INTEGRACIÓN EFICIENTE DE ENERGÍAS RENOVABLES VARIABLES AL SISTEMA COLOMBIANO

Considerations for Developing a Regulatory Roadmap for Distributed Energy Resource (DER) Integration in Colombia

Authors: David Narang, Michael Ingram, and Daniella Rough

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Project Scope

USAID-NREL Technical Assistance

To assist the government of Colombia in achieving its renewable energy integration and energy transition targets, the USAID-NREL Partnership provides technical and regulatory support to key public and private stakeholders in the Colombian energy sector. This support included a comprehensive training program in 2020 to better enable young professionals in Colombia's energy sector workforce to integrate growing volumes of variable renewable energy (VRE). The initial cohort of participants in the Young Leaders Workforce Training Program developed action plans to apply the program's training content to real-world energy questions they are facing in their respective organizations. Four teams – representing various energy sector topics and clean energy challenges – were selected to participate in ongoing technical assistance with the USAID-NREL Partnership to implement the action plans they developed. The following document represents the culmination of technical assistance and strategic advisory support provided to specialists from Colombia's Energy and Gas Regulatory Commission (CREG) regarding the integration of increasing distributed energy resources (DER).

Goal

The goal of this technical assistance was for NREL to provide working input in support of CREG's objective to establish the general steps (proposed roadmap) to be taken to update the distribution code for DER integration, including distributed renewable energy systems, electric vehicles, and energy storage systems, considering the design and development of new markets.

Application

NREL considerations and recommendations present a general framework for DER integration, and should be considered holistically, within the broader context of Colombia's clean energy transition. Policy and regulatory examples are provided for consideration but are not meant to represent the full suite of possibilities that CREG might consider to undertake when developing a regulatory roadmap for the integration of DER in Colombia.

Framework for Updating DER Interconnection Rules

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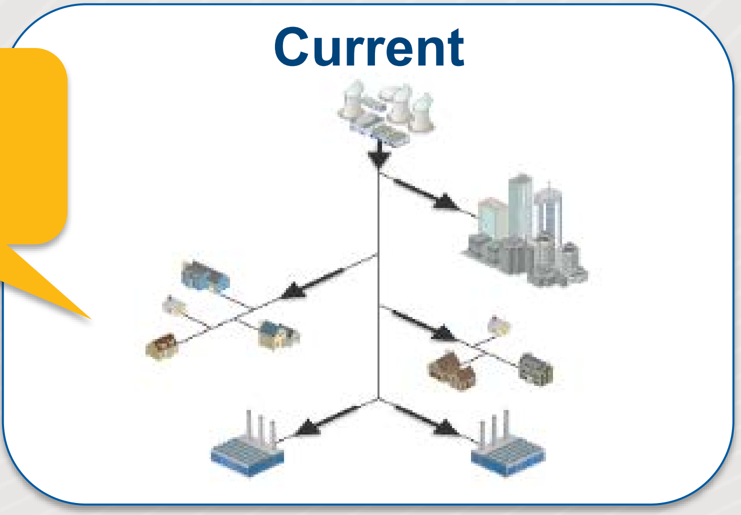
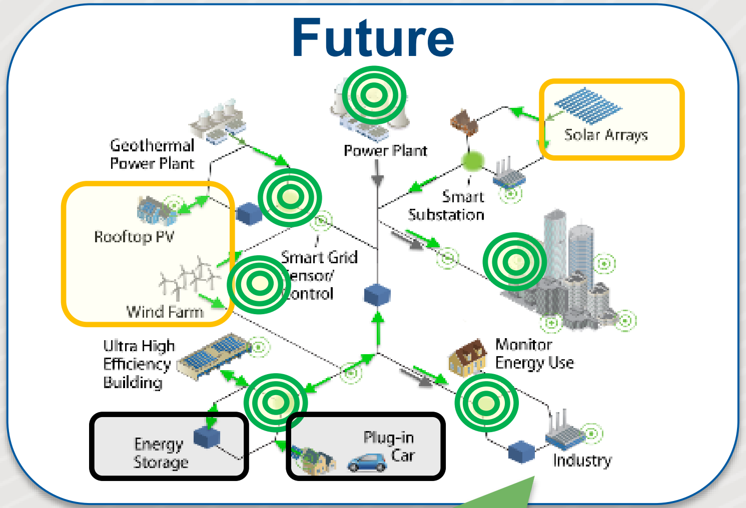
High-Level Recommendations

Develop an internal vision aligned with the broader energy sector context.

- **Carbon intensive**
- **Large generation**
- **Central control**
- **Highly regulated**





DER interconnection must be considered within the broader context of DER integration which includes national energy policy goals, market trends, technical requirements, stakeholder viewpoints, and other efforts such as grid modernization.

Our evolving power system context:

- New energy technologies and services, and multiple stakeholders
- Increasing penetrations of variable renewables on grid
- New communications and controls (e.g., smart grids)
- Electrification of transportation
- Integrating distributed energy storage
- A modern grid needs increased system flexibility.

- **Variable generation**
- **Bi-directional flow at distribution level**
- **Increased number of smart/active devices**
- **Evolving institutional environment**

1. O'Connell and Kroposki."Integration of Distributed Energy Resources and Demand Response in Energy Systems. Smart Cities Centre",

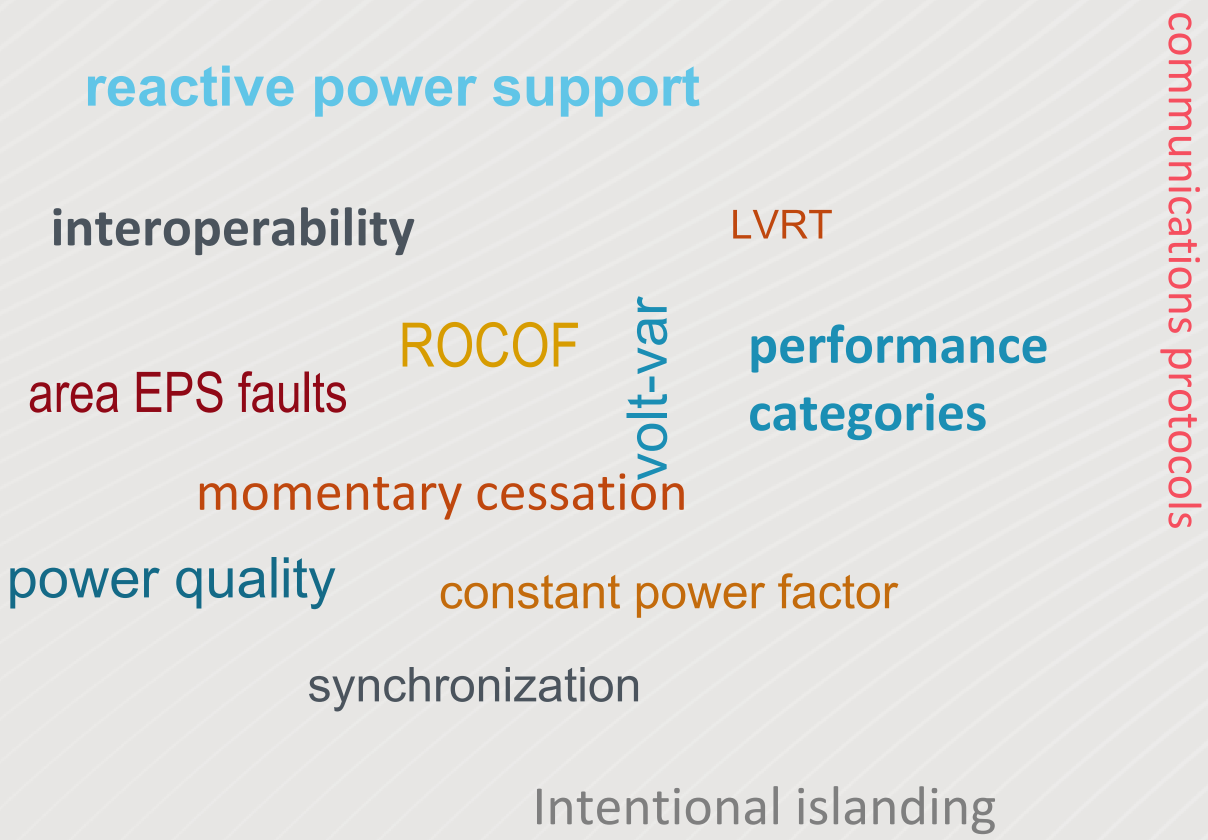
High-Level Recommendations

Define DER capabilities and intended use prior to developing technical requirements.

Technical aspects of DER interconnection regulations are a directly linked to the intended use of DER technologies. Therefore, the intended use must be clearly defined **prior** to developing technical aspects.

Factors that could influence the normal operating performance category of DER might include (but are not limited to):

- Market or policy considerations such as incentivizing a specific type of DER
- Long-term intended purpose and use of DERs
- Integrating greater shares of renewable generation
- Developing specific market segments
- Grid modernization investment plans
- Remote communications and cybersecurity



2. Ingram, Bhat, and Narang. "A Guide to Updating Interconnection Rules and Incorporating IEEE Standard 1547".

There are **three general steps** to developing and updating interconnection rules.

1

Preplanning: Determining the context, stakeholders & major drivers.

- **Define regulatory motivations and objectives.** What is the reason for regulatory action? What technical, market, or policy goals is the regulatory action expected to achieve?
- **Assess the broader context.** Decisions regarding DER interconnection process and technical requirements should be considered within the broader context of power sector planning and operations.
- **Identify and assess the role of relevant stakeholders and key decision-makers.** DER technologies expand the scope and role of relevant stakeholders in power sector decision-making – policy makers and regulators should be prepared to understand how/if these roles and incentives might change within an evolving market context. Regulators should also be prepared to address potential conflict of interest challenges that could arise from changing business models, rate structures, and revenue streams.
- **Determine how the interconnection process will be structured.** Regulators might consider developing key performance indicators, mechanisms for data collection, and/or mapping interconnection process steps, in addition to other considerations.
- **Establish a procedural timeline.** This can include key milestones and required analyses leading up to the final rule. Determine if other ongoing regulatory procedures or efforts are relevant and/or will impact this timeline.

There are **three general steps** to developing and updating interconnection rules.

2 **Updating the DER interconnection rule.**

- **Define broad goals for DER technical requirements.** These can include safety, reliability, power quality, protection, affordability, or market development, to name a few.
- **Review Institute of Electrical and Electronics Engineers (IEEE) 1547-2018 decision points.** IEEE 1547-2018 enables new DER capabilities, and the utilization of these capabilities is at the discretion of the power system operator. These capabilities can include reactive power support, fault ride-through, interoperability, intentional islanding, and/or energy storage, among others.
- **Assess rule jurisdiction and utility responsibilities.** Utilities and power system operators play a critical role in DER interconnection. The roles and responsibilities of utilities in the interconnection process should be clearly defined. For example, this can include specific metering or protection requirements.
- **Determine if further coordination is required**. DER capabilities for grid support have implications that can extend beyond the responsibility of the distribution utility (for example, bulk system reliability and resilience, black start).

There are **three general steps** to developing and updating interconnection rules.

3

Maintaining and revising the interconnection rule.

Once the interconnection rule has been revised, it is critical to monitor its implementation and impact from both the process and technical standpoints. Often, informative diagrams of interconnection processes and screens are included in the rule. The collaborative development of these diagrams from the rule can be helpful to the implementation as well as the validation of the functional accuracy of existing processes. Additionally, as new DER technology classes emerge, regulators will be required to address the challenges associated with integrating these resources into the grid. This will likely entail frequent revisions of technical requirements for interconnecting DERs in the context of technical standards such as IEEE Std 1547-2018.

Regulators should determine:

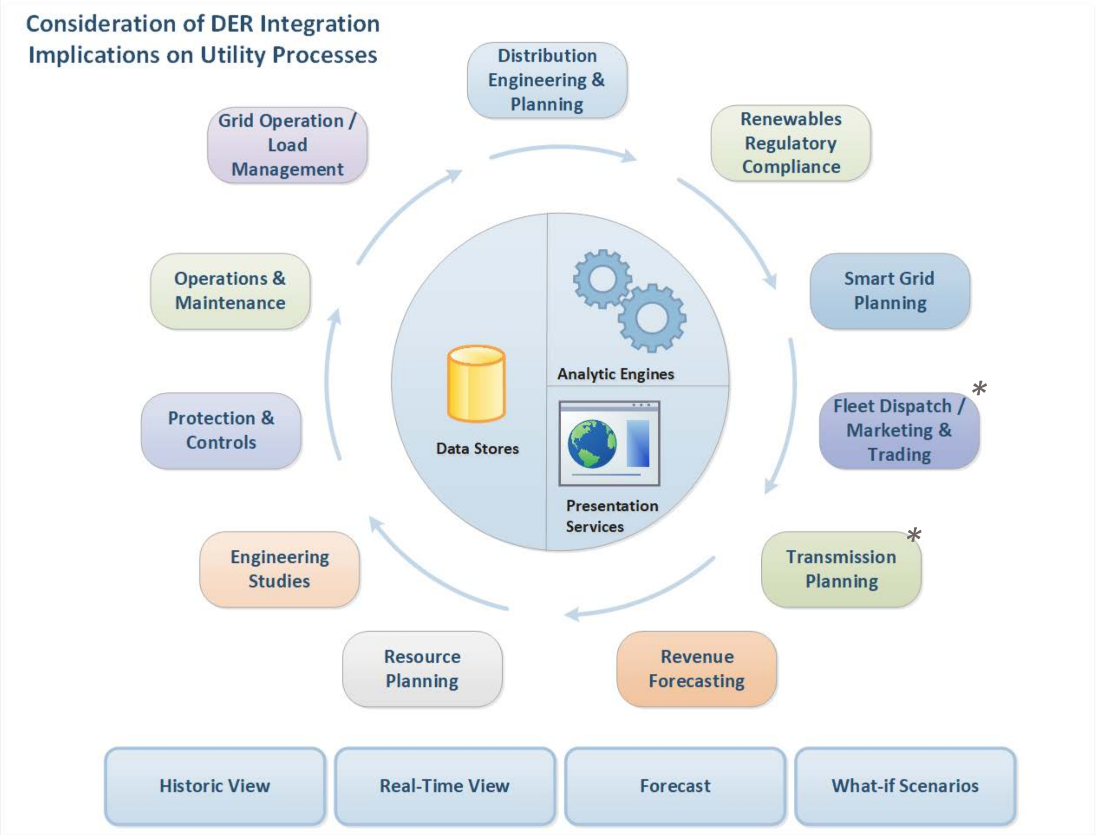
- Indicators and associated thresholds that might trigger an update.
- Defined scope and criteria for each update.
- Maintainability of the rule.

High-Level Recommendations

Understand that DER integration has major implications for the traditional utility business model.

- DER technologies can impact a range of utility planning and operations decisions, including resource and infrastructure planning, revenue forecasting, power quality management, in addition to a number of other traditional utility functions.
- Utilities are critical stakeholders and regulators must be prepared to address new questions regarding evolving utility responsibilities, incentives, and potential challenges.

Example of utility business processes and functions that may be affected by DER integration (for a vertically-integrated investor-owned utility). Image source: D. Narang

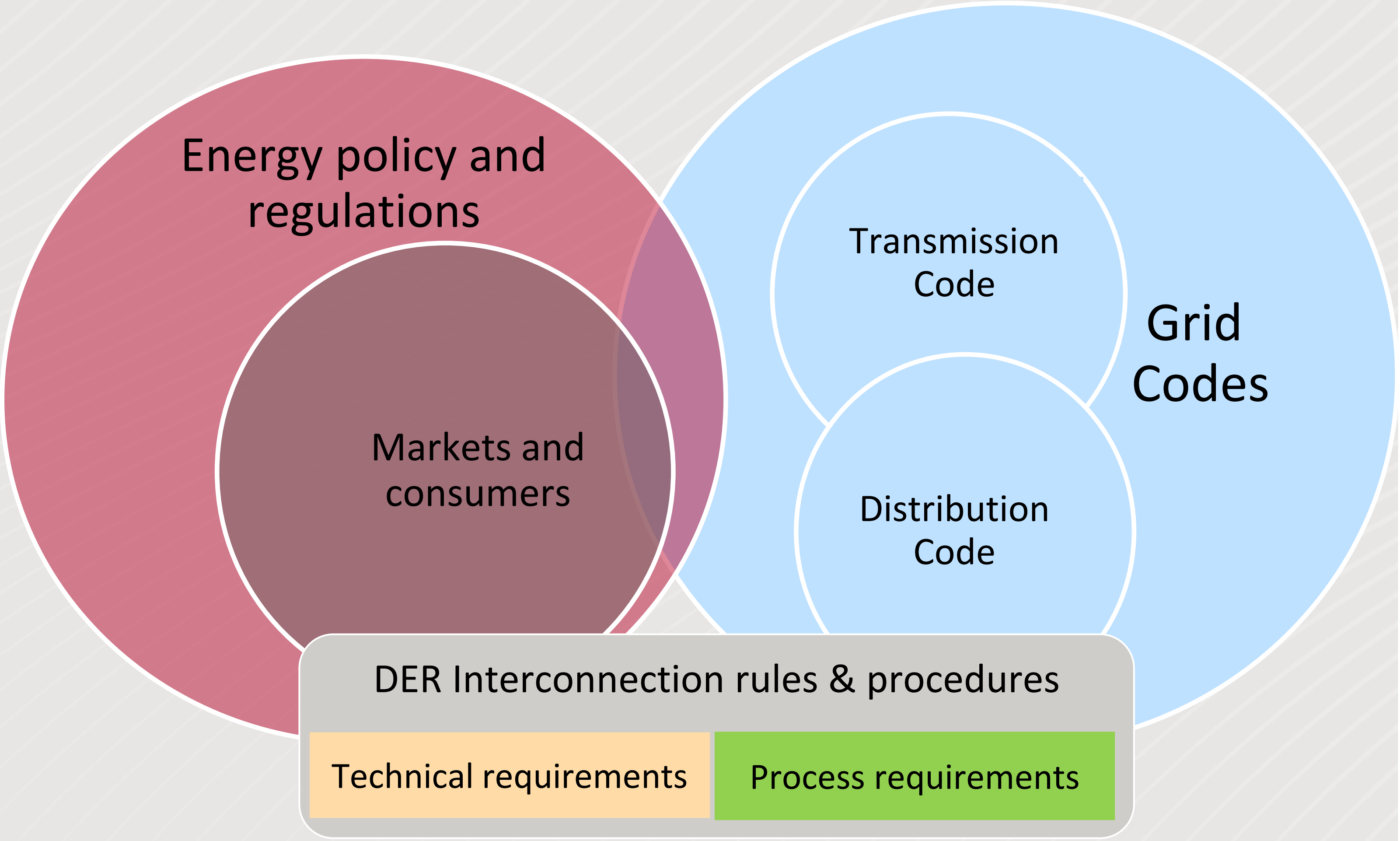


**Note: Fleet dispatch refers to the portfolio of generation assets and how they operate throughout the day to meet demand. Note that fleet dispatch / marketing and trading, as well as transmission planning and operations, are typically longer-term considerations within the context of more mature DER markets.*

High-Level Recommendations

Evaluate DER interconnection process and technical requirements holistically.

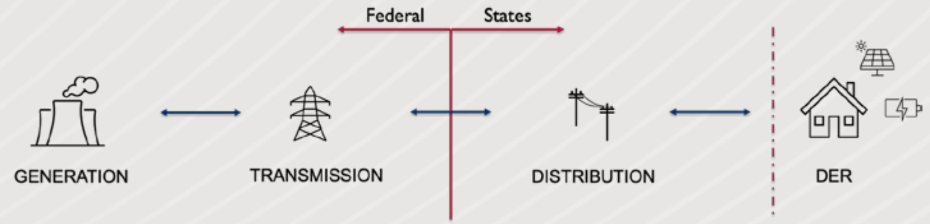
DER interconnection process and technical issues often overlap and are not easily segregated, and regulations must consider and evaluate issues for both types of topics. Additionally, technical requirements are typically only one part of interconnection regulation.



High-Level Recommendations

Evaluate jurisdictional authority and anticipate stakeholder coordination needs.

Closer and earlier coordination is required with relevant stakeholders for requirements that cross jurisdictional boundaries - for example, following IEEE Std 1547-2018 requirements.



KEY DECISION-MAKERS

- **CREG (Energy Regulator)**
- **Distribution companies (Area EPS Operator)**
- **XM (National Reliability Coordinator)**
- **DER Operator (TBD policy)**

IMPORTANT DER CAPABILITIES AND IEEE 1547-2018 REQUIREMENTS	DECISION POINTS AND COORDINATION	ADDITIONAL COORDINATION NEEDED
Safety Power Quality Protection	• Protection settings	
Testing & Certification	• Type testing • Study, evaluation	
Voltage Regulation	• Perf. Category • V. Reg. Mode	Grid services
Interoperability	• Utilization • Com. Protocols	Cybersecurity
Support for bulk system (Ride-through)	• Performance category • Trip settings • Ride-through settings	Bulk system reliability Resilience Black Start

DER Policy Stacking and Market Phases

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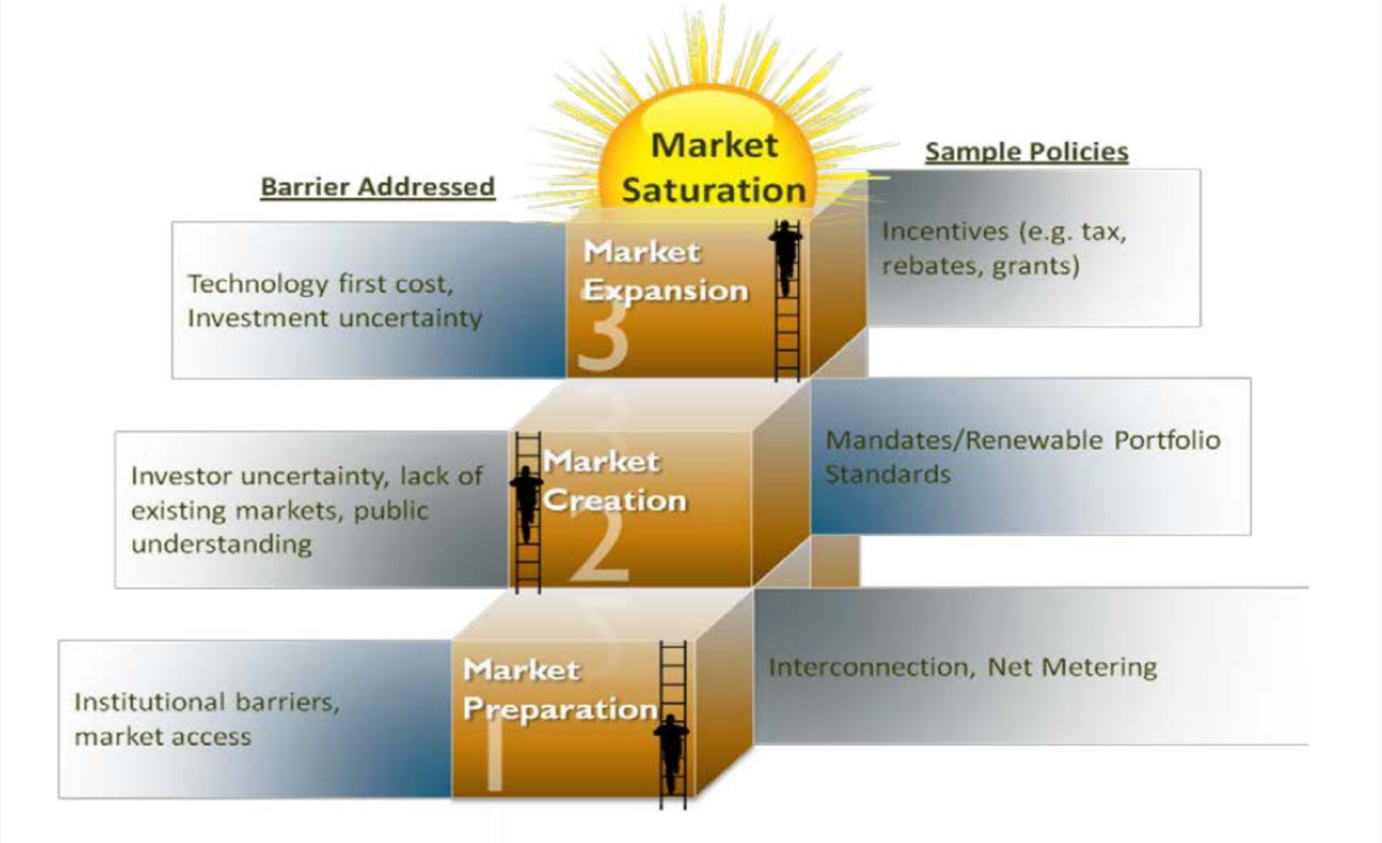
High-Level Recommendations

Regulators should consider developing regulations in coordination with a "policy stacking" framework that is sensitive to market maturity levels.

Different types of DER will likely require specific consideration of their policy stack, market adoption characteristics, intended use, and technical requirements.

Example generalized policy stack for DER



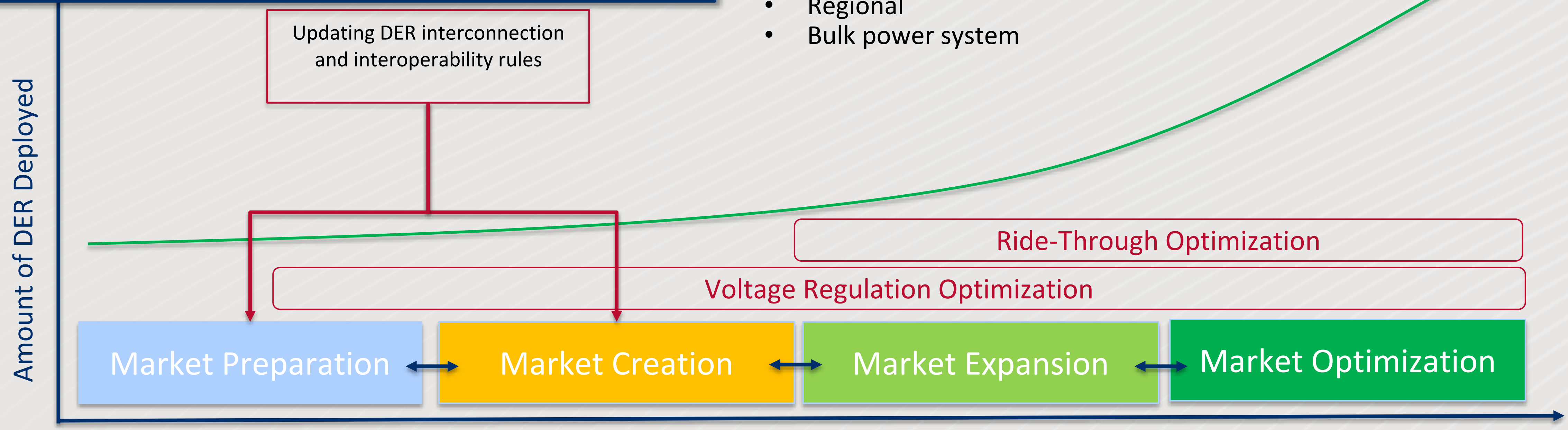
3. Doris and Krasko "Strategic Sequencing for State Distributed PV Policies: A Quantitative Analysis of Policy Impacts and Interactions".

Market Phases for DER Integration

Utilization of DER grid-support capabilities will likely be optimized over time at different DER market saturation/deployment levels. More rigorous technical detail is required for utilization of DER capabilities in the near-term.

DER penetration and technical capabilities can be evaluated at the following levels:

- Line section
- Feeder level/transformer
- Substation
- Regional
- Bulk power system



- Energy, microgrid, and resilience planning
- Value streams
- Regulatory treatment
- Interconnection standards

- Pilots
- Utility procurement
- Mandate
- Reduced investor / public uncertainty

- Financing
- Energy and market reform
- Research and development
- Reduced costs and uncertainty

- Update technical requirements to maximize latest technology
- Improve capability of installed asset base
- Provision and monitoring of ancillary services

Suggested DER Policy Stacking Example

> Market Preparation

- Revise interconnection rules (process & technical requirements)
- Establish enabling legislation/regulation for third-party ownership, clarify role vis-a-vis traditional utilities, clarify required oversight, address disruption to utility business models
- Increase transparency in permitting process and fees, include guidance to address implementation and enforcement for local jurisdictions
- Revise building energy distribution codes to support DER deployment with continued electrical and physical safeguards under normal and abnormal conditions (e.g., include emergency response such as firefighter access).

Supporting research and activities

- Research roadmap
- Value of DER studies
- Resource potential studies and forecasts
- Pilots and demonstrations
- Market monitoring

Infrastructure

- “approved equipment” list
- Online submissions portal

Suggested DER Policy Stacking Example

> Market Preparation > **Market Creation**

- Establish legislative/regulatory mandates (e.g., Renewable Portfolio Standards (RPS) with DER carve-out/set-aside)
- Establish legislative/regulatory rules for compensation to customers for DER generation (net metering)
- Establish financing mechanisms.
- Establish sources to fund financing mechanisms (e.g., loans, public benefit fund/system benefit charge)
- Encourage pilots & demonstration projects, develop "regulatory sandbox".

Supporting research and activities

- Value of DER studies
- Resource potential studies and forecasts
- Pilots and demonstrations
- Market monitoring

Suggested DER Policy Stacking Example

> Market Preparation > Market Creation > **Market Expansion**

- 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, typ. legislative action needed.
- Streamlined permitting

Supporting research and activities

- Value of DER studies
- Resource potential studies and forecasts
- Pilots and demonstrations
- Market monitoring
- Analysis of impacts to transmission planning and fleet operations - recommended for more mature DER market phase

* Note: task of public policy and not of CREG

Suggested DER Policy Stacking Example

> Market Preparation > Market Creation > Market Expansion > **Market Optimization**

- New types of DERs
- New applications of existing DERs
- New actors
- New roles for existing actors
- Update technical requirements

Supporting research and activities

- Value of DER studies
- Resource potential studies and forecasts
- Pilots and demonstrations
- Market monitoring

Types of DER to Consider in Regulatory Roadmap

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High-Level Recommendations

Evaluate unique technical and market considerations for different types of DER at relevant timescales and market maturity levels.

- Different types of DER will likely require specific consideration of their policy stack, market adoption characteristics, intended use, and technical requirements.
- Different technical capabilities are needed at different DER market saturation/deployment levels. More rigorous technical detail is required for utilization of DER capabilities in the near-term.
- DER technology deployment might be driven by national, regional or local considerations and may be closely tied to broader goals for grid modernization, climate change mitigation, and/or renewable energy deployment targets.
- Policy may also provide capacity targets for DER in general, specific types of DER, or ownership structure (for example, carve-outs/set-asides for residential customer-owned DER)
- Technical and market considerations often overlap across technologies.

Types of DER for regulators to consider could include:

- Solar PV systems
- Energy storage systems
- Hybrid PV and storage systems
- Microgrids
- Distributed wind
- Electric Vehicles, vehicle to home (V2H), vehicle to grid (V2G)
- Dispatchable loads
- Conventional (rotating machine) generators, including hydropower
- Fuel cells (e.g., hydrogen)
- Small modular reactors

Examples of unique DER technical and market considerations

- **Energy storage systems (ESS)**
  - Integration to conventional electric grids requires specially designed topologies and/or control systems, design and debugging of individual systems can be costly.
  - Energy storage systems provide different functions to their owners and the grid at large, often leading to uncertainty as to the applicable regulations for a given project.
- **Hybrid energy systems (HES)**
  - To a large extent, wholesale electricity markets, electric utility regulation, and state energy policies were designed with the expectation that power generating facilities would consist of a single technology type. HES create unique challenges for the design, operation, and regulation of wholesale electricity markets, for state regulation of electric utilities, and for the design and implementation of energy policies.
  - Optimizing the design and operations of HES also requires development of controls, sensors, telemetry, metering, and other communications equipment to facilitate the coordinated operations of subcomponents with different objectives.
- **Electric vehicles**
  - Pre-approved equipment lists might be established.
  - Energy resale and tariff / incentive schemes are important to evaluate.
- **Dispatchable loads**
  - This can include traditional demand response assets couple with modern communications and control capabilities, new types of dispatchable loads such managed charging of electric vehicles, and emerging research on ride-through for loads that have energy storage, all of which have unique technical and tariff/compensation considerations.
- **Small modular reactors**
  - Will require participation in international consortia and sufficient monitoring / oversight schemes.

Note that this list was developed by the authors. It includes a subset of sample considerations and should not be considered an exhaustive list.

Examples of unique DER technical and market considerations

Technology	Example Technical Considerations	Example Market Considerations
Solar PV[1]	• Distributed PV adoption should be evaluated at multiple scales (substation, circuit, region).	• Cost allocation and cost (un)certainty
Energy storage systems (ESS)	• Interoperability should be considered. • Integration to conventional electric grids requires specially designed topologies and/or control systems. • Costly design and debugging of each individual energy storage system.	• ESS integration has unique implications for the traditional utility business model. • Energy storage systems provide different functions to their owners and the grid at large, often leading to uncertainty as to the applicable regulations for a given project.
Hybrid energy systems (HES), including PV with storage	• To a large extent, wholesale electricity markets, electric utility regulation, and state energy policies were designed with the expectation that power generating facilities would consist of a single technology type. • Optimizing the design and operations of HES also requires development of controls, sensors, telemetry, metering, and other communications equipment to facilitate the coordinated operations of subcomponents with different objectives.	• HES create unique challenges for the design, operation, and regulation of wholesale electricity markets, for state regulation of electric utilities, and for the design and implementation of energy policies.
Microgrids[2]	• Islanding operation should meet technical performance requirements for parallel operation (i.e., grid-tied). • Interoperability should be considered.	• Microgrid integration has unique implications for the traditional utility business model. • Microgrids provide different functions/services to their owners and the grid at large, potentially leading to uncertainty as to the applicable regulations for a given project.
Distributed wind	• Lowering technology costs, developing new markets, and improving turbine reliability • Improving integration and control • Improving prediction of long-term output	• Deployment cost reduction and reliability improvement necessitate policy considerations.

Note that this table includes a subset of sample considerations and should not be considered an exhaustive list.

4. McGranaghan et al. “Renewable Systems Interconnection Study: Advanced Grid Planning and Operations”.
5. Young and Kessler. ““Electric & Plug-in Hybrid Vehicle Home Charging”.

Examples of unique DER technical and market considerations

Technology	Example Technical Considerations	Example Market Considerations
Electric Vehicles, vehicle to home (V2H), vehicle to grid (V2G)	● Pre-approved equipment list	● Energy resale, tariff and fee considerations ● Charging / discharging incentives and time of use
Dispatchable loads	● Traditional demand response assets couple with modern communications and control capabilities, ● new types of dispatchable loads such managed charging of electric vehicles ● emerging research on ride-through for loads that have energy storage, all of which have unique technical considerations.	● Tariff and compensation structure
Small modular reactors	● Participation in international consortia	● Participation in international consortia
Fuel cells	● Especially for vehicle applications, inter-organizational technical considerations and planning are required (e.g., infrastructure requirements, codes and standards) ● Stationary and V2G/V2H applications (i.e., ESS technical considerations apply)	● Largely, the hydrogen p*roduction / generation cycle* is a form of energy storage (i.e., ESS market considerations apply) ● Fuel cells have both stationary and vehicle applications (i.e., EV market considerations apply) ● Fuel infrastructure policy, procedure, and market considerations. Production (i.e., reforming, electrolysis), transportation, and/or physical storage are examples.
Conventional (rotating machine) generators, including hydropower	● IEEE Std. 1547 is the governing standard, unless there is a conflict in requirements with the IEEE Stds for synchronous generators C50.12 and C50.13, in which case their requirements will prevail. ● IEEE Std. 67 criteria for synchronization limits for frequency, voltage, and phase angle may apply for some types of synchronous generators.	● Small-scale, distributed hydro pilots to gain experience with market operations (dependability, services, dispatch)

Note that this table includes a subset of sample considerations and should not be considered an exhaustive list.

4. McGranaghan et al. "Renewable Systems Interconnection Study: Advanced Grid Planning and Operations".
5. Young and Kessler. ""Electric & Plug-in Hybrid Vehicle Home Charging".
6. Denholm et al. "Methods for Analyzing the Benefits and Costs of Distributed Photovoltaic Generation to the U.S. Electric Utility System".

Grid Services to Consider in Regulatory Roadmap

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Grid Services Context

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

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

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

Electrical interface (interconnection)

Communications interface (interoperability)

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

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

High-Level Recommendations

Regulatory support to enable and coordinate DER grid services should be evaluated at the appropriate timescale, with clearly defined technical objectives.

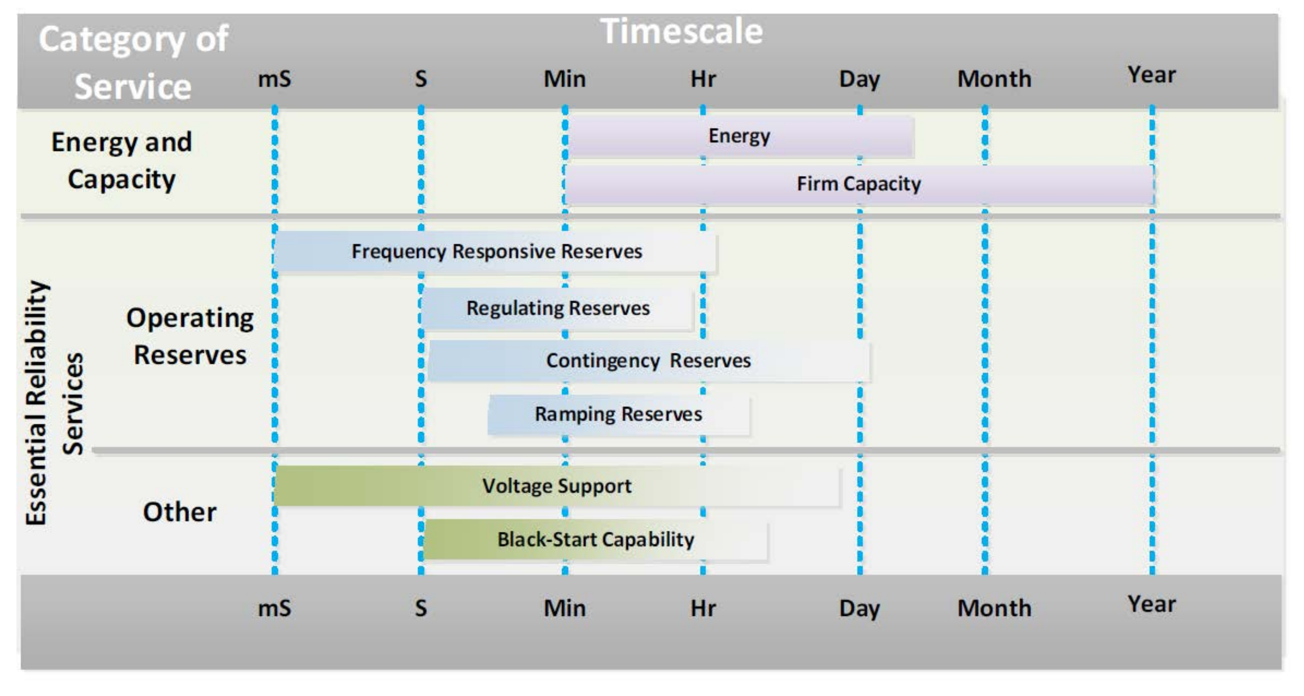

Table 1. Summary of DER Device or DER Controller-Level Functions Required for Grid Services

Type of Grid Service	**Inverter-Based DERs (PV, energy storage)**	**EVs** (or EV service equipment)	**Responsive Loads** (or Building Energy Management Systems)	**Grid-connected Microgrids** (or Microgrid Controllers)
Energy	Increase or reduce active or reactive power output (for energy storage, charging, or discharging)	Change charge or discharge rate	Change set points to increase or decrease active or reactive loads	Change set points for energy import and export
Regulation	Increase or reduce active power input	Reduce active power charging rate	Change set points to increase or decrease loads	Change set points of active and reactive power consumption
Distribution voltage management	Volt/VAR reactive power; fixed power factor; volt-watt	Volt-watt volt/VAR	Modify set points that change loading for various devices	Modify the import and export set points for power exchanges
Inertial response	Frequency-watt	Frequency-watt	Device on/off, adjust variable-frequency motors	Not yet fully defined

6. Denholm, Sun, and Mai. “"An Introduction to Grid Services: Concepts, Technical Requirements, and Provision from Wind"
7. Narang et al. "GMLC Survey of Distributed Energy Resource Interconnection and Interoperability Standards".
8. Zhou, Levin, and Conzelmann. “Survey of U.S. Ancillary Services Markets”.

Input on IEEE 1547 Technical Requirements

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High-Level Recommendations

Review and adopt IEEE Standard 1547-2018.

General Requirements Specified in IEEE Std 1547-2018

Safety

- Visible-break isolation device
- Anti-islanding
- Inadvertent energization of area EPS.

General

- Interconnect integrity
  - Protection from electromagnetic interference
  - Surge withstand.
- Integration with area EPS grounding
- Synchronization limits for frequency, voltage, and phase angle (IEEE 67 criteria okay for some types of synchronous generators[1]).

Power Quality

- Limitation of DC current injection
- Limitation of DER-caused voltage fluctuations
  - Flicker (revised method)
  - Rapid voltage changes (new).
- Limitation of current distortion
- Limitation of overvoltage contribution
  - Temporary overvoltage
  - Transient overvoltage.
- Harmonics.

Protection

- Response to short-circuit faults:
  - IEEE Std 1547-2018 requires the DER to cease to energize and trip
- Open phase conditions
- Coordination with area EPS circuit reclosing.
- Response to abnormal grid conditions:
  - Appropriate to ensure grid stability *(e.g.,* voltage and frequency ride-through capabilities) while maintaining safety of utility personnel

NOTE: Different requirements in IEEE Std 1547-2018 are set such that *no specific technology is given preference*, and the standard is technology neutral.

[1]For example, round rotor synchronous generators with ratings 10 MVA and larger and salient pole synchronous generators with ratings 5 MVA and larger may use the synchronization criteria described in IEEE 67, which are tighter than the ones specified here, and can therefore meet the requirements of this standard.

10. Mahmud and Ingram. "*Background Information on the Protection Requirements in IEEE Std 1547-2018*".

IEEE 1547-2018 Active Voltage Regulation Requirements

DER are required to provide voltage regulation capabilities and distribution companies must specify the required voltage regulation control modes for DER to participate in voltage regulation.

IEEE 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.

Performance Categories (Grid support under normal grid conditions)		Mandatory Voltage Regulation Capabilities				
		Constant Power Factor Mode	Constant Reactive Power Mode ("reactive power priority")	Voltage-Reactive Power Mode ("volt-VAR")	Active Power-Reactive Power Mode ("watt-VAR")	Voltage-Active Power Mode ("volt-watt")
Category A	Meets minimum performance capabilities needed for area EPS voltage regulation Reasonably attainable by all state-of-the-art DER technologies	✓	✓	✓	Not required	Not required
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	✓	✓	✓	✓	✓

11. Narang et al. "An Overview of Issues Related to IEEE Std 1547-2018 Requirements Regarding Voltage and Reactive Power Control".

IEEE 1547-2018 Tripping and Ride-Through Requirements

DER must meet specific requirements to provide grid support under abnormal conditions.

Ride-Through:

Ability to withstand voltage or frequency disturbances

Required

1. Voltage ride-through
2. Frequency ride-through
3. Rate-of-change (ROCOF)
4. Voltage phase angle change
5. Frequency droop.[12]

Other allowed capabilities

- Inertial response [3]
- Dynamic voltage support [4]

[1]Frequency response is capability to modulate power output as a function of frequency.
[2]Mandatory capability for Categories II and III under high frequency conditions, Mandatory for Categories II and III under low frequency conditions, optional for Category 1
[3]Inertial response is capability for DER to modulate active power in proportion to the rate of change of frequency.
[4]Dynamic voltage support provides rapid reactive power exchanges during voltage excursions.

Driver for New Ride-Through Requirements: Potential for Widespread DER Tripping

- 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 bulk power system event could be greatly aggravated.
- System frequency is defined by the balance between load and generation.
- Frequency is the same across entire interconnection; all DERs can trip simultaneously during disturbance.
- Impact is the same whether or not DER is on a high-penetration feeder.

IEEE 1547-2018 mandates BOTH:
Tripping requirements, and ride-through requirements.

Ride-through is not a "setting"; it is a capability of the DER:
i.e., it is the DER's robustness.

Tripping points are adjustable over an allowable range.
Range does not allow DER tripping to seriously compromise BPS security.

Tripping points are specified by the area EPS operator (utility) within constraints of the regional reliability coordinator.

Based on a slide Dr. Jens Boemer

IEEE 1547-2018 Ride-Through Requirements

Performance Categories (Grid support under abnormal grid conditions)		Mandatory Ride-Through Capabilities						
		Voltage Ride-Through	Frequency Ride-Through	Rate-of-Change-of-Frequency (ROCOF) Ride-Through	Voltage Phase Angle Change Ride-Through	Frequency Droop (freq-power)	Inertial Response	Dynamic Voltage Support
Category I	Essential bulk system needs Attainable by all state-of-the-art DER technologies	✓	✓	✓ (.5 Hz/s)	✓	Low freq. optional	Permitted	Permitted
Category II	Full coordination with all bulk system power system stability/ reliability needs (e.g., NERC) Coordinated with existing reliability standards to avoid tripping for a wider range of disturbances (than Category I)	✓	✓	✓ (2.0 Hz/s)	✓	✓	Permitted	Permitted
Category III	Designed for all bulk system needs and distribution system reliability/power quality needs Coordinated with existing requirements for very high DER levels (e.g., CA, HI)	✓	✓	✓ (3.0 Hz/s)	✓	✓	Permitted	Permitted

[1]Frequency response is the capability to modulate power output as a function of frequency.
[2]Mandatory capability for categories II and III under high-frequency conditions, mandatory for categories II and III under low-frequency conditions, optional for Category 1
[3]Inertial response is the capability for the DER to modulate active power in proportion to the rate of change of frequency.
Dynamic voltage support provides rapid reactive power exchanges during voltage excursions

Bulk Power System Considerations
PV Reliability Impacts in the Western U.S. Interconnection

NERC Reports

"**1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report**"

Southern California 8/16/2016 Event, June 2017

- Key finding: mis-measurement of system frequency and momentary cessation on low voltage, inconsistency in requirement interpretation

"**900 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report**"

Southern California Event: October 9, 2017 Joint NERC and WECC Staff Report, February 2018

- Key finding: no erroneous frequency measurements, continued use of momentary cessation, interpretation of voltage trip requirements, phase-locked loop operation.

"**Distributed Energy Resources: Connection Modeling and Reliability Considerations**", February 2017

- Report outlines potential impacts of DER on bulk system reliability.
- Recommends specific modeling methods and data requirements for DERs.

IEEE 1547-2018 Interoperability Requirements

Interoperability:

The capability of two or more networks, systems, devices, applications, or components to **externally exchange** and **readily use information securely and <u>effectively</u>.**

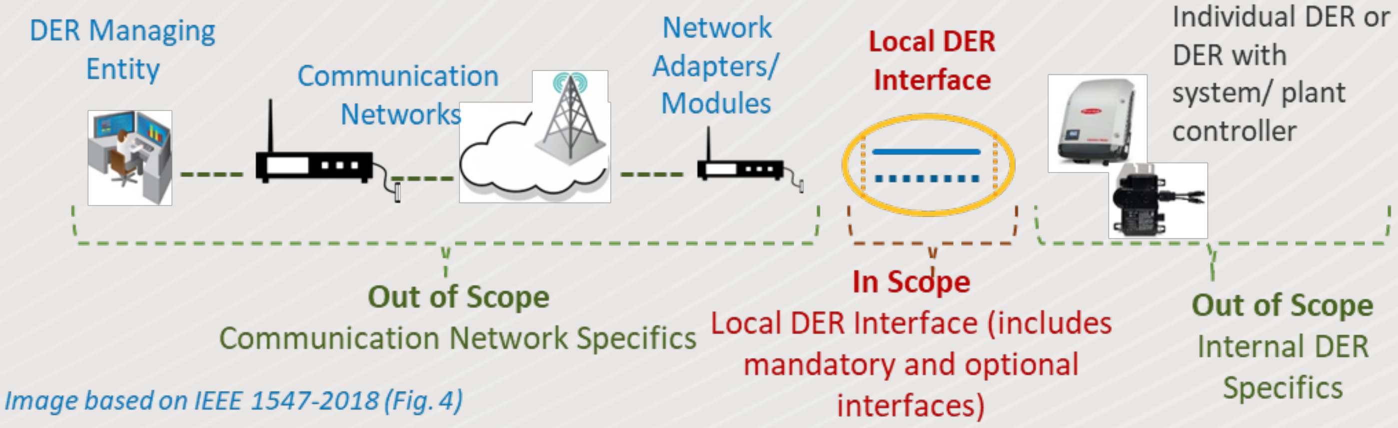

Image based on IEEE 1547-2018 (Fig. 4)

Interoperability Capability Requirements	
Communications capability	**Mandatory:** "A DER shall have provisions for a local DER interface capable of communicating…"
Communications protocol	**Shall support at least one of these protocols** …(IEEE Std 2030.5, IEEE Std 1815, SunSpec Modbus)
DER information exchange	**Nameplate:** (read) as-build characteristics **Monitoring:** (read) present operating conditions **Configuration**: (read/write) present capacity and ability to perform functions **Management:** (read/write) updates to functional and mode settings
Communications performance	**Availability of communications**: (DER is operating in continuous or mandatory operation region) **Information read response times:** (≤ 30 s, maximum amount of time to respond to read requests)
Cybersecurity: Of critical importance but out of scope (can be mutual agreement, possible regulatory requirements)	

12. Ingram, Mahmud, and Narang. "Informative Background on the Interoperability Requirements in IEEE Standard 1547-2018".

Additional Considerations

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Additional Considerations as Market Matures

- Energy justice and energy equity implications of interconnection processes and requirements
- High inverter-based DER resources implications (e.g., impacts on bulk power system)
  - Recommended to incentivize and conduct pilots with DER owners in government, commercial, other user sectors and in coordination with network operators
  - Recommended to incentivize and develop partnerships with Colombia's universities and research organizations on these topics (and international organizations as appropriate)

13. Denholm. "Inertia and the Power Grid: A Guide Without the Spin"

Roles and Responsibilities

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Roles and Responsibilities

Regulatory Agencies

1. Public policy and guidelines designer. Works with local entities and agents. Articulation.
2. Designs the regulation and looks out for its articulation; gather information from agents for it.
3. Develops resources projections (e.g. electricity, infrastructure) and studies future trends. Supports the goals compliance checking. Think Tank.

Grid operators

Gathers very important information regarding distribution grids to support the regulation actualization.
Grid operators make the investments.

Other agents - e.g. distribution companies, demand aggregators, etc.

Represent users in the market and participate in electric energy transactions. Relevant actors regarding new business models development.

Local Authorities

Articulation with national government and grid operators regarding infrastructure planning, land use planning and municipal agreements.

Universities

Develops studies of future trends and technical recommendations to support the regulation update

Conclusions and Recommendations

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NREL Key Conclusions and Recommendations

1. DER interconnection must be considered within the broader context of DER integration which includes national energy policy goals, market trends, technical requirements and stakeholder viewpoints (materiality) and other efforts such as grid modernization.
2. Technical aspects of DER interconnection regulations are directly linked to the intended use of DER technologies. Therefore, the intended use must be clearly defined PRIOR to developing technical aspects.
3. Understand that DER integration has major implications for the traditional utility business model.
4. DER interconnection process and technical issues often overlap and are not easily segregated, and regulations must consider and evaluate issues for both types of topics. Additionally, technical requirements are typically only one part of interconnection regulation.
5. Requirements that cross jurisdictional boundaries need close and early coordination with relevant stakeholders.
6. Regulators should consider developing regulations in coordination with a "policy stacking" framework that is sensitive to market maturity levels.
7. Different types of DER will likely require specific consideration of their policy stack, market adoption characteristics, intended use, and technical requirements.
8. Different technical capabilities are needed at different DER market saturation/deployment levels. More rigorous technical detail is required for utilization of DER capabilities near-term.
9. DER integration is a dynamic process – strategies and tools to manage DER will evolve as adoption increases and market activities or goals change.
10. The latest version of IEEE 1547 – 2018 should be used as a reference.

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Thank You

For questions, please contact:

David Narang: david.narang@nrel.gov
Michael Ingram: michael.ingram@nrel.gov
Daniella Rough: daniella.rough@nrel.gov

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