Grid Code Essentials and Streamlining Process for Interconnections

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A Practitioner's Guide to Implementing Solar Rooftop Programs and Navigating Net-Metering Policies Webinar
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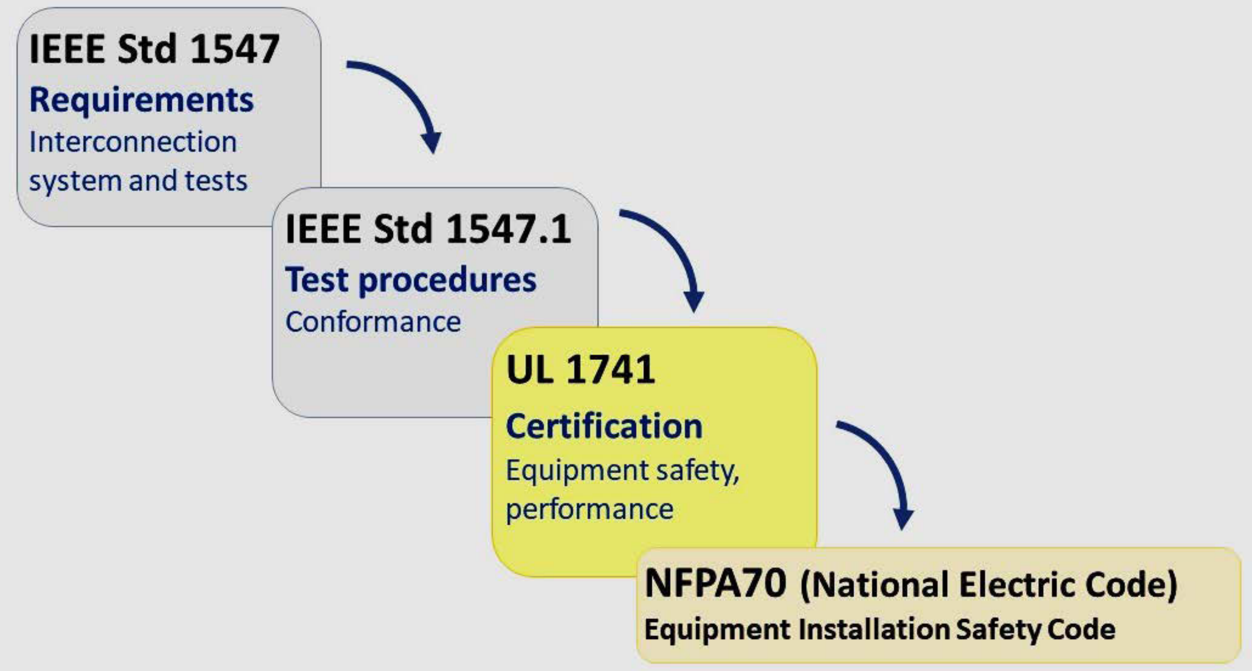
What Are Grid Codes?

- Key mechanisms that utilities use to ensure safe and reliable interconnection processes when connecting new resources
- Recent considerations include voltage/frequency ride-through and voltage regulation of inverter-based variable generation on the grid.



General Grid Code Requirements

- **Active power control** (As in response to over-frequency conditions)
- **Reactive power supply and voltage support**
- **Power quality:** Certain limits on harmonics, voltage change, and so on
- **Ride-through capability:** Response to grid faults
- **Protection concepts:** Unintentional islanding protections, for example.

Considerations for Grid Codes to Manage Distributed Energy Resources (DERs)

- **Mutually agreeable voltage support modes during continuous operation**
- **Mutually agreeable voltage/frequency support modes during abnormal grid conditions**
- **Safety: Fails safely and provides adequate fire protection**
- **Ability to communicate and comply with existing standards:**
  - Support acceptable communication protocols
  - Support well-known data object models (speaks same language).
- **Interoperability: Plug-n-play for DER.**

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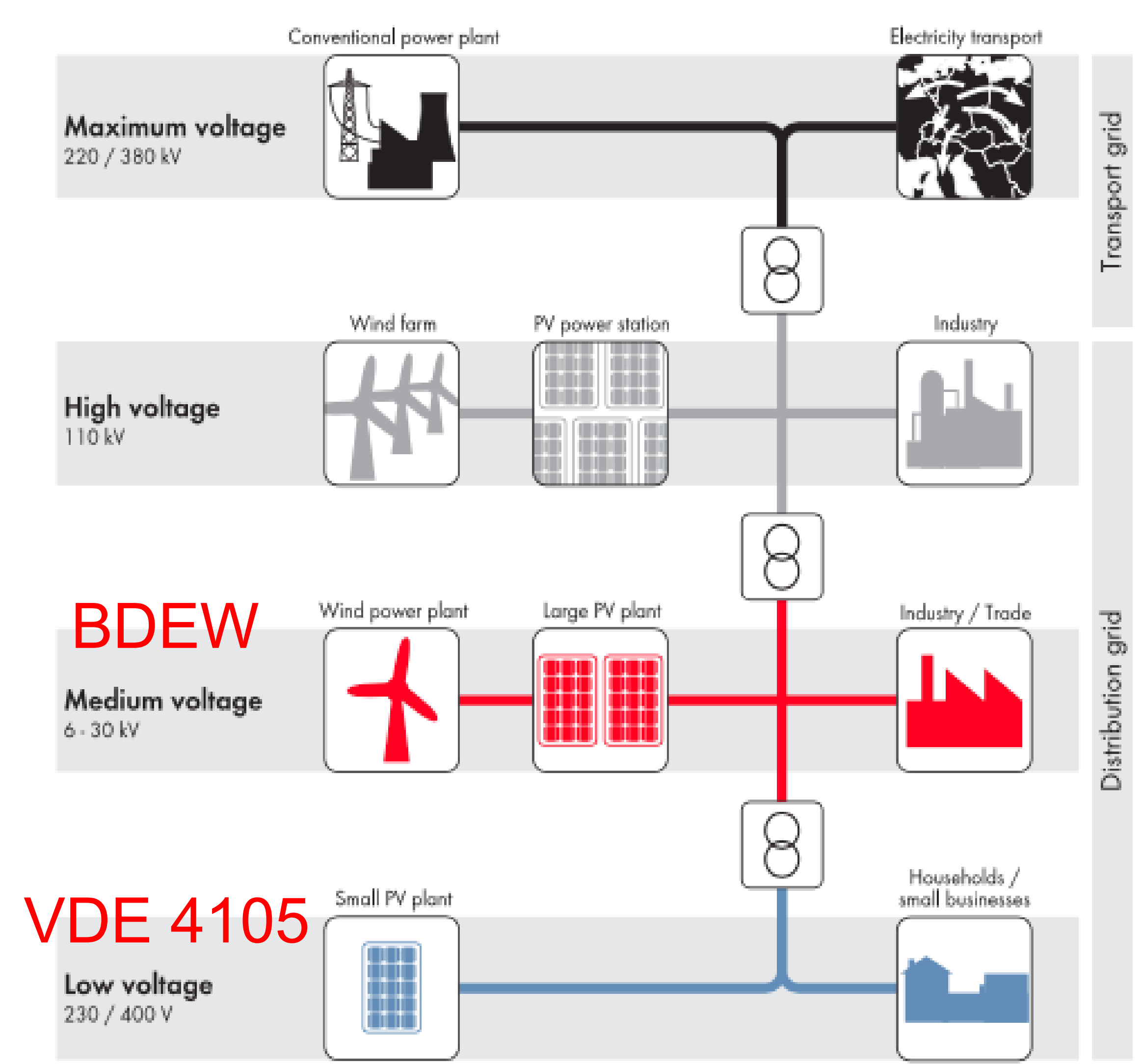
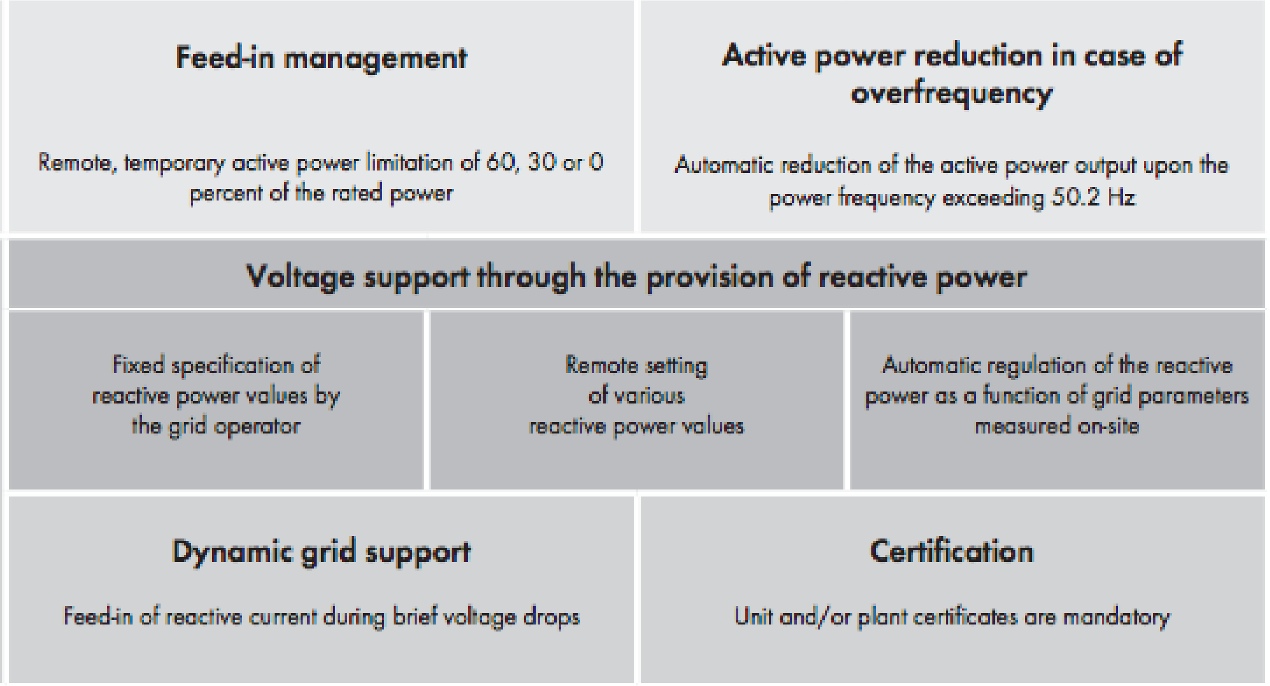
Germany Grid Codes: BDEW and VDE 4105 Key Guidelines



- Feed-in management
- Active power reduction during over-frequency
- Provision for reactive power
- Dynamic grid support (fault ride-through).



SOURCE: Adarsh Nagarajan, NREL. Available at: https://cleanenergysolutions.org/sites/default/files/documents/grid-codes-webinar-oct4.pdf

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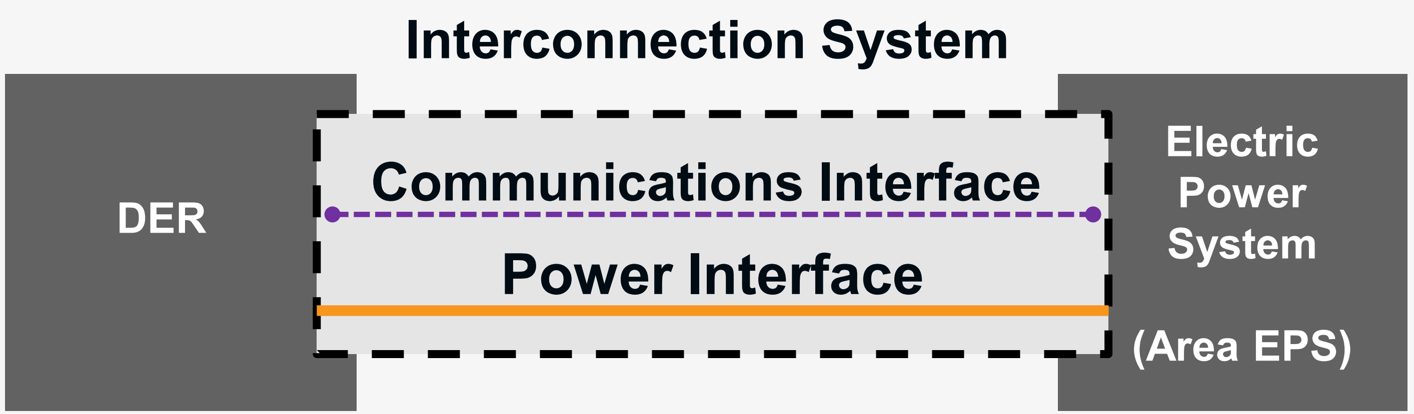
IEEE 1547 Scope and Purpose



Title: Standard for **Interconnection** and **Interoperability** of Distributed Energy Resources with Associated **Electric Power Systems Interfaces**

Scope: This standard establishes criteria and requirements for interconnection of DERs with electric power systems (EPS) and associated interfaces.

Purpose: This document provides a uniform standard for the interconnection and interoperability of DERs with EPS. It provides requirements relevant to the interconnection and interoperability performance, operation, and testing, and safety, maintenance, and security considerations.

1547 IS

- A technical standard—functional requirements
- A single (whole) document of mandatory, uniform, universal, requirements apply at PCC or PoC
- Technology neutral (i.e., it does not specify particular equipment or type).

1547 IS NOT

- A design handbook
- An application guide (see IEEE 1547.2)
- An interconnection agreement
- Prescriptive (i.e., it does not prescribe other important functions and requirements such as cyber-physical security, planning, designing, operating, or maintaining the area EPS with DER).

Solving Grid Planning and Operation Challenges Using DER

Increasing DER penetration was a major driver for revising IEEE 1547.

- Grid performance support
- Ride-through, stabilizing frequency response, voltage support

- Safety and reliability: Do no harm
- Anti-islanding, no interference with primary voltage regulation

Slide credit: IEEE 1547-2018

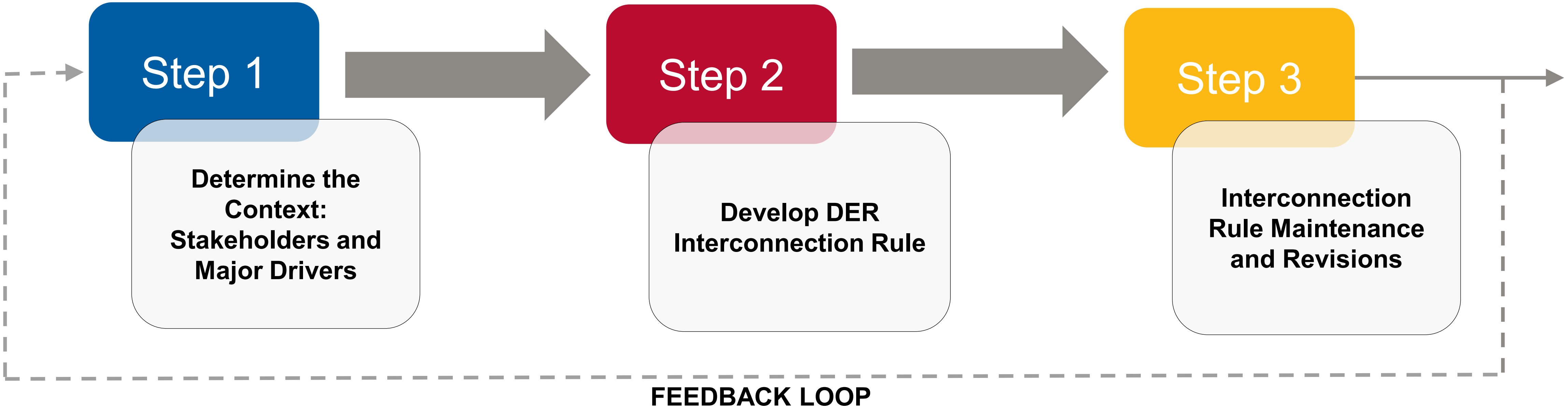
Interconnection Maturity Model

NREL's "*An Overview of Distributed Energy Resource (DER) Interconnection: Current Practices and Emerging Solutions*," (Horowitz, et al.) introduces the concept highlighted here of an "Interconnection Maturity Model." Accessible: https://www.nrel.gov/docs/fy19osti/72102.pdf.

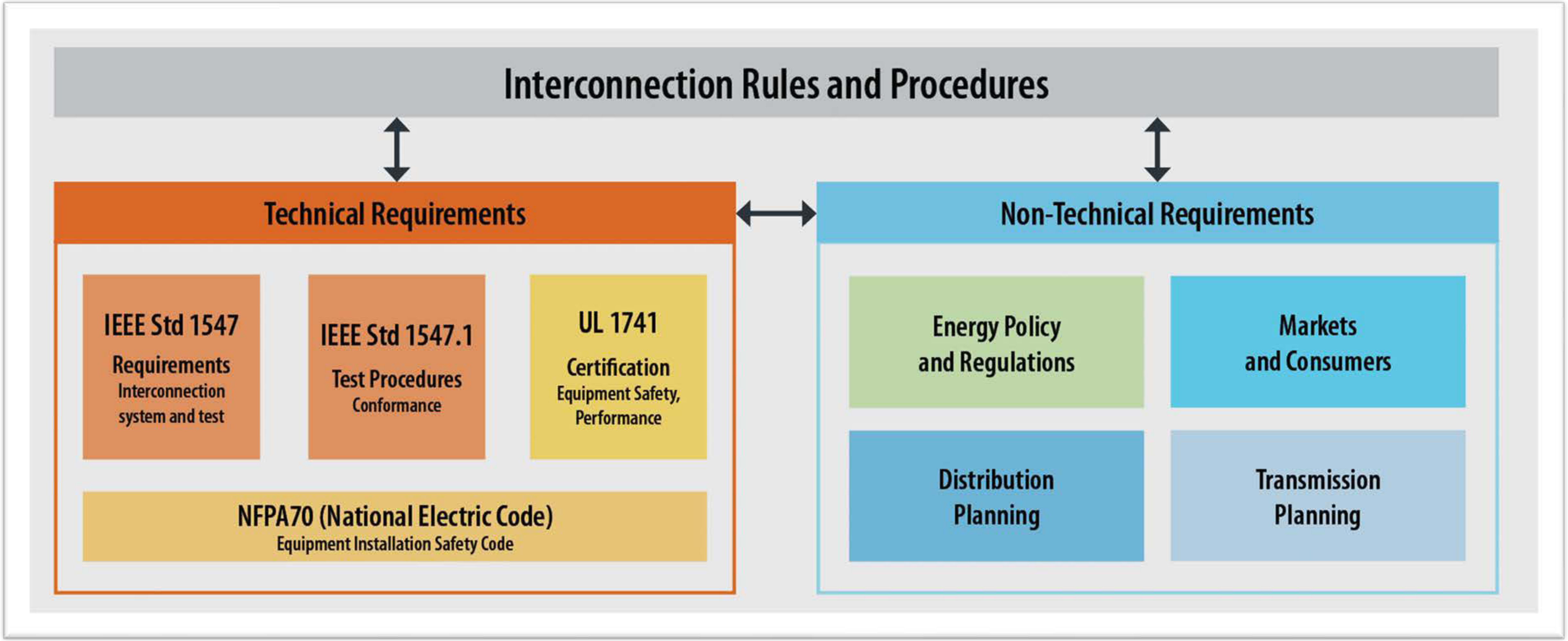
- **Approaches at low DER penetrations:**
  - Adopt the IEEE 1547-2018 standard
  - Collect and maintain data sets
  - Provide system information to applicants
  - Implement online application platforms.
- **Approaches at moderate to high DER penetrations:**
  - Move toward proactive integration approach with planning, data management, and analysis
    (versus individual interconnection applications)
  - Improvements in DER deployment forecasting techniques may be warranted.

Updating Interconnection Procedures

INTERCONNECTION PROCEDURE RULEMAKING PROCESS



Broader Context for DER Interconnection



SOURCE: Ingram, David Narang, Akanksha Bhat. *A Guide to Updating Interconnection Rules with IEEE Standard 1547.* Publication forthcoming.

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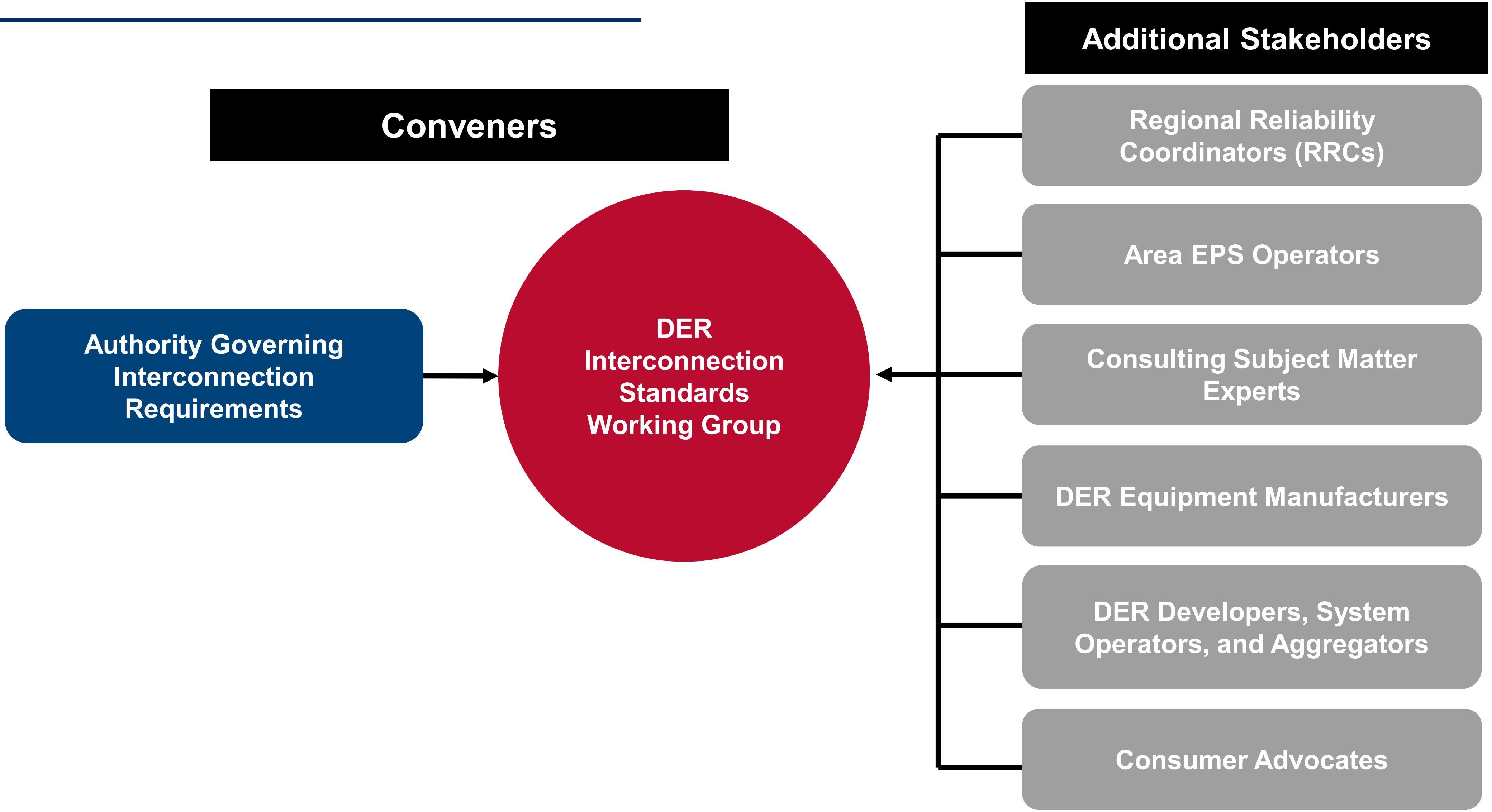
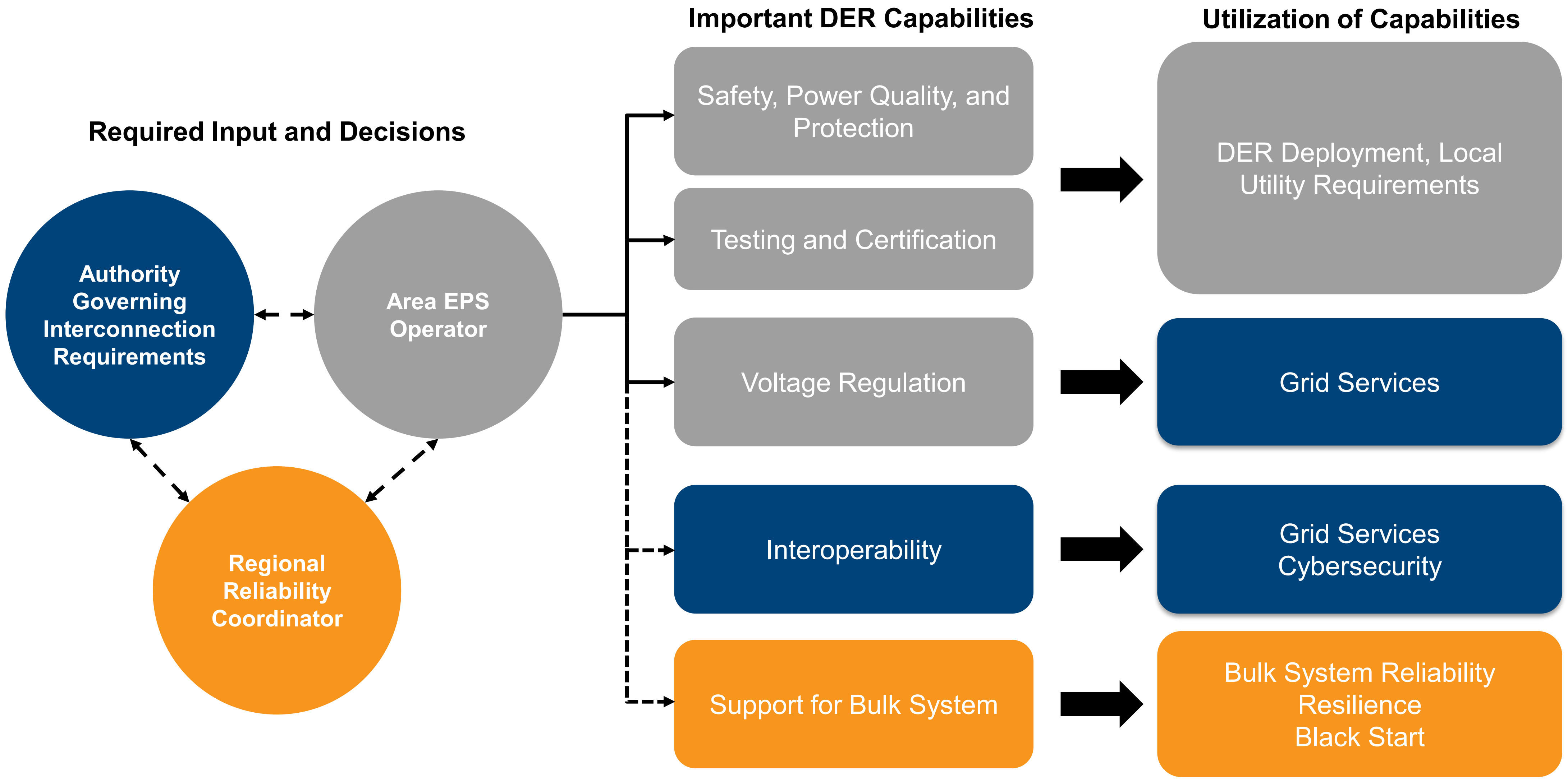
Stakeholders

1



Developing Technical Requirements

2



Responsibilities

2

Principal roles fall upon the following parties:

- Area EPS operator, the entity responsible for designing, building, operating, and maintaining the area EPS
- Authority governing interconnection requirements (AGIR) for U.S. investor-owned utilities (IOUs): This is the state commission's role with some detailed requirements delegated to the area EPS operator. Municipal and co-ops boards have this role for their public power utilities.
- Regional reliability coordinator.

Over 50 responsibilities have been identified in IEEE 1547-2018: Area EPS operator has a role in over 40 of these responsibilities, some of which require input from the regional reliability coordinator and the responsible transmission planners.

Responsibilities (continued)

2

There are three responsibilities for the AGIR that require input from the area EPS operator, the regional reliability coordinator, manufacturers, DER developers, and perhaps others:

- Set categories related to reactive power capability and voltage regulation performance requirements
- Set categories related to response to area EPS abnormal conditions
- Approve periodic testing requirements and intervals.

NREL's "*Clause-by-Clause Summary of Requirements in IEEE Standard 1547-2018*," (Narang, Ingram, Hoke, Bhat, Danial) summarizes the standard stakeholder-decision relationships and highlights "defaults" in the standard. Accessible: https://www.nrel.gov/docs/fy20osti/75184.pdf.

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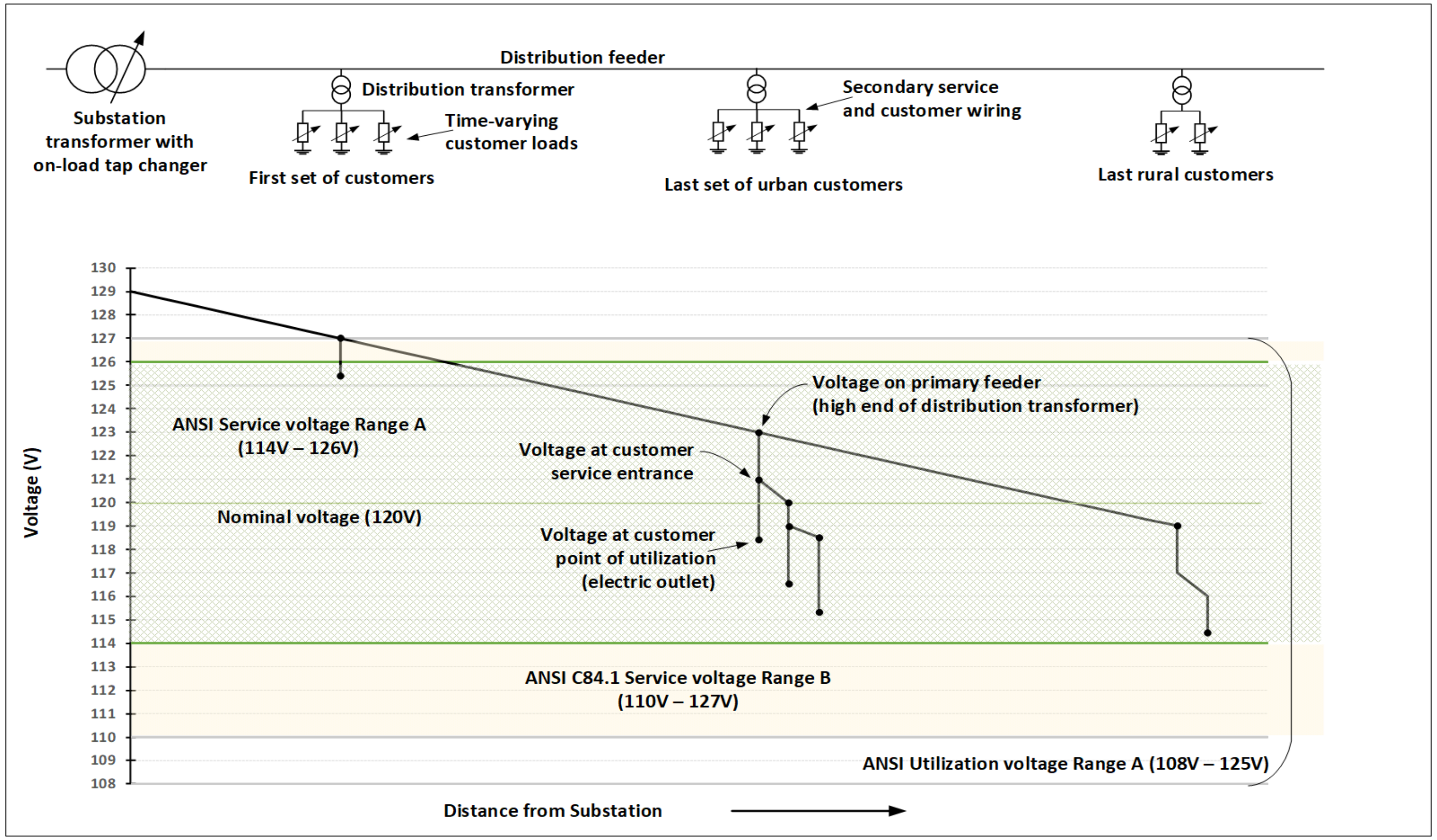
Distribution System Objectives

- **Supply electric power to customers:**
  - Economically
  - Safely
  - Reliably.
- **Maintaining delivery voltage is one of the fundamental drivers of distribution system reliability.**



SOURCE: David Narang, Rasel Mahmud, Michael Ingram, and Andy Hoke. *Informative Background on the Voltageand Reactive Power ControlRequirements in IEEE Std 1547-2018.* Publication forthcoming.

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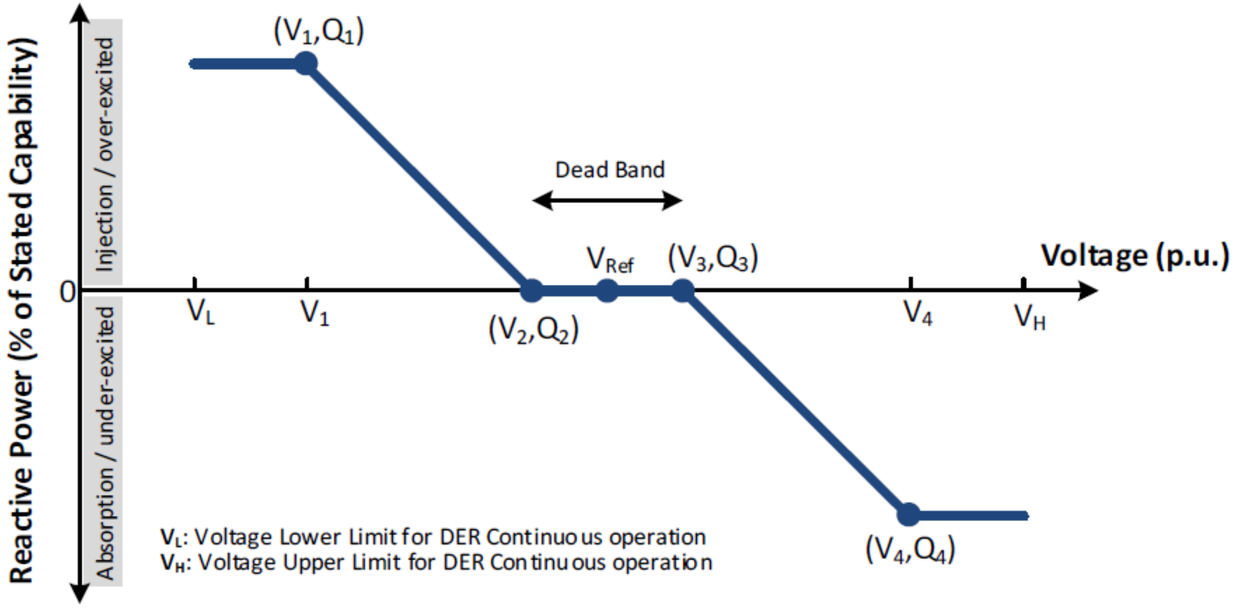
Active Voltage Regulation Capabilities

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

Capability required for all DER – (Cat A, B)
Constant power factor mode
Constant reactive power mode
Voltage-reactive power mode ("volt-var").

"State-of the art" DER – Cat B
Active power-reactive power mode ("watt-var")
Voltage-active power mode ("volt-watt").



- The area EPS operator (utility) 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.
- Settings can be adjusted locally or remotely.

Figure credit: IEEE 1547-2018

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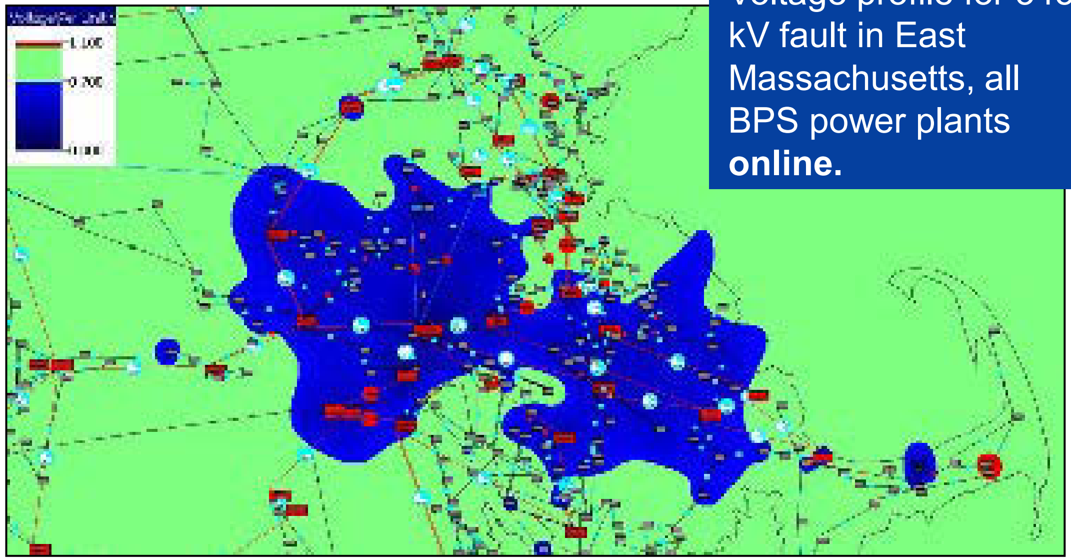
Potential for Widespread Distributed Generation (DG) Tripping

SUPPORT FOR BULK SYSTEM

- **Transmission faults can depress distribution voltage over very large areas.**
- **Central-station generator trips can depress system frequency.**
- **Sensitive tripping (i.e., 1547-2003) can cause massive “orchestral” loss of DG.**
- **Resulting bulk power system (BPS) event may be greatly aggravated.**



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

IEEE 1547-2018 mandates BOTH:

- Tripping requirements and
- Ride-through requirements.

Ride-through is not a “setting”; it is a capability of the DG.

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

Source: ISO-New England

Frequency Ride-Through Requirements for all DERs (IEEE 1547)

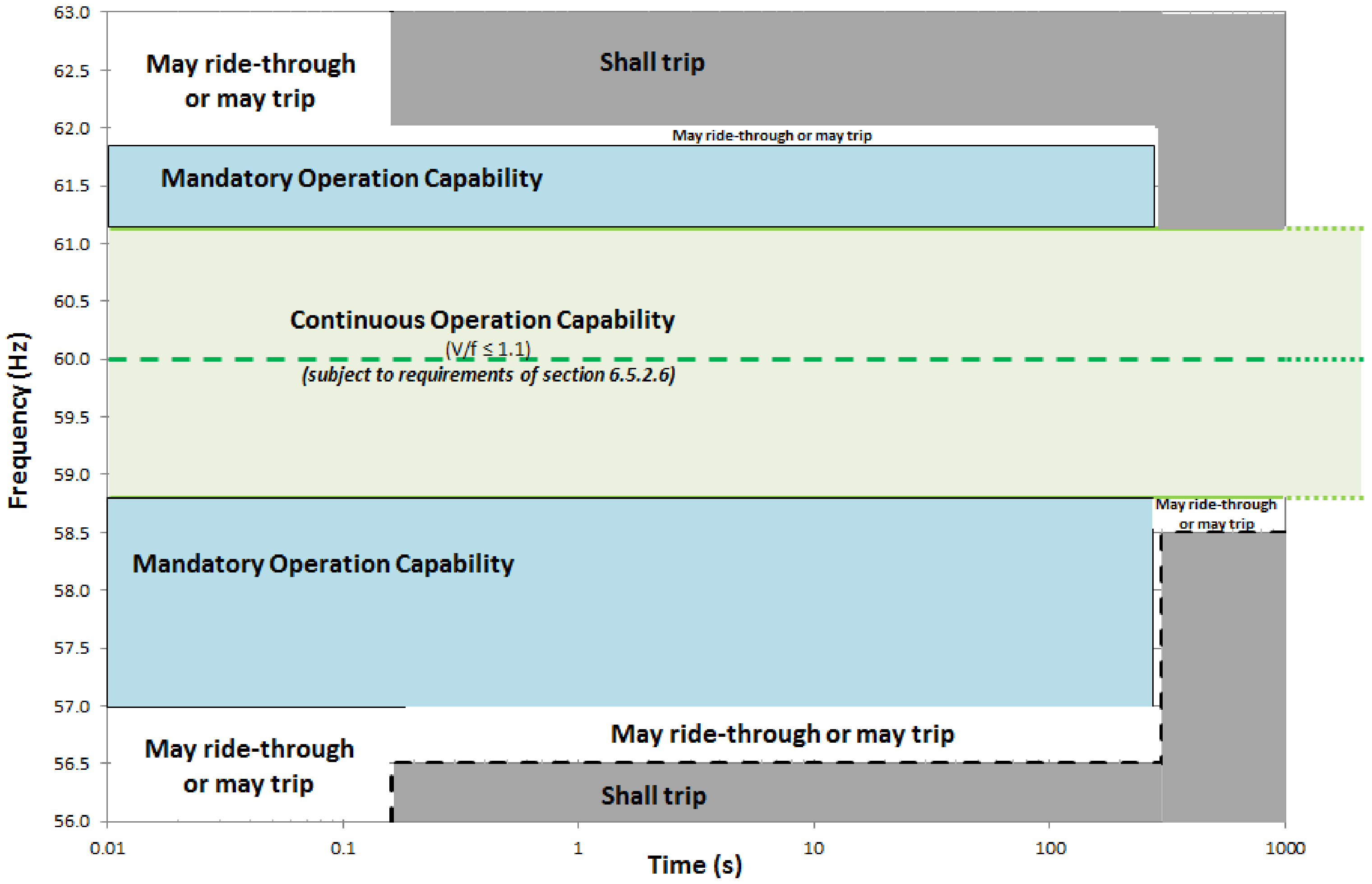


Figure credit: David Narang, NREL.

Voltage Ride-Through Requirements for all DERs (IEEE 1547)

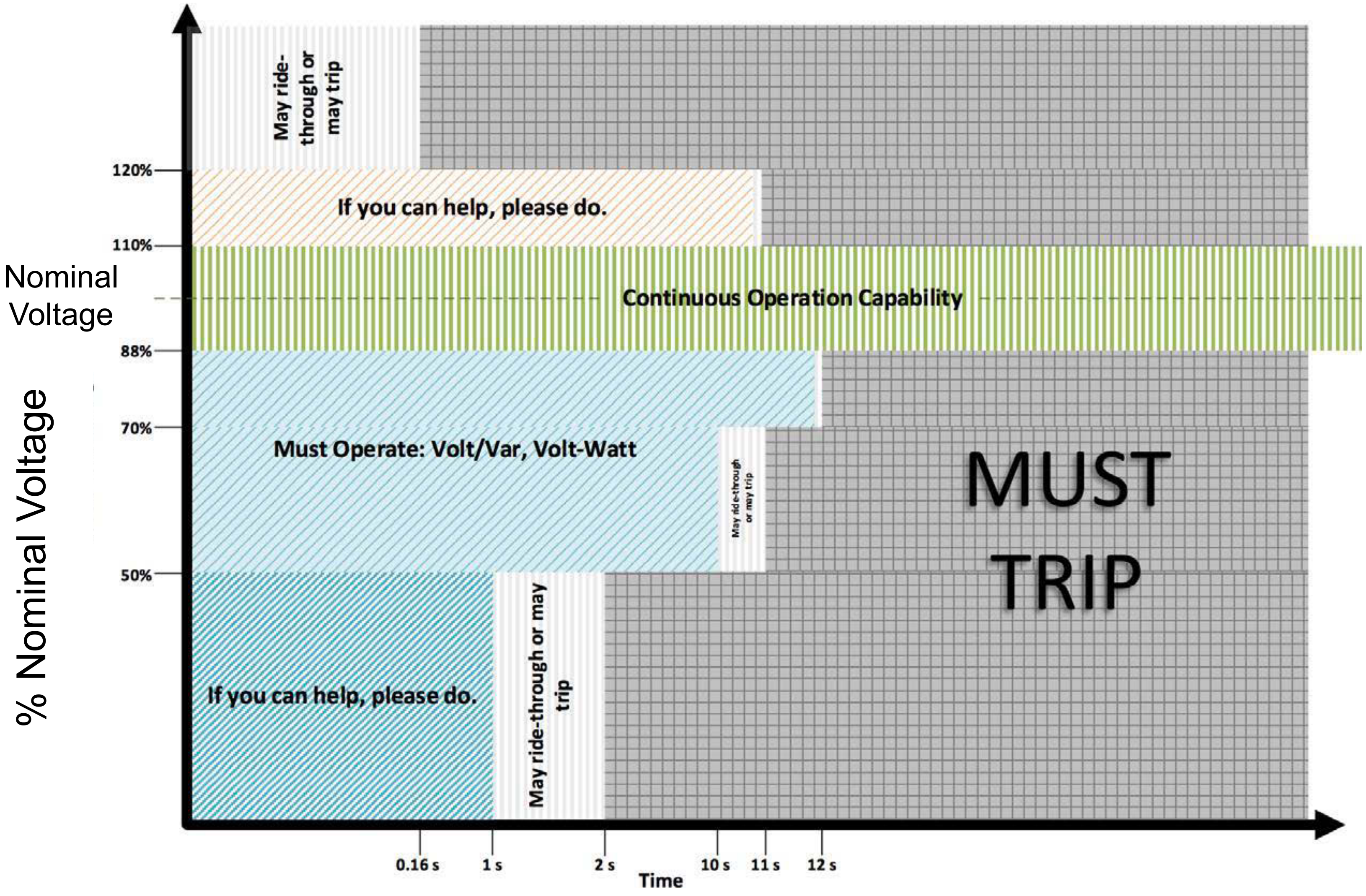
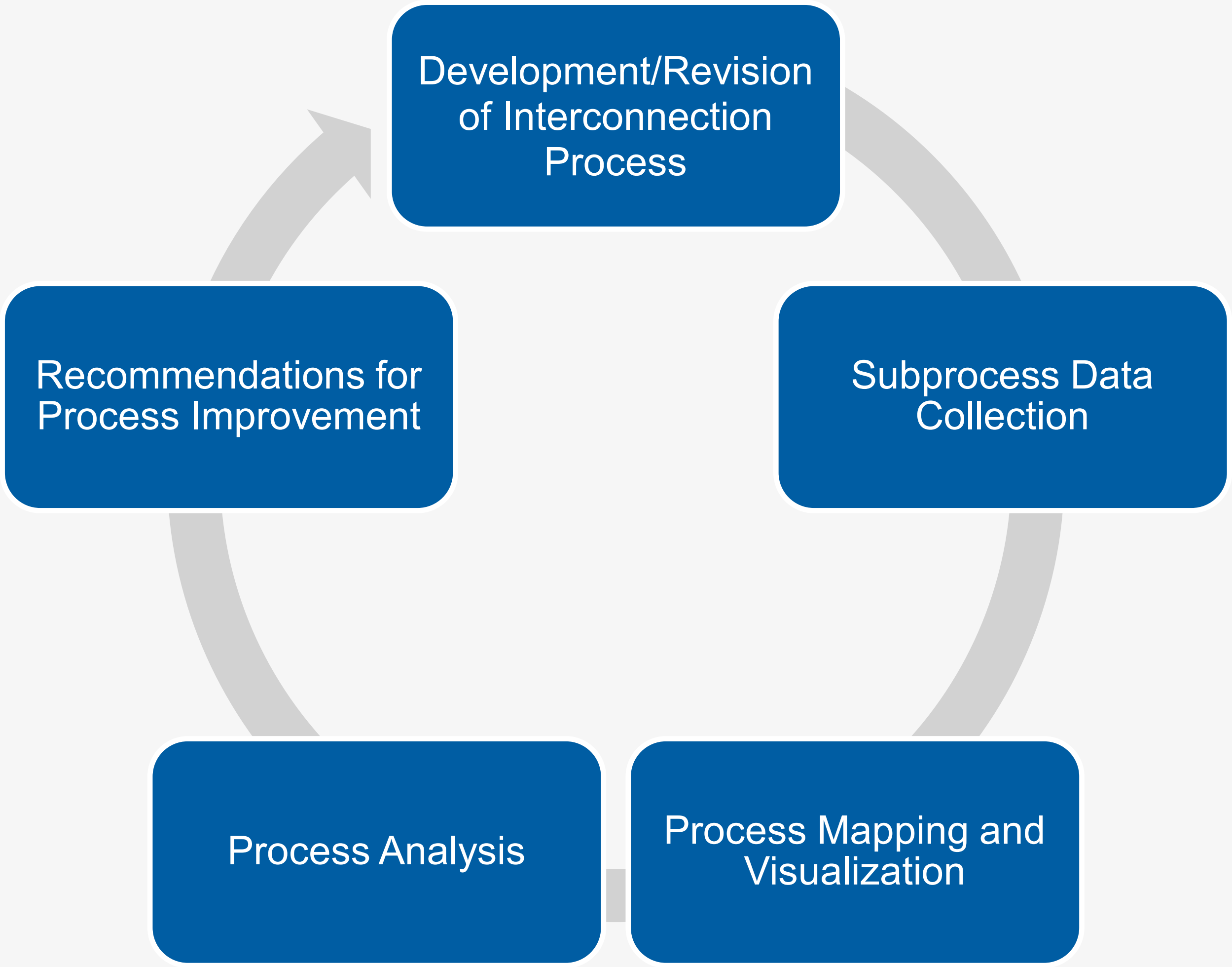


Figure credit: Adarsh Nagarajan - NREL

Safety, Power Quality, and Protection

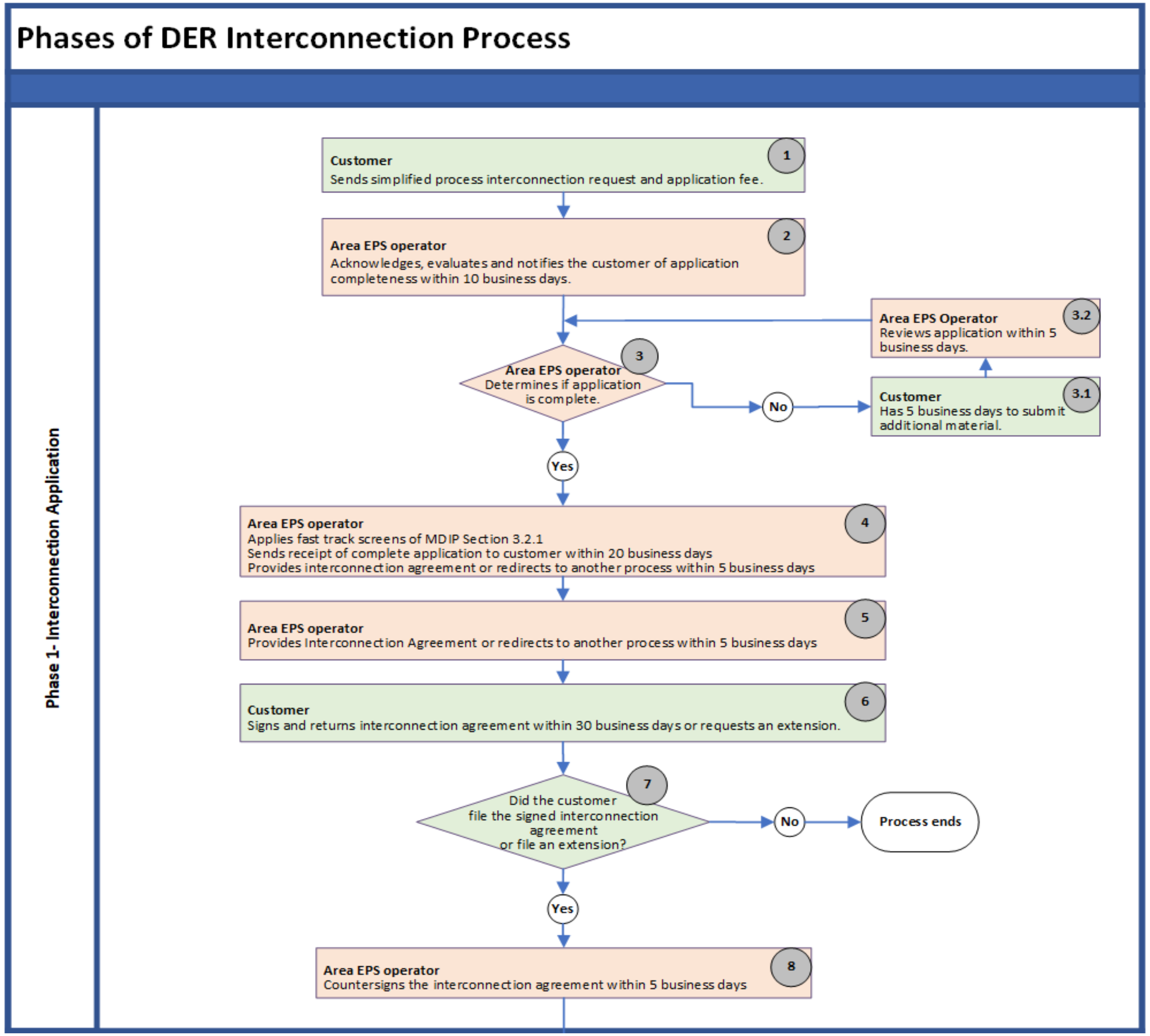
- **IEEE Std 1547 is not a safety standard:**
  - Written minimize the chances of DERs increasing risk to the public or electric workers
  - Includes performance requirements that can be coordinated with utility protection equipment.
- **Anti-islanding (unintentional) protection and response to short-circuit fault and open-phase conditions are part of the core requirements.**
- **Requirements for DER output power quality are quantifiable and include limits on:**
  - Harmonics causing distortion
  - Voltage fluctuations, including contributions to overvoltage at the point of common coupling
  - New synchronization tolerances.

Interconnection Process Life Cycle



Example

- Charting a process:
  - Useful to validate accuracy
  - Understand information flow and handoffs.
- Mindful of schedules and time-lines:
  - "*Work expands to fill the time available**." *If you have six months to complete a project, it will take six months to complete. Set deadlines accordingly*.
- Provides for improvement:
  - Data collection
  - Process analysis.



*SOURCE: C. Northcote Parkinson, *Parkinson's Law or the Pursuit of Happiness*, 1958.

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https://www.surveymonkey.com/r/IEEE-1547-2018

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https://www.nrel.gov/grid/ieee-standard-1547/

Thank you

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Backup: Other Grid Codes

European Photovoltaic (PV) Interconnection Outside Germany

- **European level: European Network of Transmission System Operators for Electricity (ENTSO-E)**
- **Italy: CEI 0-21 standard governing the connection of power generation and consumption plants in the low-voltage grid was published in Italy in December 2011—also AEEG 084-12 from March 8, 2012.**
- **Spain: Royal decree RD 1565/2010, dynamic grid support is already mandatory for all PV plants exceeding two megawatts in Spain today.**

Indian Grid Codes Timeline

CEA* (Technical Standards for connectivity to the grid) Regulations

CEA (Technical Standards for Connectivity of the distributed generation resources) Regulations

CEA (Technical Standards for connectivity to the grid) Amendment Regulations

Best Practices Guide, Implementation of State-Level Solar Rooftop Photovoltaic Programs in India, MNRE**

CEA (Technical Standards for connectivity to the grid) Amendment 2

2007	2010	2013	2014	2016	2018

CEA (Measures relating to Safety and Electric Supply) Regulations

Bureau of Indian Standards (BIS) Guidelines on Standards for interoperability in power system communications

To incorporate provisions pertaining to charging of Electric Vehicles, the following were amended:

- CEA (Technical Standards for Connectivity of the distributed generation resources) Regulations
- CEA (Measures relating to Safety and Electric Supply) Regulations.

CEA (Technical Standards for Communication system in power sector) Regulations

***CEA: Central Electricity Authority,**
**** MNRE: Ministry of New and Renewable Energy**

Network Structures: Spain and Germany

- **Grid:** 3ø, 50 Hz at all voltage levels.
- **Voltage Levels:** LV grid: 400 V system
- **Low-Voltage Protection:** In general, outgoing cables in secondary substations are protected by a high-load breaking capacity fuse.
- **Urban and Rural:**
  - Germany:
    - Urban LV grids are operated as meshed grids (to achieve high service reliability)
    - Rural LV grids are mainly configured radially.
  - Spain:
    - LV grids are built and operated radially.

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Physical Infrastructure in Germany

Rated Power of the Generation Plant	Voltage Level of Grid Connection (PCC)	
Up to 30 kW	Low-voltage grid without verification	400 V
30 to 200 kW	Low- or medium-voltage grid	400 V; 30 kV, 20 kV,15 kV, 10 kV
0.15 to 20 MW	Medium-voltage grid	30 kV, 20 kV,15 kV, 10 kV
15 to 80 MW	High-voltage grid	110 kV
80 to 400 MW	Extra-high voltage grid	380 kV, 220 kV

KEMA, Inc. (2011). “European Renewable Distributed Generation Infrastructure Study – Lessons Learned from Electricity Markets in Germany And Spain.” December 2011.