, Peter Cappers**

***** Lawrence Berkeley National Laboratory

† E9 Insights

NREL DER Interconnection Workshop 1

December 15th, 2022

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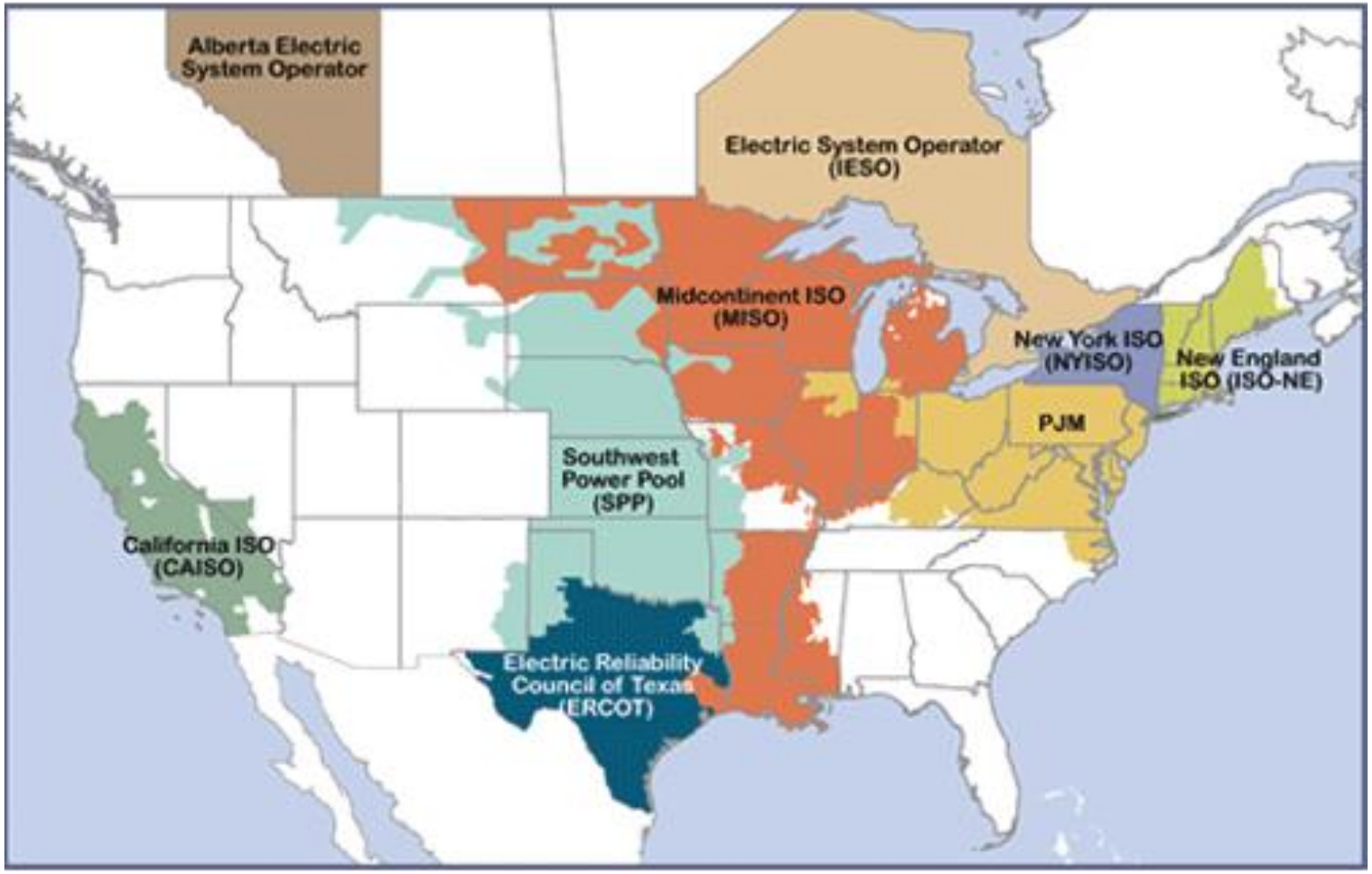
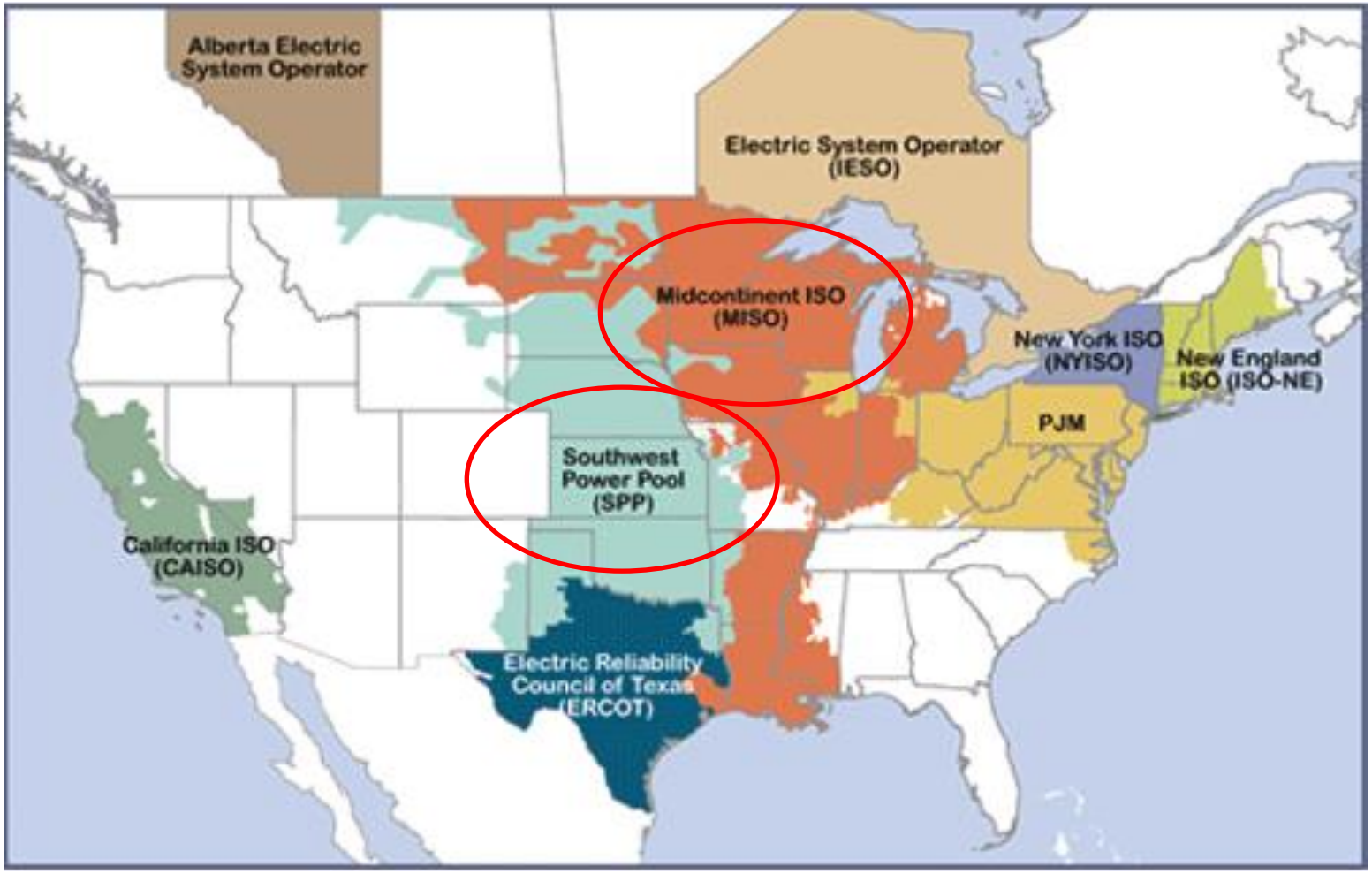
Order 719 Opt Out



Source: FERC

- FERC Order 719 was issued in 2008
  - Reduced barriers of participation for DR in wholesale markets
  - Allowed states to opt out
- Many states in the MISO and SPP region opted out
  - States are primarily vertically integrated
  - Of 19 total states, 16 opted out

Order 719 Opt Out



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Order 2222 impact on the opt out

- Order 2222 (generally) does *not* offer an opt out
  - One exception: Opt in mechanism for small utilities with less than 4M MWh of retail sales in the previous fiscal year
  - A DR resource in a heterogeneous aggregation is not subject to the opt out/opt in, however, a homogeneous DR aggregation is considered DR, so subject to Order 719 (incl. opt out/opt in)

- Implications
  - States will no longer be able to opt out to comply with Order 2222
  - Moreover, FERC is considering whether to reverse the DR opt out as well

MISO and SPP states: Where are we at?

RTO/ISO	2020	
	Demand Resources (MW)	Percent of Peak Demand [8]
CAISO [1]	3,290	7.0%
ERCOT [2]	3,939.0	5.1%
ISO-NE [3]	476.2	1.9%
MISO [4]	13,024.0	11.1%
NYISO [5]	1,274.1	4.2%
PJM [6]	8,915.0	6.0%
SPP [7]	34.2	0.1%
Total	30,787.5	6.6%

*Source: FERC, 2021**

- Demand response exists in each wholesale market (at varying levels)
- Aggregations do exist in small numbers in the MISO/SPP markets and have provided value to the system
  - MISO June 10, 2021 Maximum Generation Event saw 400+ MW of aggregated DER participation over a three-hour Load Modifying Resource dispatch*
- Existing, untapped DERs could provide additional value
  - Organization of MISO States expressed concern over reserve margins "trending towards their minimum requirements" and the ability for quick deployment of DERs over slower incumbent generation that could be more expensive to ratepayers†

**2021 Assessment of DR and AMI (FERC, 2021)*

† *State Response to 2022-2023 PRA Results (Org. of MISO States, 2022)*

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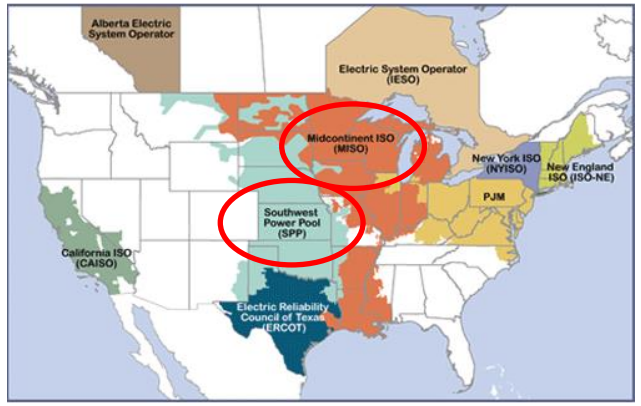
MISO and SPP states: Where are we at?

- Sixteen of Nineteen states in MISO and SPP opted out under Order 719
  - IL is the only fully competitive state in MISO and has active aggregations at the retail and wholesale market levels
  - KS and OK did not opt out, however, their markets were functionally closed until recent commercial and industrial customer aggregation activity

- Has any state reversed the opt out?
  - AR* investigated this issue but chose *not* to reverse the opt out despite recommendations from its DER investigation
  - MI† *partially* reversed its opt-out for the 10% of retail customers that have retail choice



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**Docket No. 16-028-U, Order 10 (AR PSC, 2018)*

† *Case No. U-20348 (MI PSC, 2019)*

Logistics of reversing the opt out: Jurisdiction

- States in MISO/SPP may have concern over maintaining jurisdiction
  - Where aggregations do exist, state regulators have generally taken one of two approaches:
    - Assume implicit jurisdiction due to jurisdiction over regulated utilities and DERs interconnected in their territory (option used by majority of states)
    - Declare explicit jurisdiction over aggregators (in MISO/SPP, this is solely AR* despite having no aggregations participating in the wholesale market level)

- FERC and ISO/RTOs recognize this "implicit" jurisdiction via Order 2222 text
  - Supported by Order 2222 text along with (preliminary) MISO and SPP Order 2222 compliance filings

"DER interconnections to the distribution system are based on [regulator] rules, and as mentioned previously, [the regulator] may choose to develop and oversee Technical Review processes, including any [regulator]-defined DER interconnection rules. Under the proposal, [regulators] may also put rules in place governing operational overrides of [aggregated DER]." †

**In the matter of an investigation of policies related to DERs (AR PSC, 2018)*

† Order 2222 Compliance Filing (MISO, 2022)

Logistics of reversing the opt out: Role of state regulator

- States in MISO/SPP may have concern over developing rules to govern aggregators and their role
- States in MISO/SPP with active aggregations have ad hoc rules that borrow heavily from existing processes
  - Rely on more general DER registration processes from the retail utility and/or resource registration processes from the ISO/RTO
  - Rely on existing data governance practices and rules from the retail utility and/or ISO/RTO
- Dual participation between retail and wholesale markets necessitates coordination
  - Order 2222 language puts the burden on aggregators to collect and report required data to all parties
  - Role of regulator applies to each DER because DERs in aggregations must comply with local regulation

Possible roles and responsibilities of state regulators with respect to coordination may include but would not be limited to:

- *developing interconnection agreements and rules;*
- *developing local rules to ensure distribution system safety and reliability, data sharing, and/or metering and telemetry requirements;*
- *overseeing distribution utility review of DER participation in aggregations;*
- *establishing rules for multi-use applications; and*
- *resolving disputes between DER aggregators and distribution utilities over issues such as access to individual DER data. – FERC Order 2222*

What is next?

- Michigan opened a proceeding considering a full reversal of the opt out*
  - Note that they partially reversed the opt out previously
- Minnesota is expected to initiate a docketed proceeding*
- Indiana just began a stakeholder process on Order 2222 implementation †

- States may be interested in beginning this process ahead of ISO/RTO Order 2222 for a variety of reasons
  - Possible FERC reversal of Order 719 opt out; Order 2222 compliance
  - Improve resource adequacy, capture value from existing and future resources
  - Take advantage of aggregation-specific benefits such as quick and accurate response, distributed locations, etc.
  - Support other state policy priorities
  - Learn via a slower onramp

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**Regulating DR and Aggregators in the Midwest While Safeguarding Local Jurisdiction (Dotson-Westphalen & Schisler -Cpower, 2022)*

† *https://www.in.gov/iurc/home/implementation-re-ferc-order-2222/*

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For more information

Download publications from the Electricity Markets & Policy Group: https://emp.lbl.gov/publications

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Acknowledgements

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Key DER Capabilities that Support Aggregation

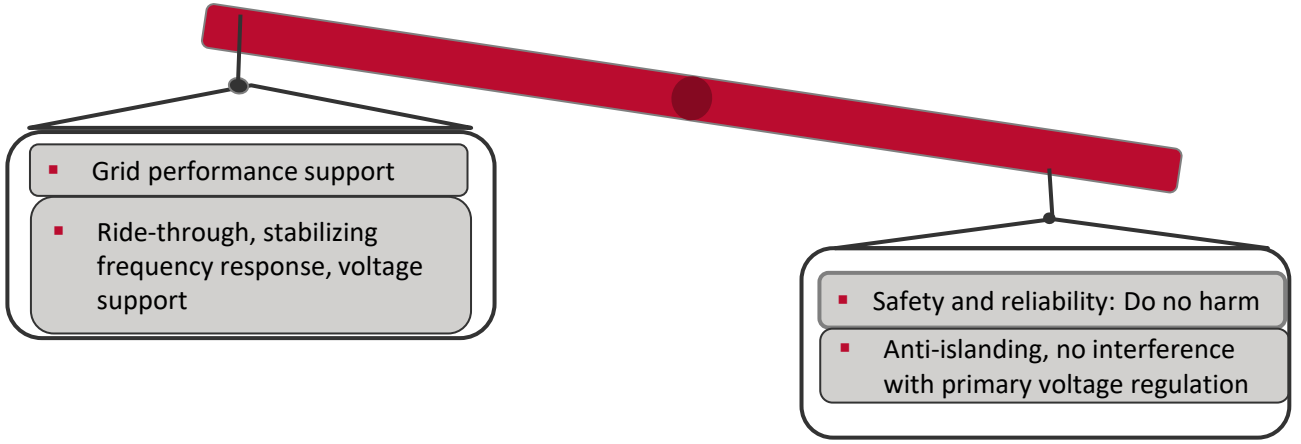
Topic Highlight

Support for Bulk Power System Reliability

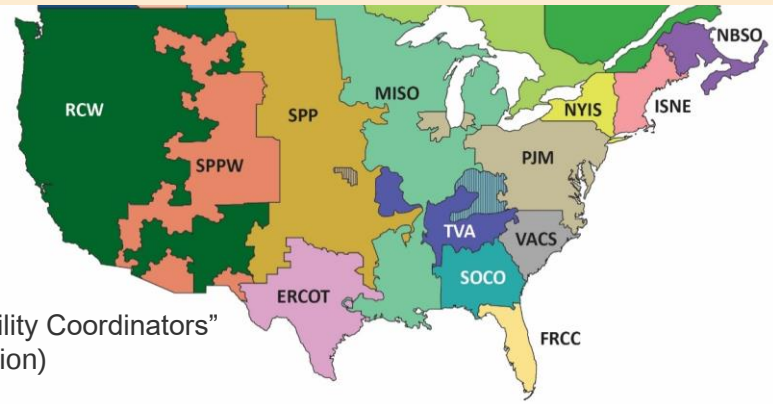
How can DER effect Bulk Power System reliability?

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 aggregate DER response to abnormal voltage or frequency can contribute to the (in)stability of the BPS
- This possibility prompted inclusion of ride-through requirements in IEEE Std 1547-2018



Stakeholders for ride-through settings include "regional reliability coordinators" (RRC) and the local utilities



Source: NERC "Reliability Coordinators" (reprinted with permission)

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 2030)

Value of interoperability:

- Improves situational awareness/monitoring
- Provides more data for modeling & 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:

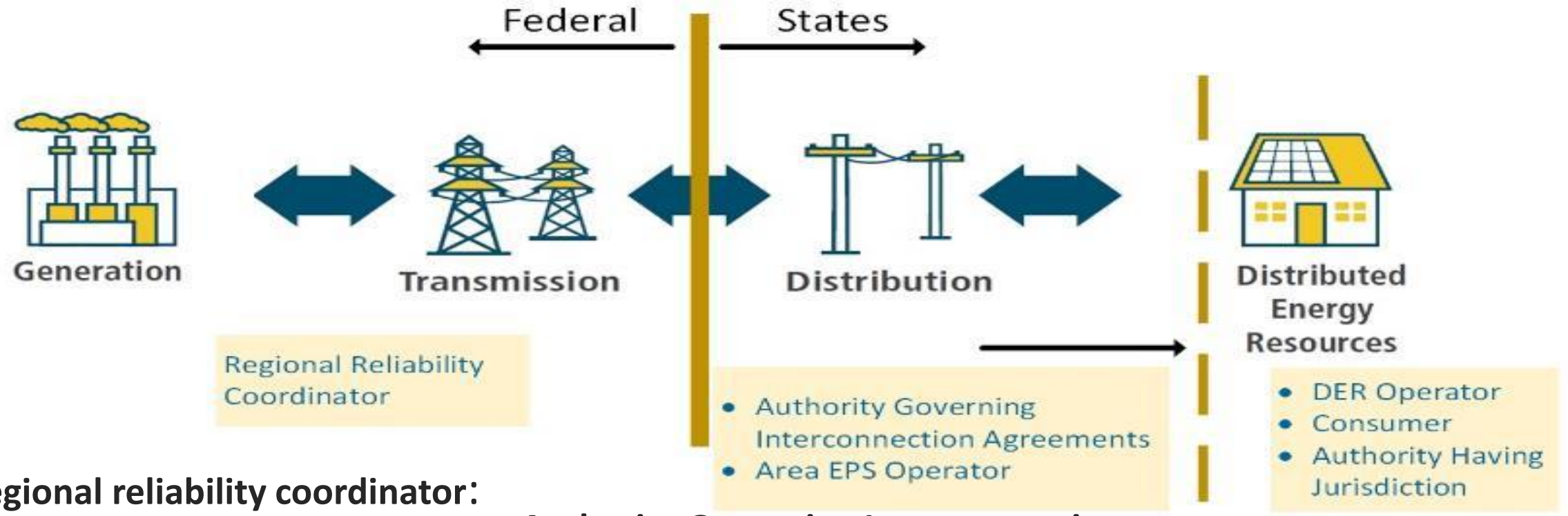
- Communications requirements
- Identified functions to communicate
- Scope of interoperability
- Protocols.

Increased capabilities come with increased complexity:

Examples of increased complexity to be considered

Topic Highlight

1547 Context - Key Terms and Entity Jurisdictional Boundaries



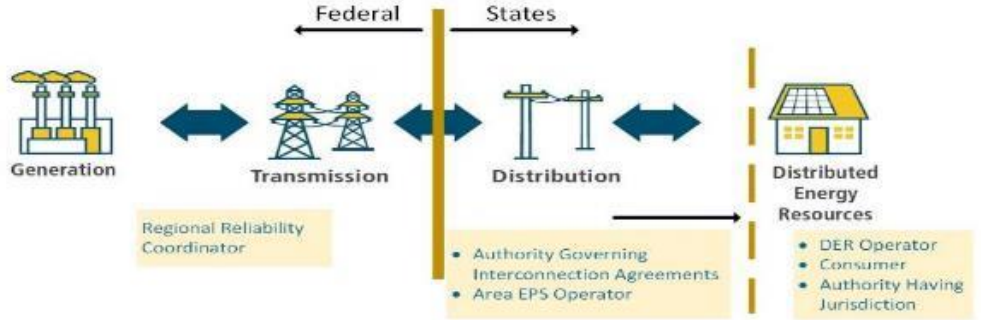
Regional reliability coordinator:
Maintains real-time operating reliability of bulk power system within a reliability coordinator area

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

DER Capabilities Required in IEEE Std 1547 Cross Jurisdictional Boundaries.



Regulator (AGIR)

Area EPS operator

Regional reliability coordinator

- power quality
- protection settings

- Testing & certification

- Performance categories
- Voltage regulation modes

- Interoperability requirements
- Communications protocols

- Performance categories
- Trip settings
- Ride-through

Application
(beyond 1547 scope)

- Grid services

- Grid services
- Data access
- Cybersecurity

- Bulk system reliability
- Resilience
- Black start

Education and Support Resources

Topic Highlight

NREL's IEEE 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 1547-2018.

Sponsored by:
Solar Energy Technologies Office

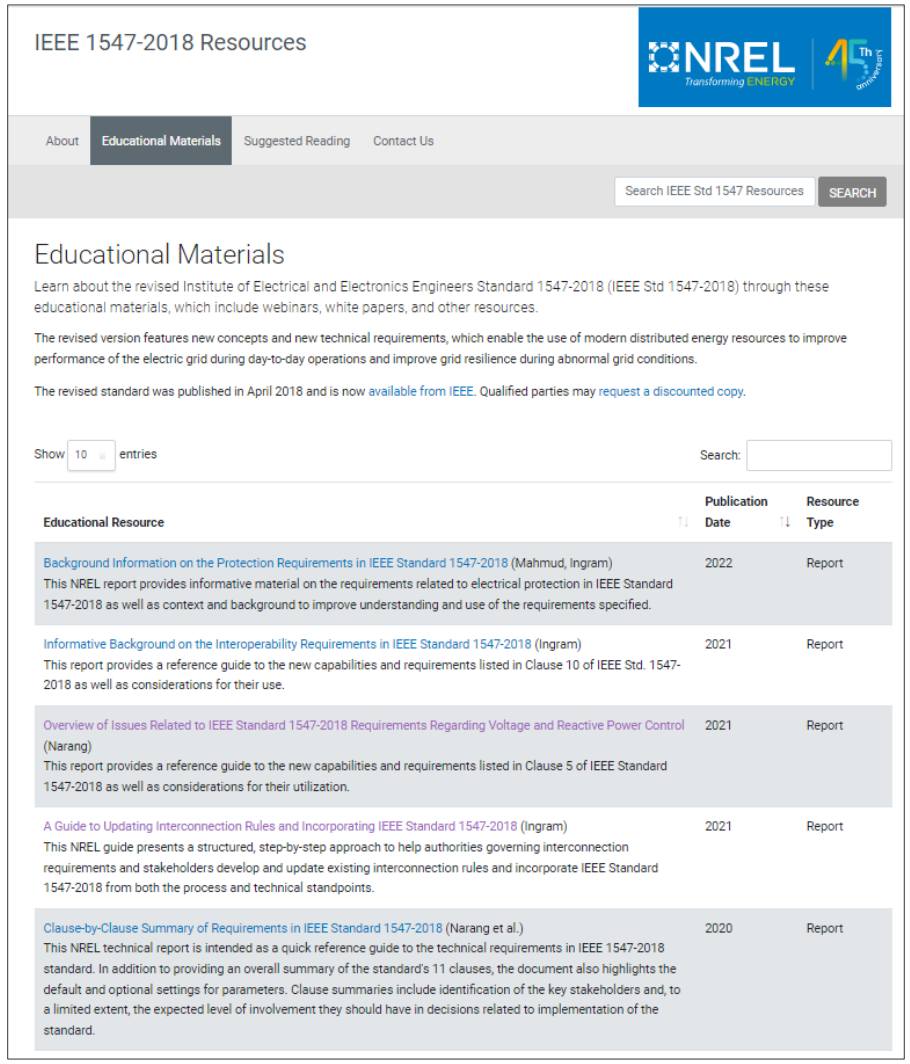
Partners and Advisors:

- 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

An NREL Guide for Authorities Governing Interconnection Requirements

A Guide to Updating Interconnection Rules and Incorporating IEEE Standard 1547-2018 presents a structured, step-by-step approach to help governmental 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.

- Three main sections to report:

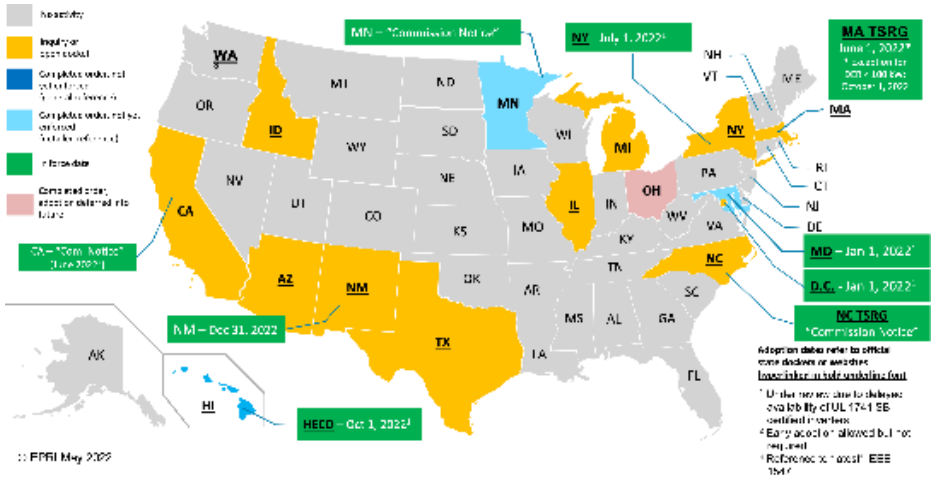
- Key considerations include:
  - Has the governing authority sufficiently identified motivations for updating the interconnection rule? How do the identified technical requirements relate to the desired outcome?
  - Has the governing authority allowed for the use of DER capabilities (even if they are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

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

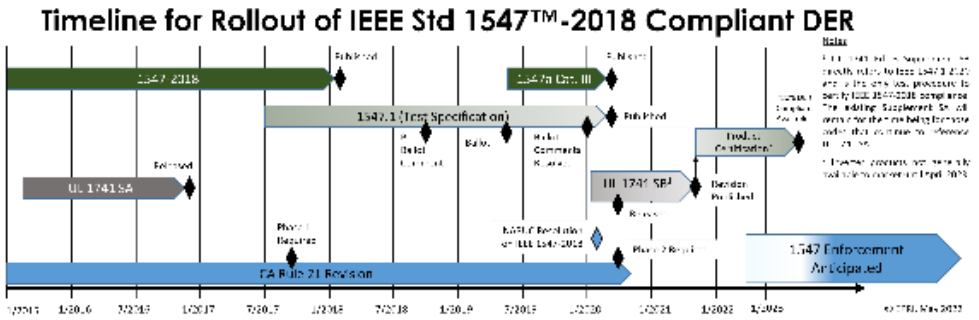
Find the full report on NREL's IEEE Resource Website or at nrel.gov/docs/fy22osti/75290.pdf.

IEEE Standards Coordinating Committee 21 (SCC21) Resources and Outreach

- **Public web site 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 SMEs
  - Catalog of ISO/RTO T&D coordination activities
  - State activity map (maintained ~ quarterly)
  - Inverter rollout timeline ("regularly" maintained)
- **Informal industry/stakeholder coordination calls (quarterly)**
- **Coordination with other IEEE societies, committees & related standards (constant)**



State activity map



Inverter rollout timeline

Highlights of other public education efforts

- EPRI U:

  Public (with free EPRI account):
  https://www.epri.com/#/epri-u/courseslang=en-US

- IREC
  - Publications: https://irecusa.org/blog/tag/ieee-1547/
  - Informal inverter manufacturer discussion forum (FIIGI, typ. weekly)

- others?

INTERCONNECTION INNOVATION e-XCHANGE

U.S. DEPARTMENT OF ENERGY

an EERE collaboration between SETO & 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**
  - Direct Access to i2X Leadership
- **Preliminary i2X Working Groups**
  - Energy Justice Working Group
  - IEEE 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

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Transforming ENERGY

Examples of Activities in Process on Related Topics

DER cybersecurity: Acknowledged as critical but considered out of scope for 2018 version of 1547 due to scope of IEEE Std 1547, scope and complexity of cybersecurity requirements, system architecture flexibility, testability. Very active area of debate (e.g., https://sunspec.org/cybersecurity-work-group/, https://www.nist.gov/programs-projects/cybersecurity-smart-grid-systems, https://www.nist.gov/programs-projects/cybersecurity-smart-grid-systems)

Interactions with bulk power system: Very active across all areas (e.g., NERC and many others, https://www.nerc.com/comm/RSTC/Pages/IRPWG.aspx, https://www.nerc.com/comm/PC/Pages/System-Planning-Impacts-from-Distributed-Energy-Resources-Subcommittee-(SPIDERWG).aspx)

Unintentional islanding: Areas of detection, mitigation, evaluation/interconnection screens are all under review (e.g., CA Rule 21 WG 4, https://gridworks.org/initiatives/rule-21-working-group-4/)

Grid-forming inverters: Very active area focused on resilience (e.g., Grid-Forming Technologies Research Consortium https://www.energy.gov/articles/energy-department-announces-45-million-funding-solar-technologies)

DER aggregation: FERC 2222 opens door for aggregation from bottom up rather than top down (https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet ; https://pv-magazine-usa.com/2021/07/27/sunnova-and-solaredge-partner-to-provide-grid-support-services-in-new-england/)

Standards conformance: How to ensure standards are implemented properly? (e.g., https://standards.ieee.org/products-services/icap/programs/der/index.html)

Many other areas of active research and development.

Examples of Standards in Process on Related Topics

IEEE Std P2800 - IEEE Draft Standard for Interconnection and Interoperability of Inverter-Based Resources (IBR) Interconnecting with Associated Transmission Electric Power Systems
https://standards.ieee.org/project/2800.html

IEEE Std P1547.2 - Application Guide for IEEE Std 1547(TM), IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, https://standards.ieee.org/project/1547_2.html

IEEE Std P1547.3 - Guide for Cybersecurity of Distributed Energy Resources Interconnected with Electric Power Systems, https://standards.ieee.org/project/1547_3.html

IEEE Std P1547.9 - Guide to Using IEEE Standard 1547 for Interconnection of Energy Storage Distributed Energy Resources with Electric Power Systems, https://standards.ieee.org/project/1547_9.html

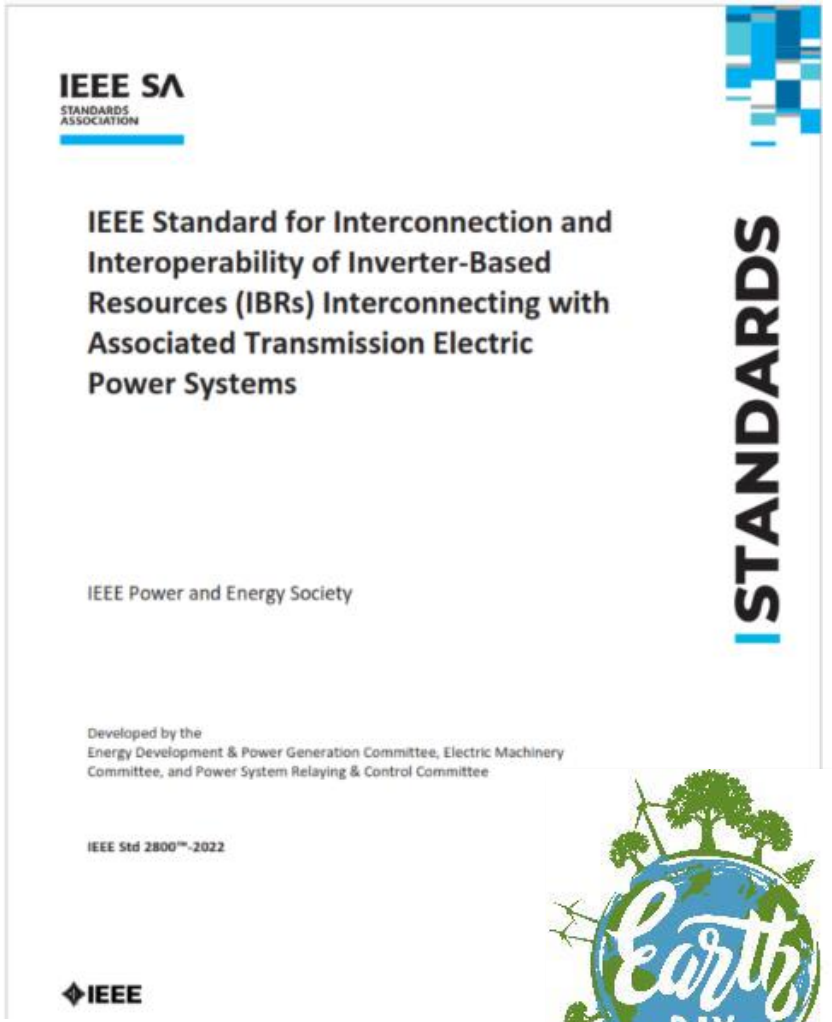
IEEE Std P2030 - Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads

IEEE 2030.11-2021 - IEEE Guide for Distributed Energy Resources Management Systems (DERMS) Functional Specification, https://standards.ieee.org/standard/2030_11-2021.html (published in June 2021)

Summary of IEEE 2800 Standard

- The standard **harmonizes** Interconnection Requirements for Large Solar, Wind and Storage Plants
- It is a **consensus-based** standard developed by over ~175 Working Group participants from utilities, system operators, transmission planners, & OEMs over 2 years
- It has successfully passed the IEEE SA ballot among 466 SA balloters **(>94% approval**, >90% response rate)
- **Published on April 22, 2022 (Earth Day)**

More Info at https://sagroups.ieee.org/2800/



Available from IEEE at https://standards.ieee.org/project/2800.html and via IEEExplore: https://ieeexplore.ieee.org/document/9762253/

Slide courtesy of IEEE 2800 leadership team

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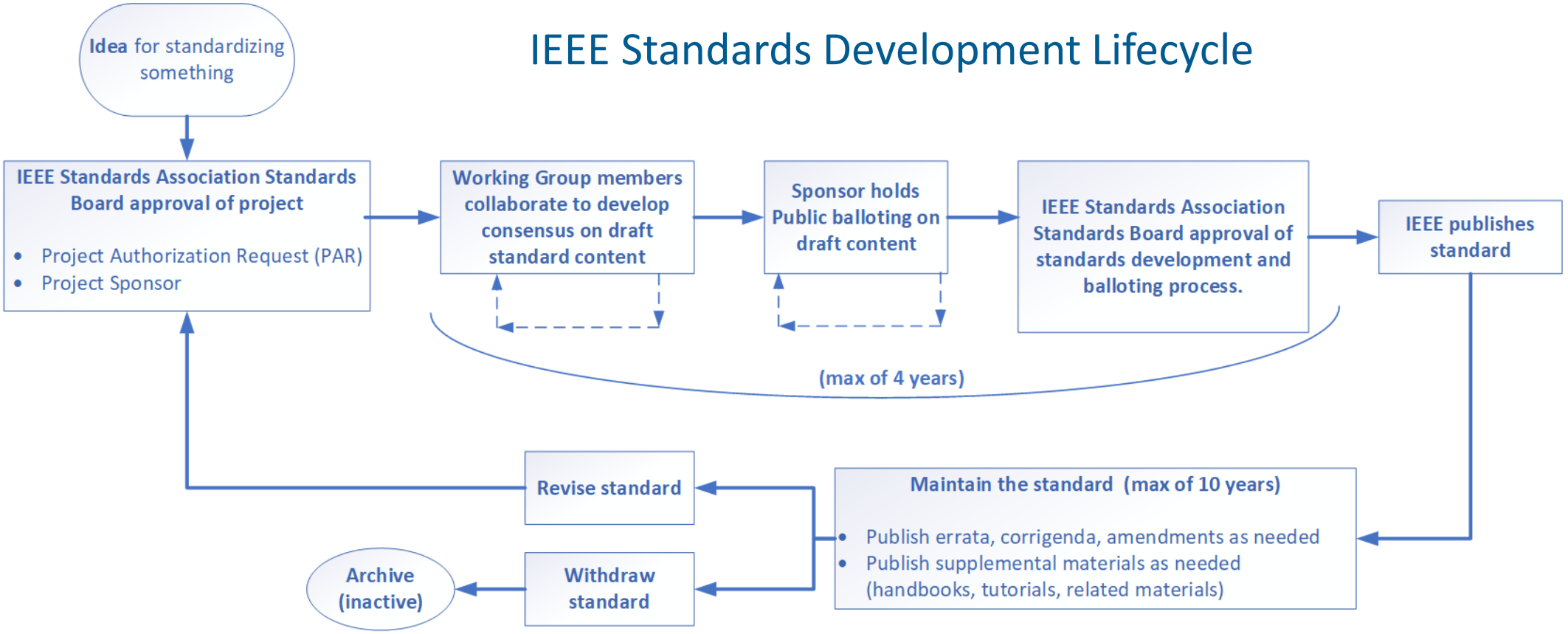
Preplanning for the Next 1457 Revision Is Underway

- DRAFT potential scope
- DRAFT general timeline
- Outreach to potential IEEE cosponsors (in addition to IEEE Standards Coordinating Committee 21)
- Outreach to stakeholders
- Development of DRAFT project authorization request (PAR)

New working group kickoff in Q1 2023

Rely on the Latest National Standards



Source: based on https://standards.ieee.org/develop/develop-standards/process.html

Rely on the latest (most up-to-date) national technical standards.

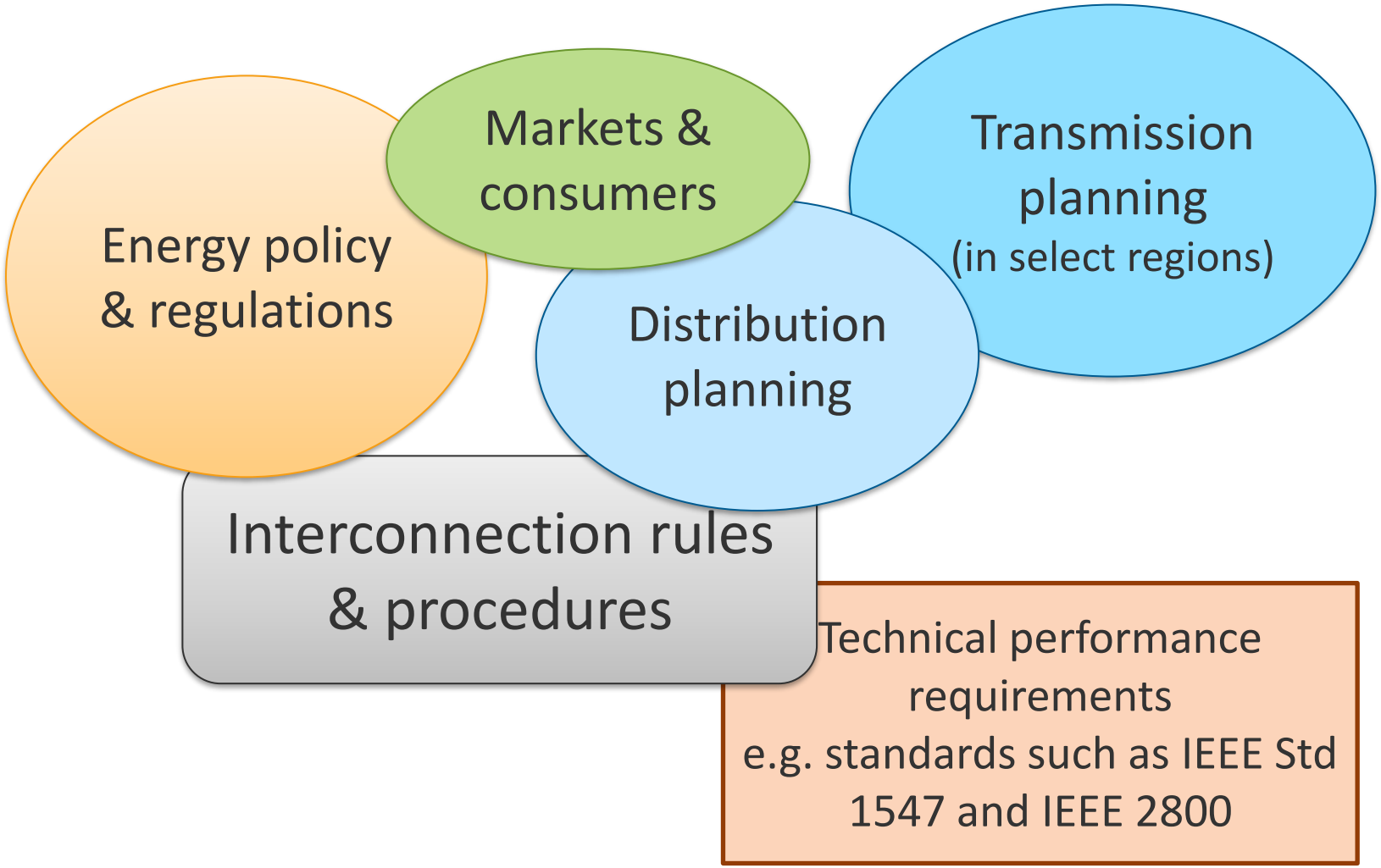
e.g.,

- IEEE Std 1547-2018
- IEEE Std 2800-2022

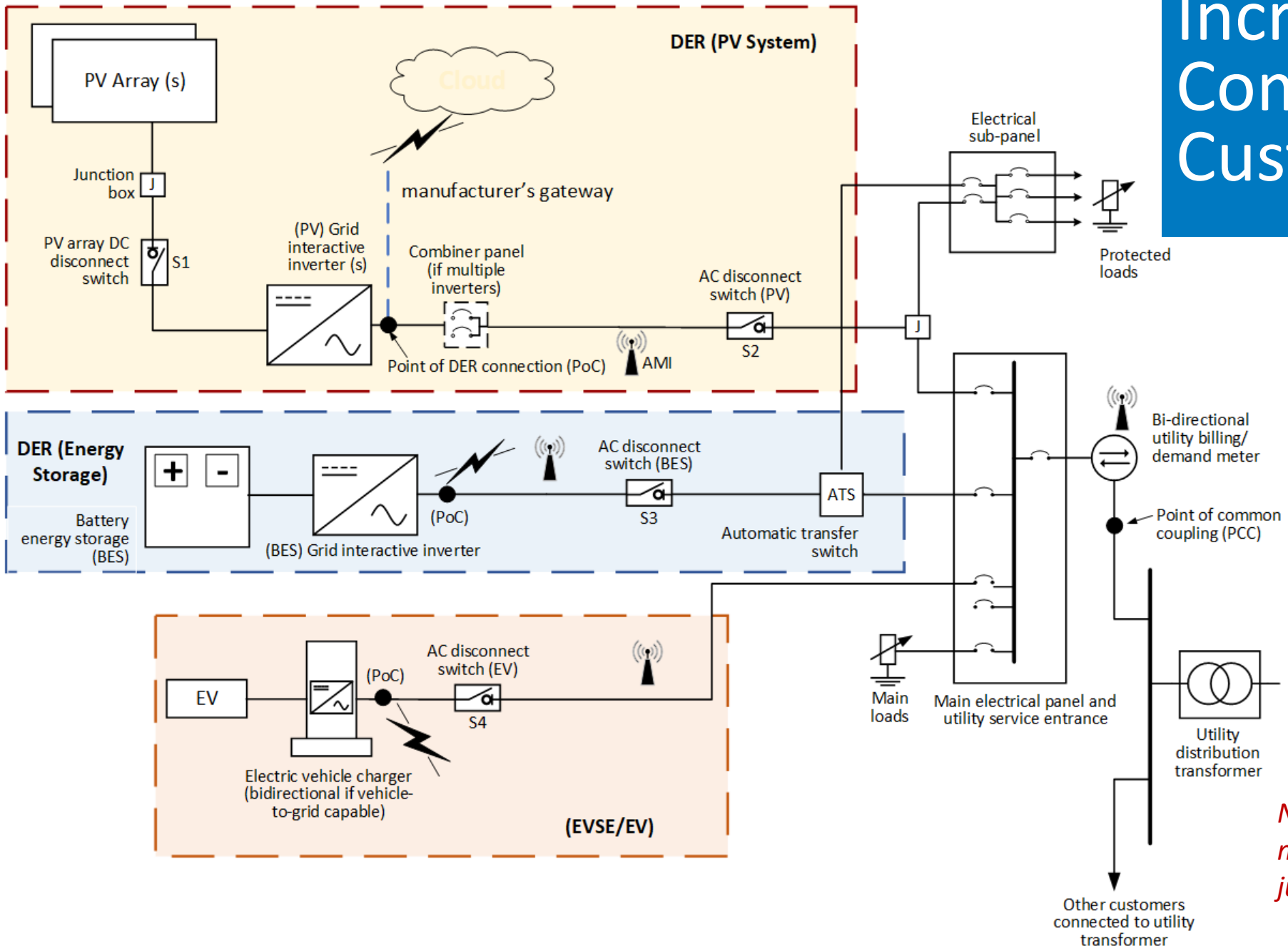
The National Association of Regulatory Utility Commissioners (NARUC) resolution in February 2020 recommends state commissions act to adopt and implement the revised standard. https://pubs.naruc.org/pub/E86EF74B-155D-0A36-3138-B1A08D20E52B

Ref: IEEE standards process overview: https://standards.ieee.org/develop/index.html

Increased Complexity at Local Regulatory Level

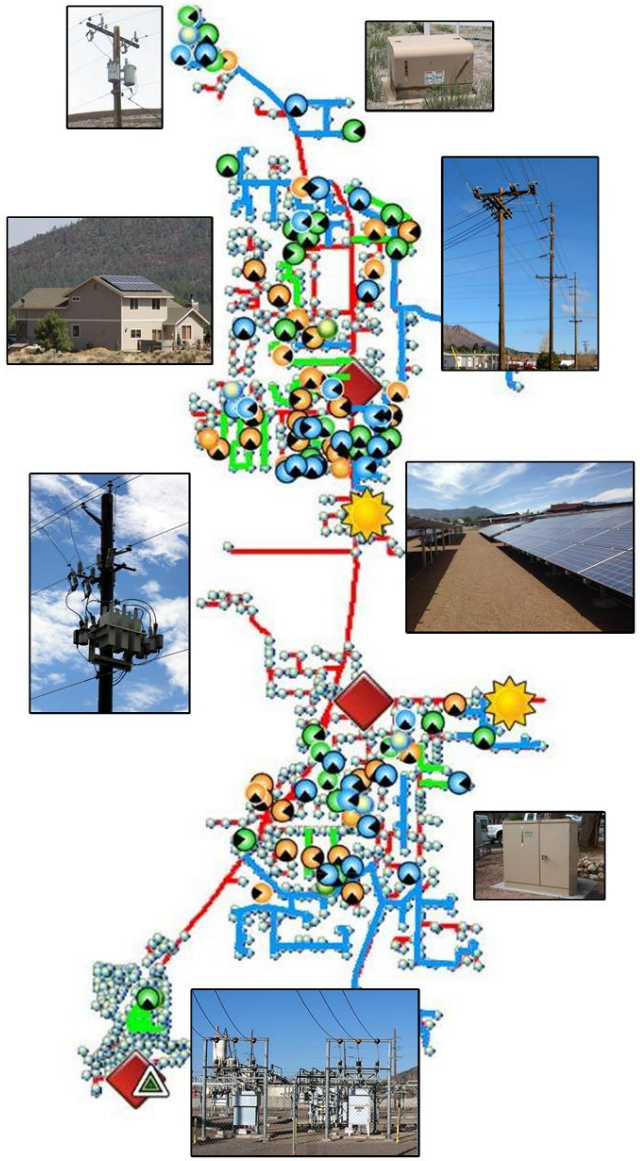


Increased Complexity at Customer Facility



Note: Installation configurations and metering requirements vary across jurisdictions and utilities

Increased Complexity at Distribution Level



Photos by author

Distribution Operations/Situational Awareness

Feeder topology (GIS): Equipment specifications/ratings, DG size, location, adjacent feeder characteristics

Substation transformer loading (EMS): Measurements interior to feeder

Feeder load balancing

Equipment status/state/settings (mix—EMS, manual): Reclosers, capacitor banks, fuses, settings for dynamic voltage control devices, DG size, location, orientation, specifications

Solar irradiance: Historic, real-time forecast.

Power System Studies and Tools

Feeder historic peak load (manual process—annual): Feeder minimum daytime load

Steady-state studies: Load (power) flow, short-circuit/protection coordination, feeder PV hosting capacity, distributed generation point of interconnection "stiffness ratio"

Dynamic studies: Voltage stability (PSLF—transmission planning), interactions between smart grid devices

New scenarios: Optimal location and size of energy storage, control settings for smart inverters, feeder reconfiguration, microgrid applications, aggregation of distributed generation, forecast, transients, harmonics

Increased Complexity at Bulk System Level: e.g., Recurring Reliability Issues with IBRs

- Unexpected tripping, cessation of active power, oscillations, etc.
- Mis-application of IEEE 1547 standard for Transmission connected resources
- Analysis found **opportunity for standardization** of IBR performance to maintain grid reliability

Source: NERC, 2017-2022

Slide courtesy of IEEE 2800 leadership team

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