icf.com

we are ICF

Enabling Advanced Capabilities for DER

Takeaways from the Full Revision of Interconnection and Interoperability Standard IEEE 1547

Patrick Dalton
Manager, DER

3 February 2020

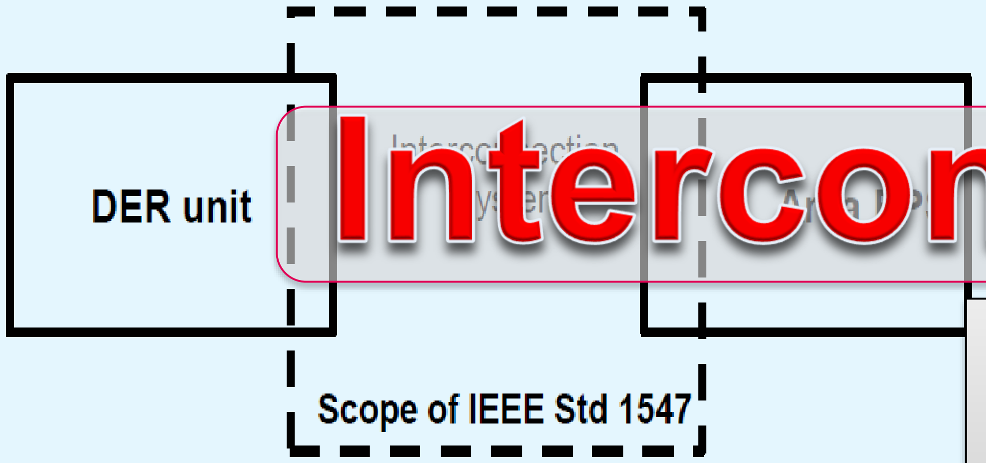
Overview

- **IEEE 1547 Revision and Implementation Process**
- **DER General Capabilities**
- **Local Distribution System Support**
  - Active and Reactive Capabilities (“voltage regulation”)
- **Bulk System Support**
  - Voltage and Frequency Ride-Through
- **Interoperability**
  - DER Local Communications Interface

DER Interconnection Standard Update
IEEE 1547 Full Revision

Revision to Interconnection Standard

Scope Changes in IEEE 1547



IEEE Std 1547-2003

- Focused on distribution system aspects.
- Specifications for the "interconnection system" sufficiently achieve the standard's objective.
- Meant as DER interconnection standard but mainly used for equipment listing.
- Limited to electrical requirements.

Interconnection

Integration

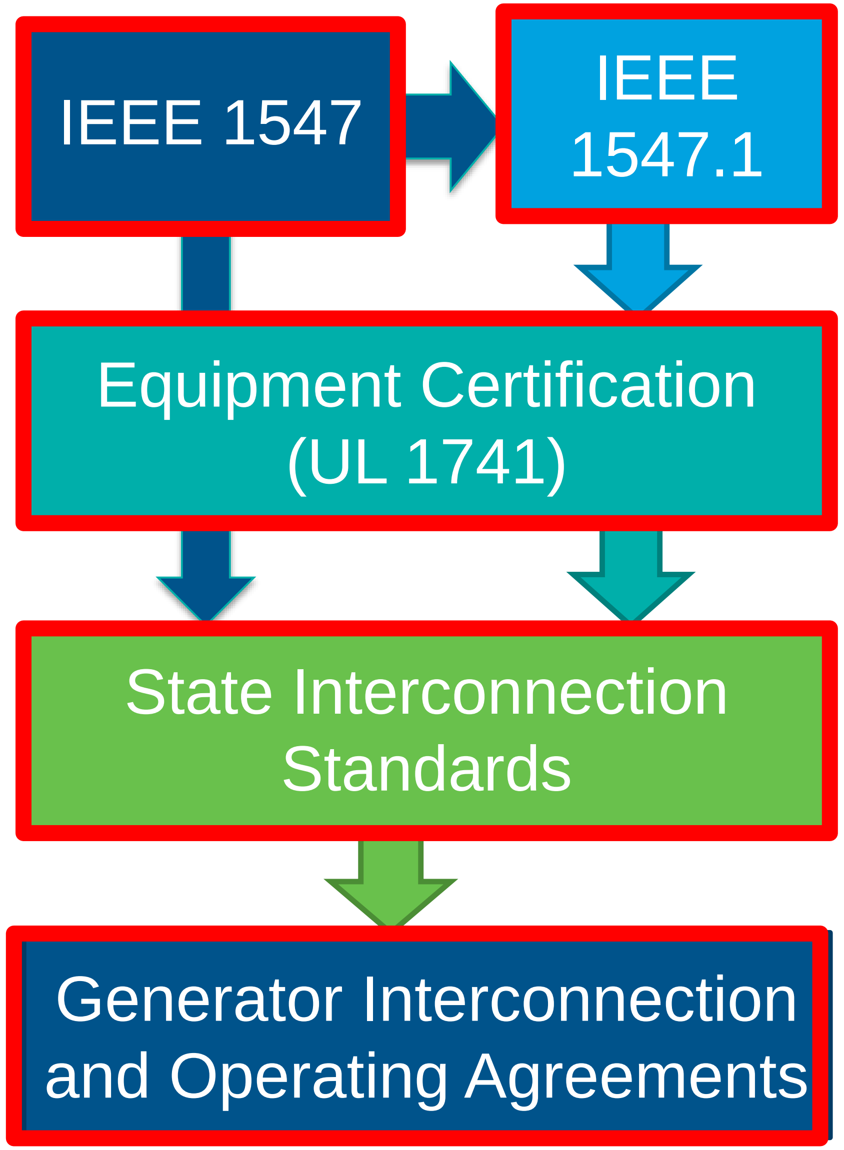
Source: Adaptation of EPRI Figure

Brief History of Interconnection Standards

- **2000** — California Rule 21
- **2003** — IEEE 1547-2003
  - **Shall** trip in response to abnormal voltage/frequency condition
  - **Shall not** actively regulate voltage or frequency
- **2005** — FERC SGIP (Small Generator Interconnection Procedure)
- **2011** — Updated California Rule 21 *(consistent with IEEE 1547-2003)*
- **2014** — IEEE 1547a-2014
  - **May** ride through abnormal V/F
  - **May** actively regulate voltage by changing real/reactive power
  - **May** change real power in response to frequency deviations
- **2015** — Updated California Rule 21 *(more prescriptive than IEEE 1547a-2014)*
- **2016** — Amended UL 1741 (SA) *(inverter certification driven by CA Rule 21)*
- **2018** — IEEE 1547-2018
- **2019/2020?** — IEEE 1547.1rev-201x
  - **Shall** ride through abnormal V/F
  - **Shall be capable of** actively regulating voltage by changing real/reactive power
  - **Shall be capable of** changing real power in response to frequency deviations
  - **Shall have** communication interface
- Interconnection Agreements / Markets / etc.

Source: EPRI

Process for Implementing Smart Inverters



Standard for DER Interconnection and Interoperability

Standard for DER Equipment Conformance Test Procedures

Inverter Equipment Type Testing Certification Procedures

Statewide Interconnection Standards

DER Interconnection Tariffed Agreements

Standard Adoption Approximate Timeline

Interconnection Standard
IEEE 1547

Publication: 2018

Test Procedures Standard
IEEE 1547.1

Completion: Early 2020

Equipment Certification
UL 1741

Completion: Late 2020 – Early 2021

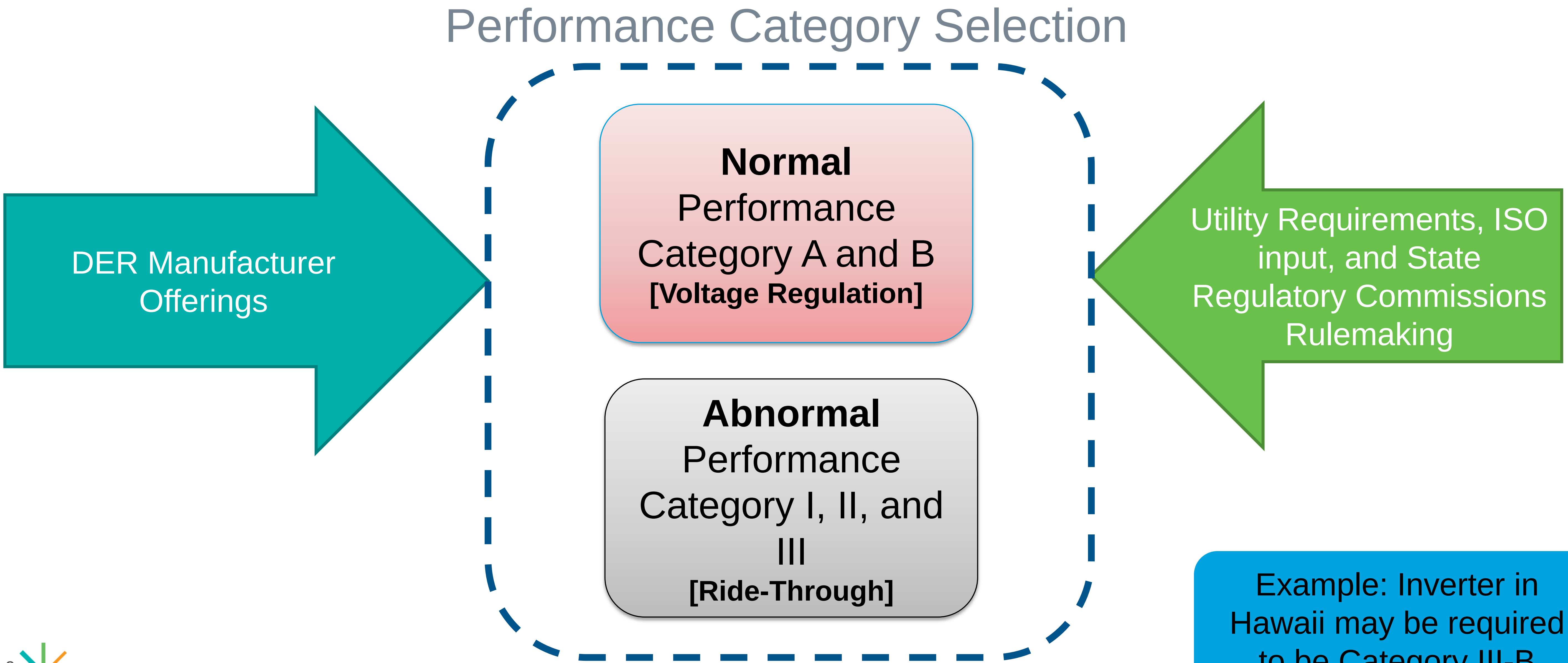
Equipment Adoption

Equipment Available: Late 2021?

Increasing Timeframe Uncertainty

DER General Requirements

IEEE 1547 Performance Category Approach



Example: Inverter in Hawaii may be required to be Category III-B

Defining Normal and Abnormal Conditions

IEEE 1547-2018 defines a ***continuous operation*** region which applies to the ***normal operating performance category*** and ***active and reactive power control***.

The ***abnormal operating performance category*** and ***ride through*** applies outside the ***continuous operation*** region.

Analogy on Active and Reactive

Force Expended

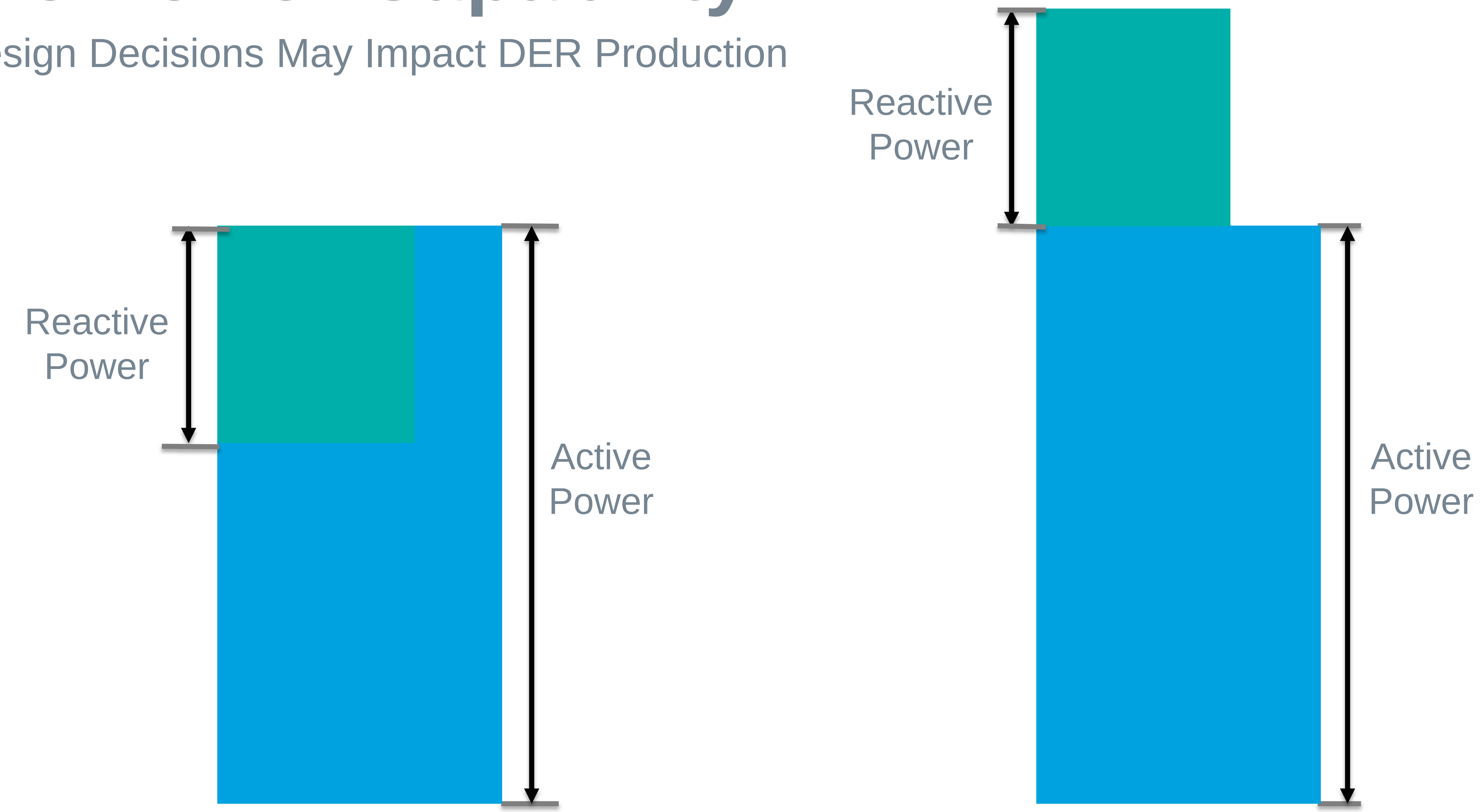
Reactive Power (Vars)

Force Leading to Work

Active Power (Watts)

Reactive Power Capability

DER Owner Design Decisions May Impact DER Production

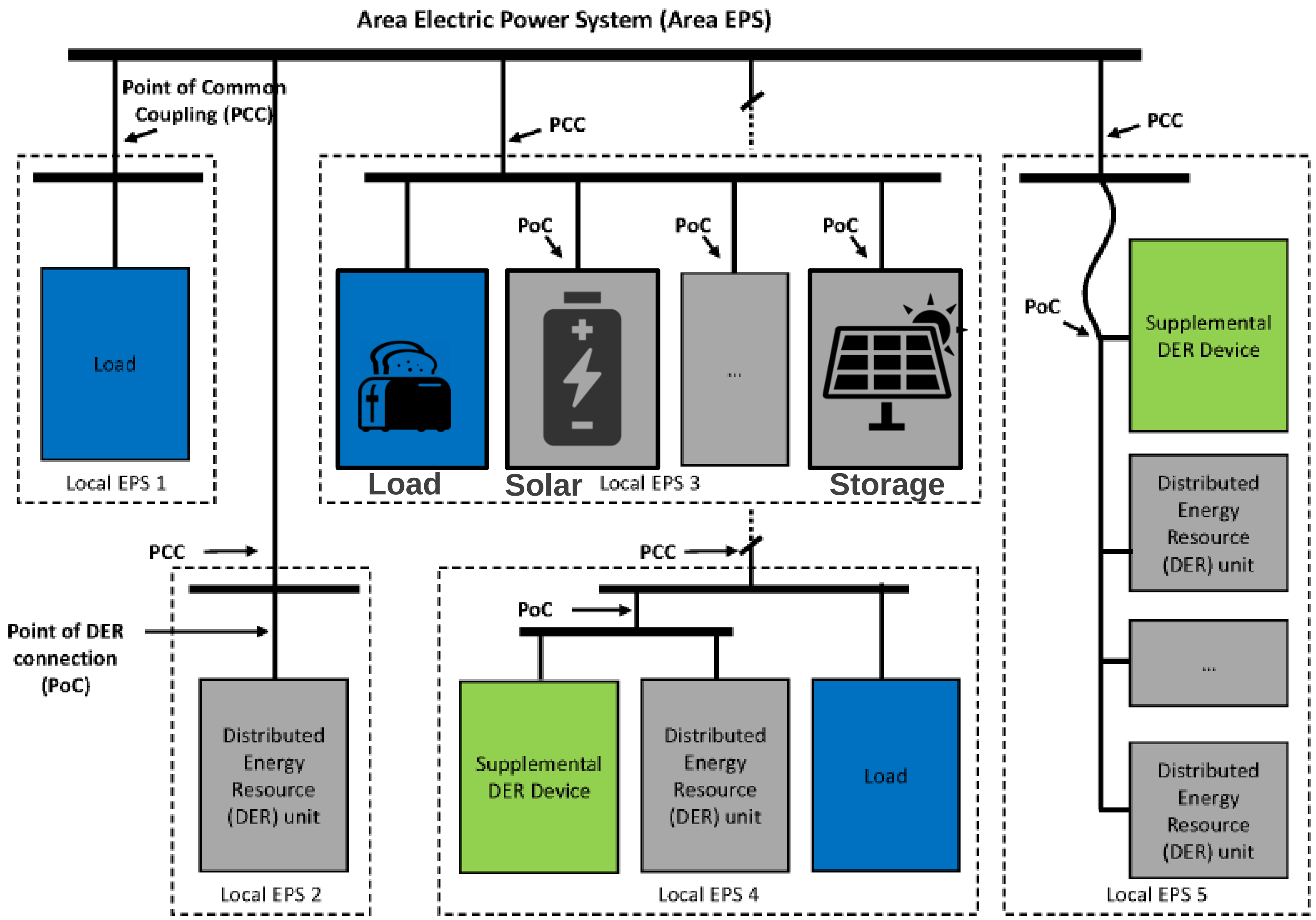


Option 1: Reduce Active Power

Option 2: Oversize Inverter

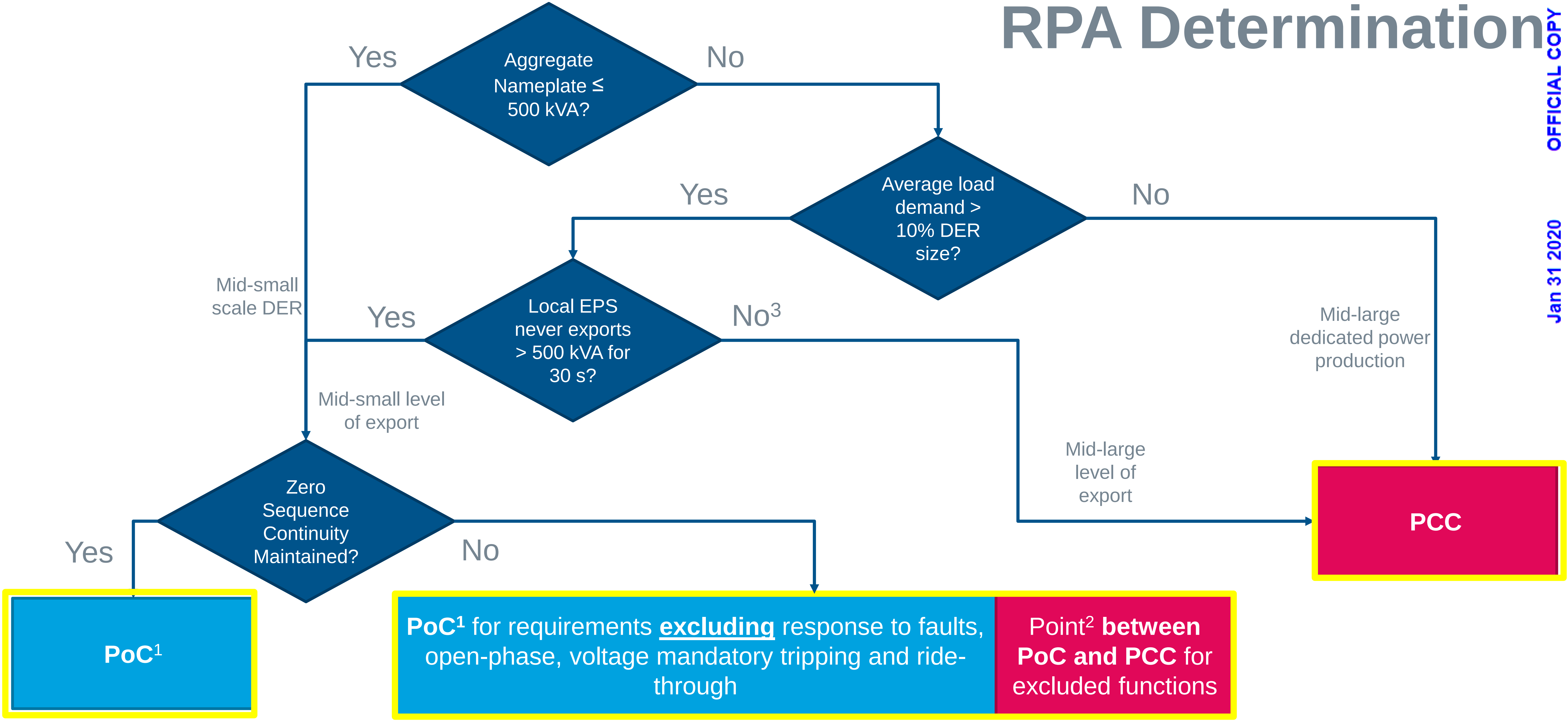
Reference Point of Applicability

- Point of DER Connection (PoC) vs Point of Common Coupling (PCC)
- Basic idea behind determination is whether the DER is a “dedicated power production” facility or a relatively “small” behind-the-meter DER
  - “Small” could be either in terms of DER size or when compared to site load



Notes: 1) Zero sequence continuity is a key factor; 2) Can be point in-between PoC and PCC by mutual agreement

RPA Determination



1) Allowed to be point between the PoC and PCC by mutual agreement
2) Point selected must be appropriate to detect abnormal voltage conditions
3) Reactive power capability and power quality requirements evaluation may exclude influence of load for RPA at PCC under these conditions

Control Capability Requirements

Limit Active Power

- Can be Export or Nameplate limit → Energy Storage Applications

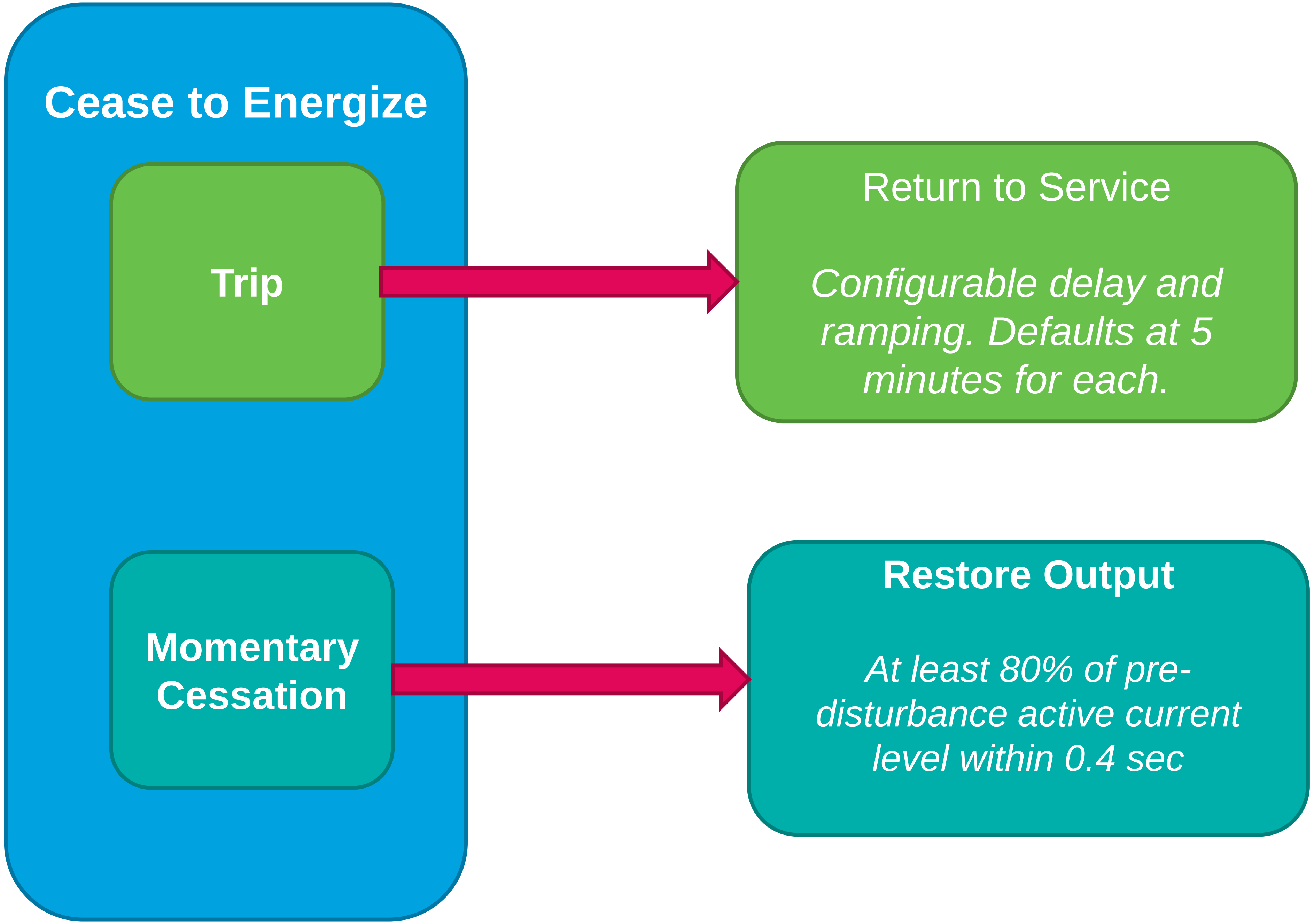
Disable Permit Service

- Cease to Energize and Trip within 2 seconds

Execution of mode or parameter changes

- Examples: volt-var to fixed PF; Changing PF from 0.98 to 0.95

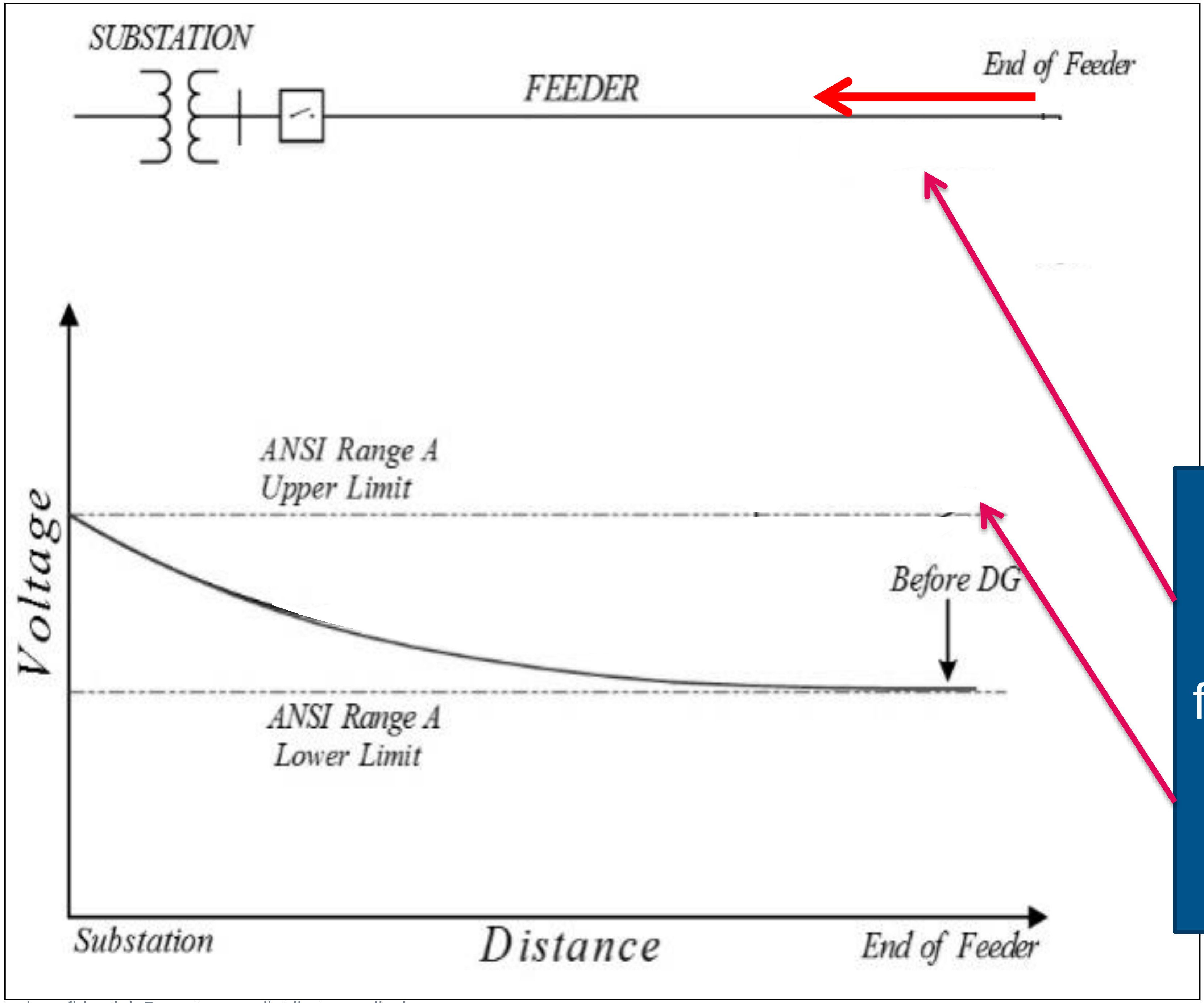
Cease to Energize Responses



Local System Support

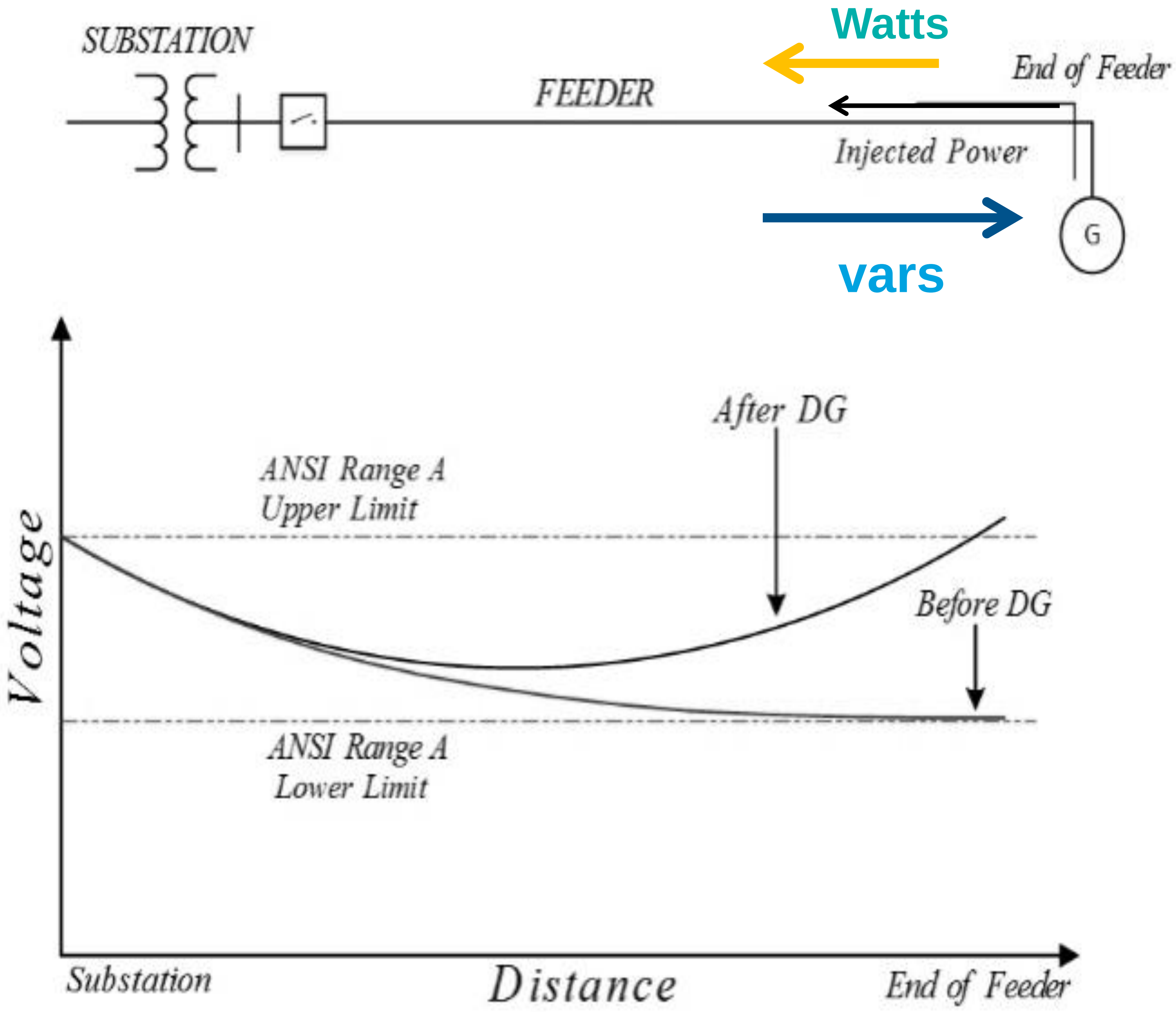
Active and Reactive Power Functions

DER Impacts on Feeder Voltage



Reverse Power Flow from Generator Can Lead to **High Voltage**

DER Impacts on Feeder Voltage



Two ways DER can reduce voltage

1. Consume Reactive Power (vars)

2. Reduce Active Power Injection (Watts)

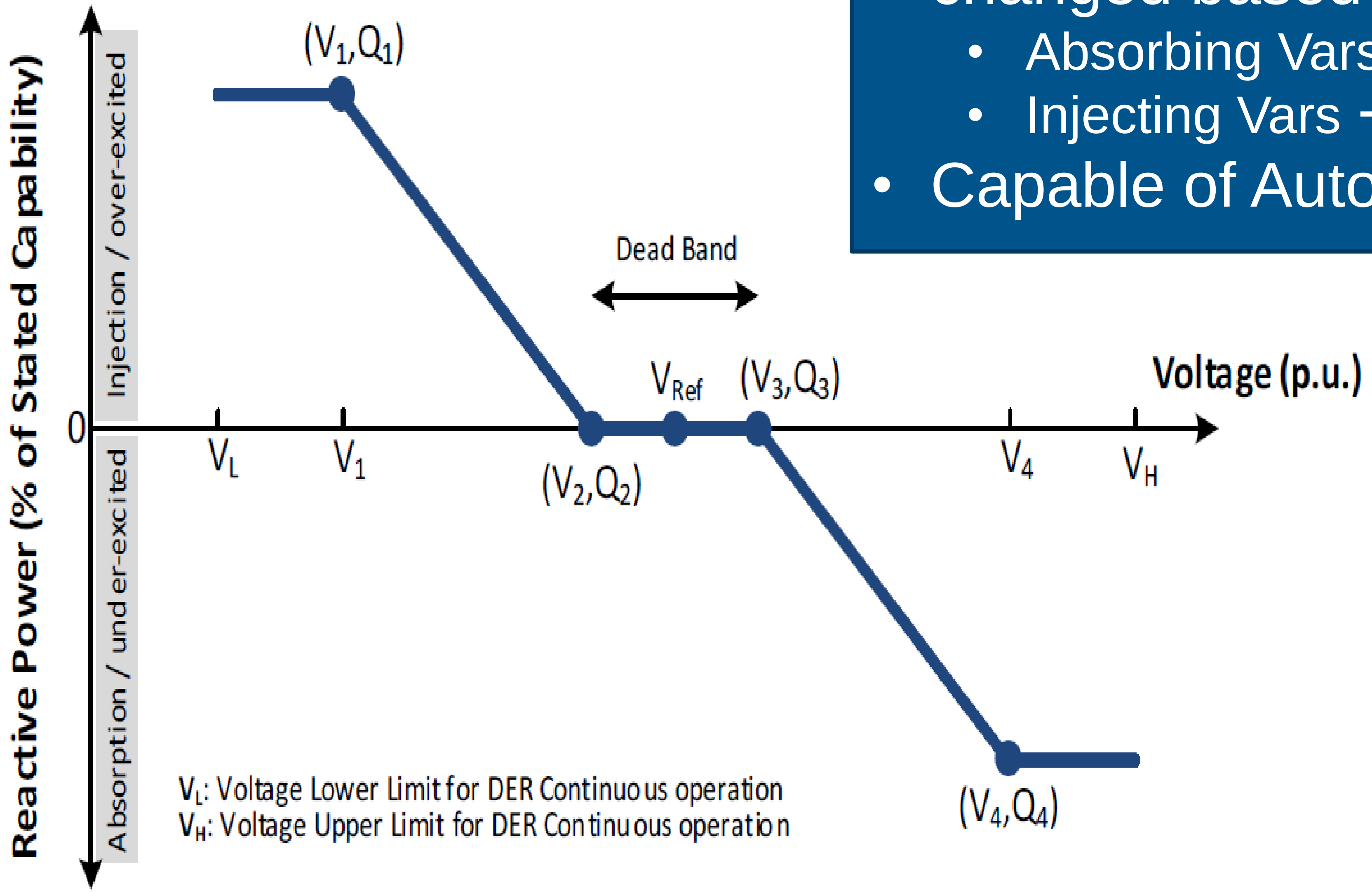
Active and Reactive Power Control Capabilities

Voltage and Reactive Power Control
Adjustable Constant Power Factor [Note: Default mode with unity PF]
Adjustable Constant Reactive Power
Voltage – Reactive Power (Volt-Var)
Active Power – Reactive (Watt-Var)*

Voltage and Active Power Control
Voltage – Real Power (Volt-Watt)*

* Required for Category A only (i.e. Inverters)

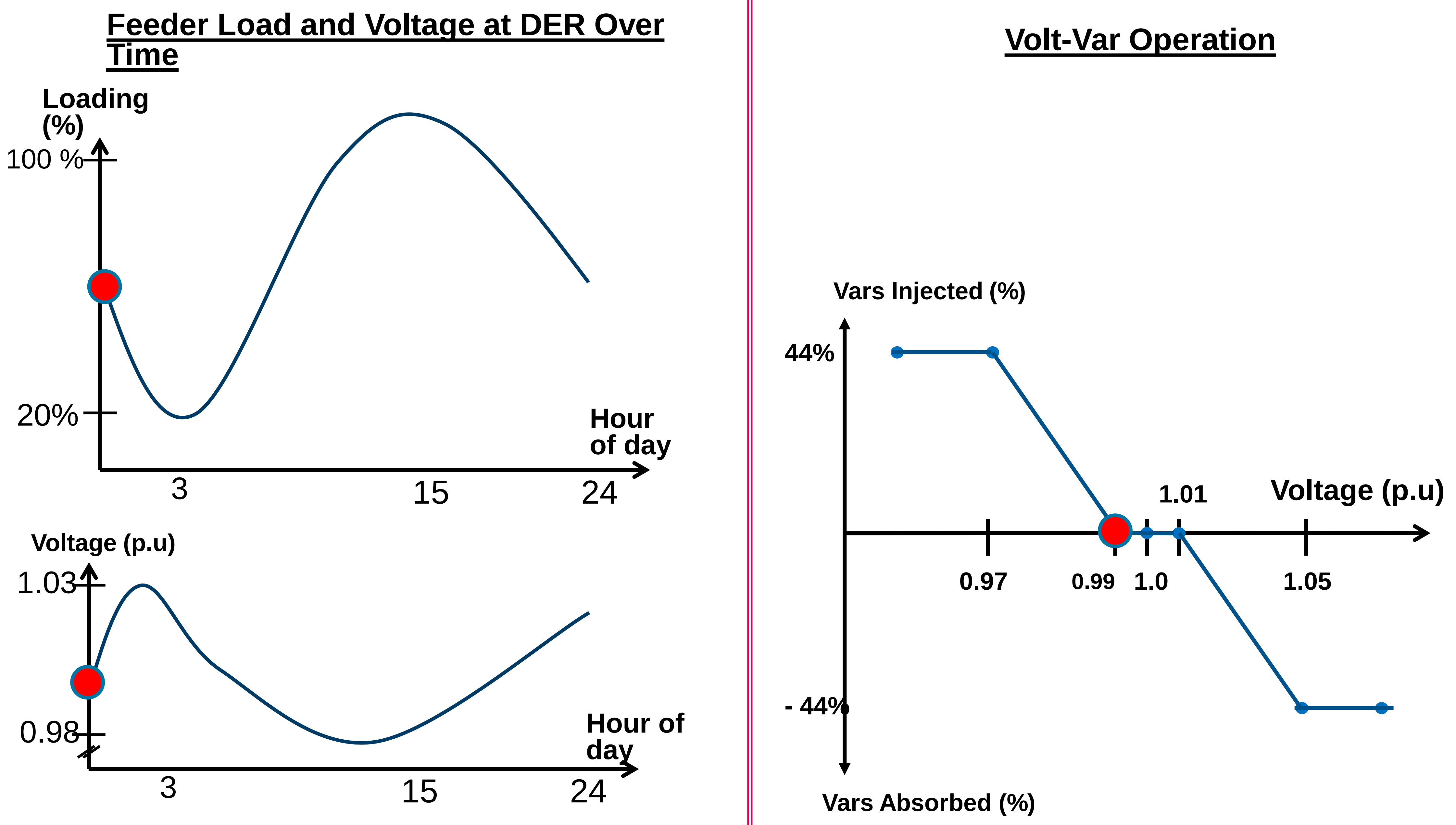
Volt-Var Function



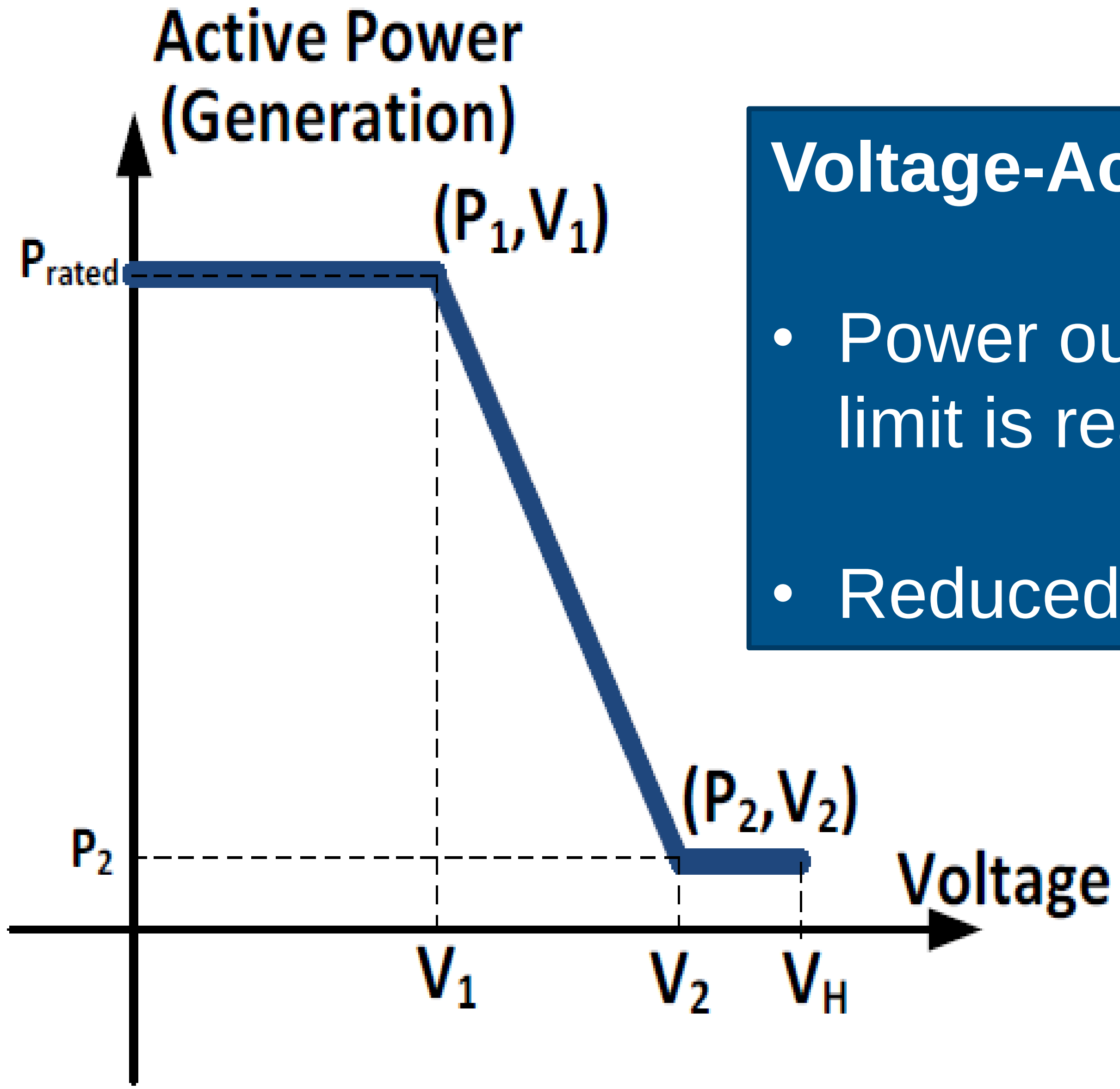
Voltage-Reactive Power Mode (Volt-Var)

- Reactive power absorption or injection is changed based on voltage
  - Absorbing Vars → Lowers voltage
  - Injecting Vars → Raises voltage
- Capable of Automatically Adjusting V_{Ref}

Volt-Var Example



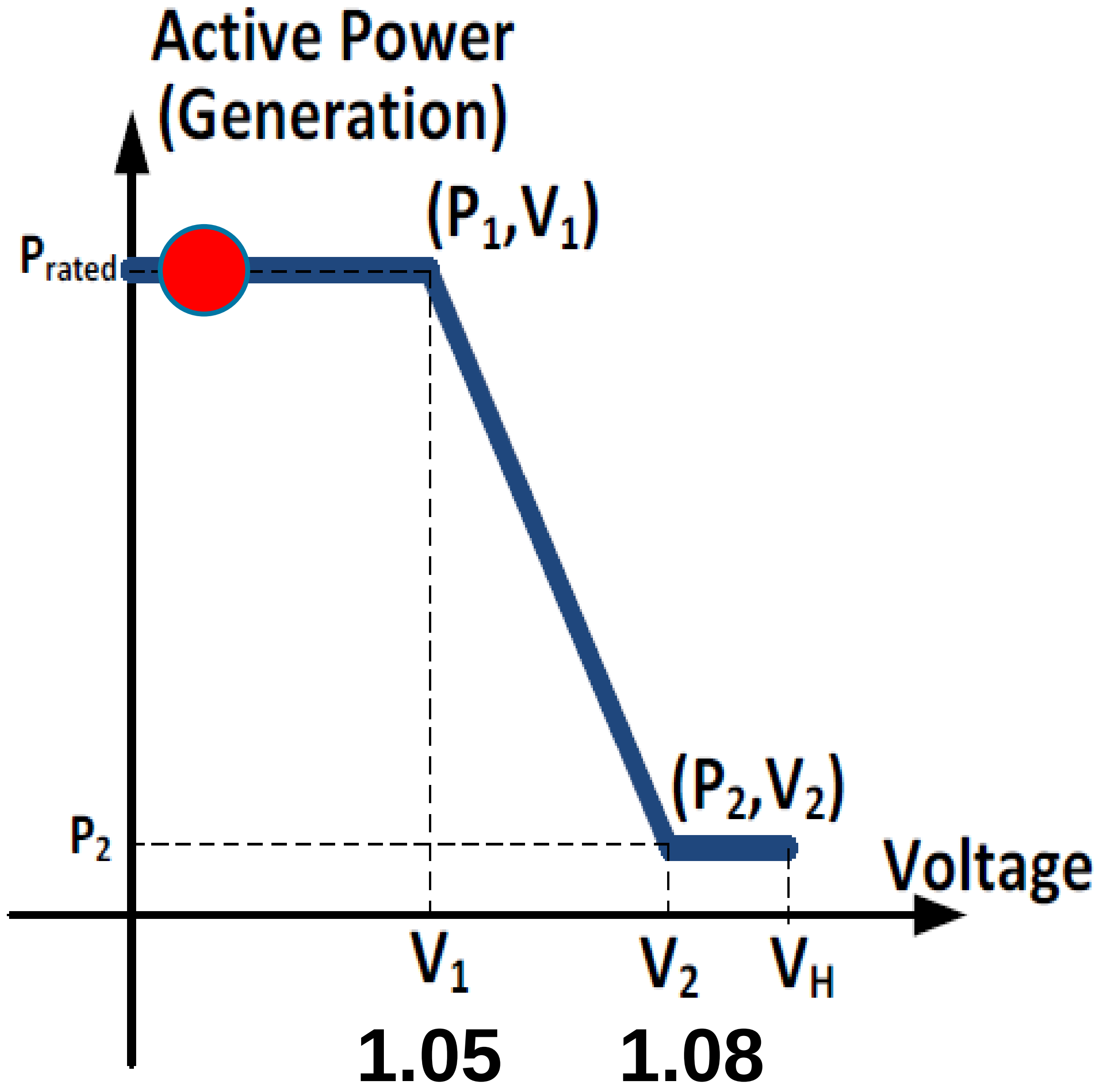
Volt-Watt Function



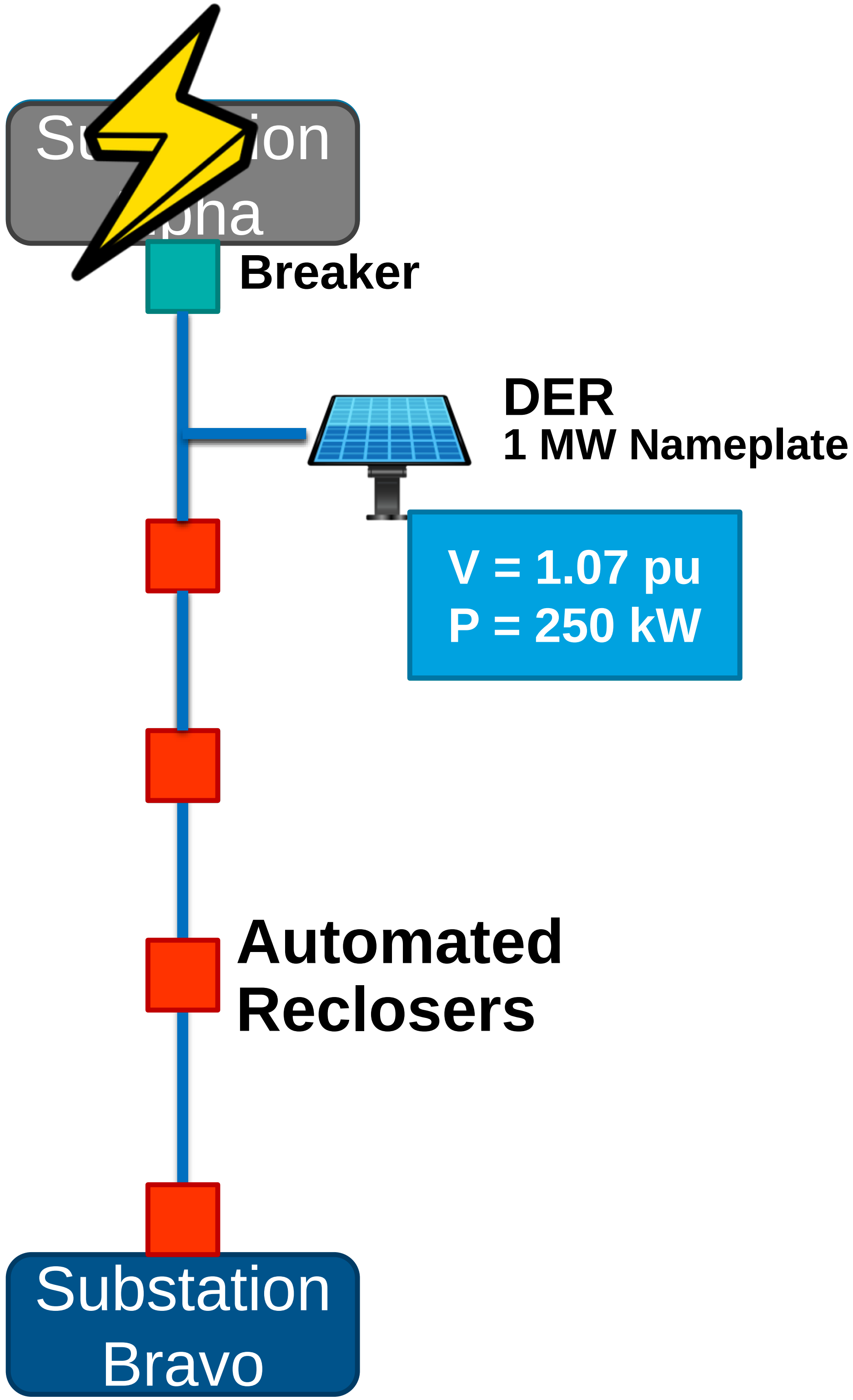
Voltage-Active Power Mode (Volt-Watt)

- Power output reduced when V_1 voltage limit is reached
- Reduced power results in lower voltage

Application of Volt-Watt

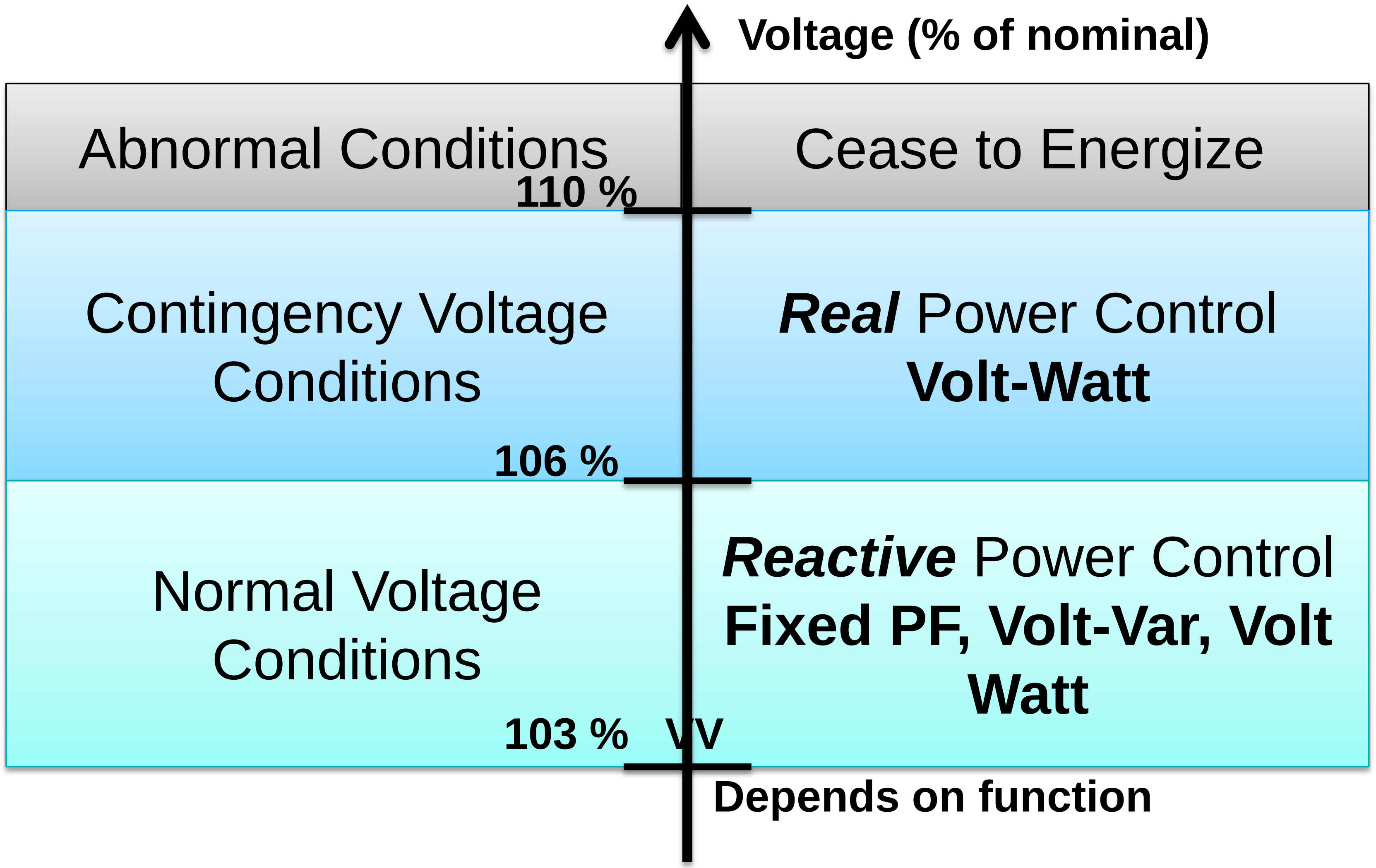


Per unit volages



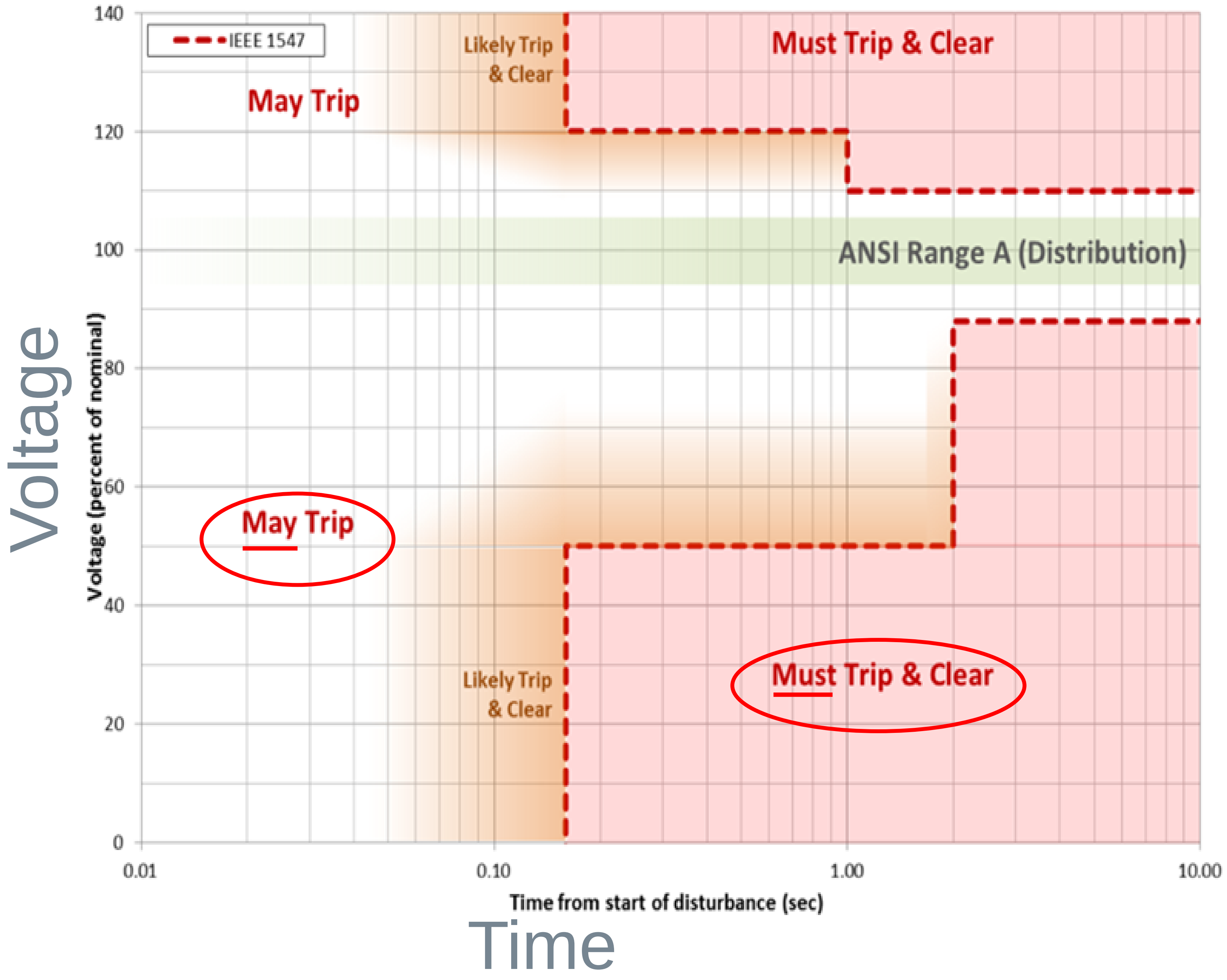
Stacking of Real and Reactive Control

- ***Reactive*** **power control functions for *normal (long term operating)* voltage conditions and Real power control for contingency (unplanned emergency or temporarily maintenance) voltage conditions**



Bulk System Support Functions
Ride-Through and Frequency Response

Historic Voltage Trip Requirements



Source: NERC, "Performance of Distributed Energy Resources During and After System Disturbance: Voltage and Frequency Ride-Through Requirements," North American Electric Reliability Corporation, 2013.

DER Impacts on Bulk System

NERC Report on Events in California

Table E.1: Generating Resource Reductions		
Type	Angeles Forest [MW]	Palmdale Roost [MW]
CAISO BPS-Connected Solar PV	860 MW	630 MW
SCE BPS-Connected Solar PV	670 MW	620 MW
PG&E BPS-Connected Solar PV	225 MW	225 MW
SDG&E BPS-Connected Solar PV	0 MW	0 MW
LADWP BPS-Connected Solar PV	17 MW	48 MW
IID BPS-Connected Solar PV	0 MW	33 MW
Combined-Cycle Power Plant	200 MW[5]	N/A
CAISO Net Load Increase[6]	130 MW	100 MW

- ➢ 100-130 MW of DER tripped for Transmission Events
- ➢ ~ 13% of total PV generation


NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

April and May 2018 Fault Induced Solar Photovoltaic Resource Interruption Disturbances Report

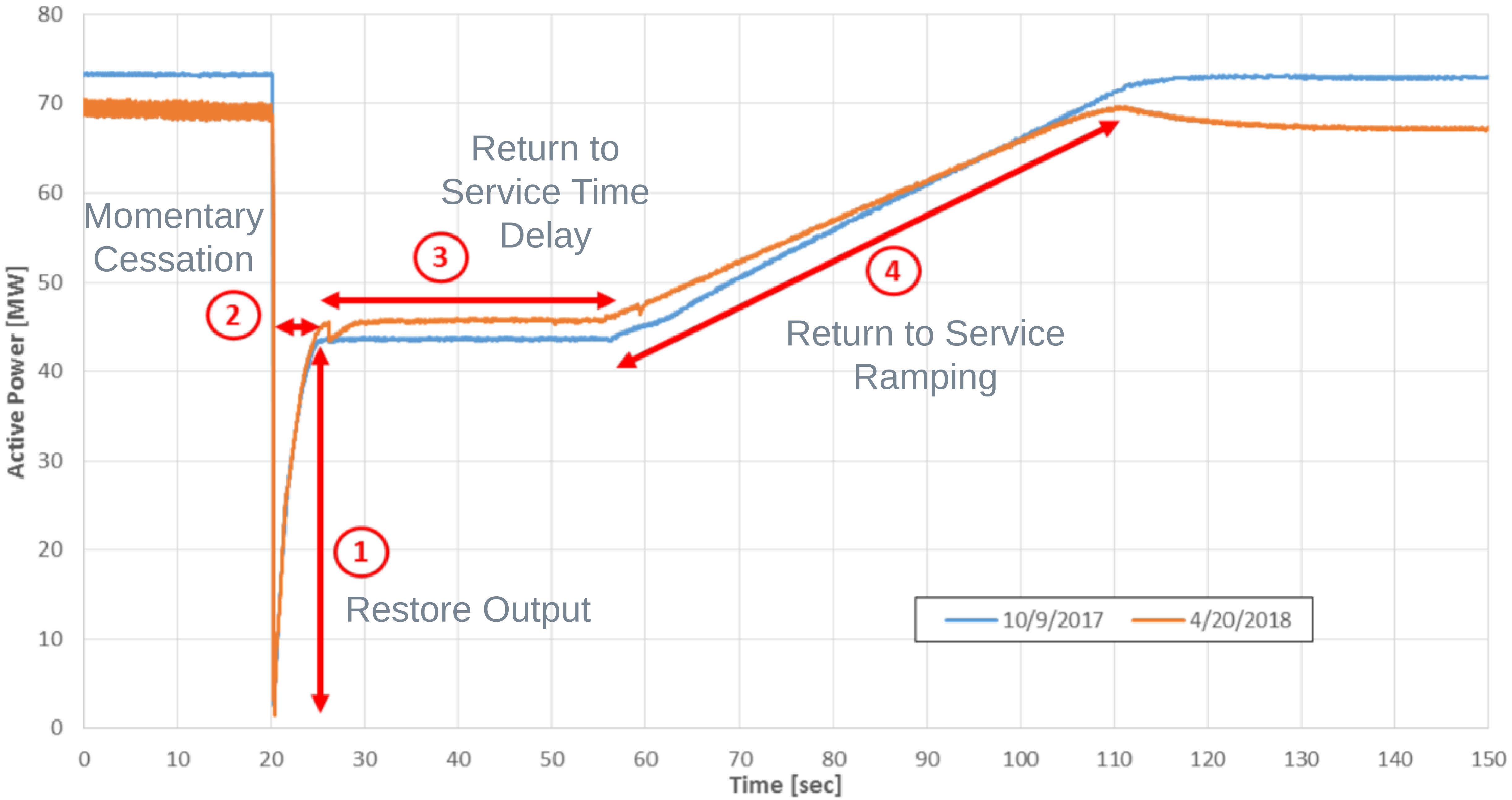
Southern California Events: April 20, 2018 and May 11, 2018
Joint NERC and WECC Staff Report

January 2019

RELIABILITY | ACCOUNTABILITY

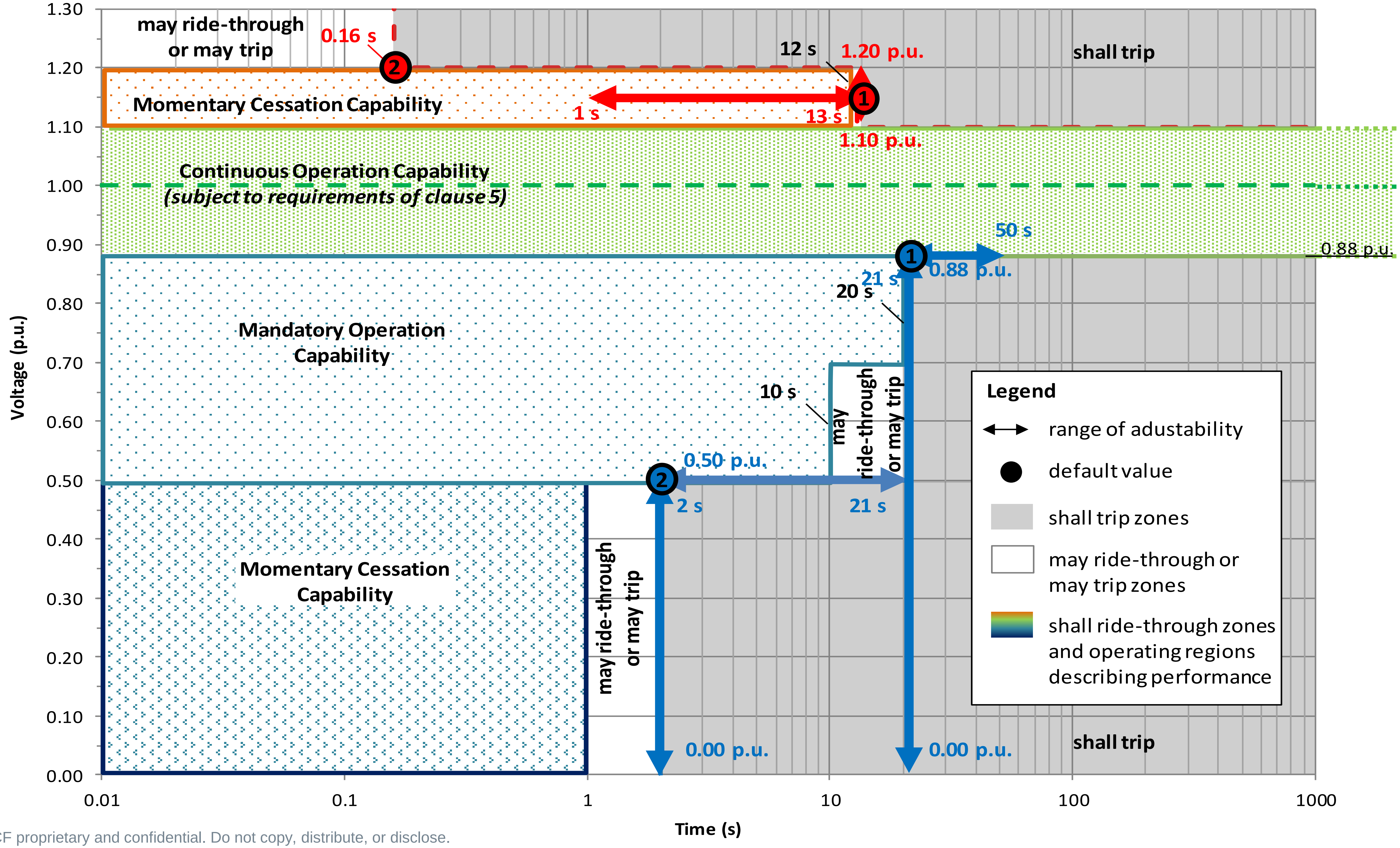
3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

Inverter System Responses



NERC and WECC Staff, April and May 2018 Fault Induced Solar Photovoltaic Resource Interruption Disturbances Report
https://www.nerc.com/pa/rrm/ea/April_May_2018_Fault_Induced_Solar_PV_Resource_Int/April_May_2018_Solar_PV_Disturbance_Report.pdf

Voltage Ride-Through – Category III

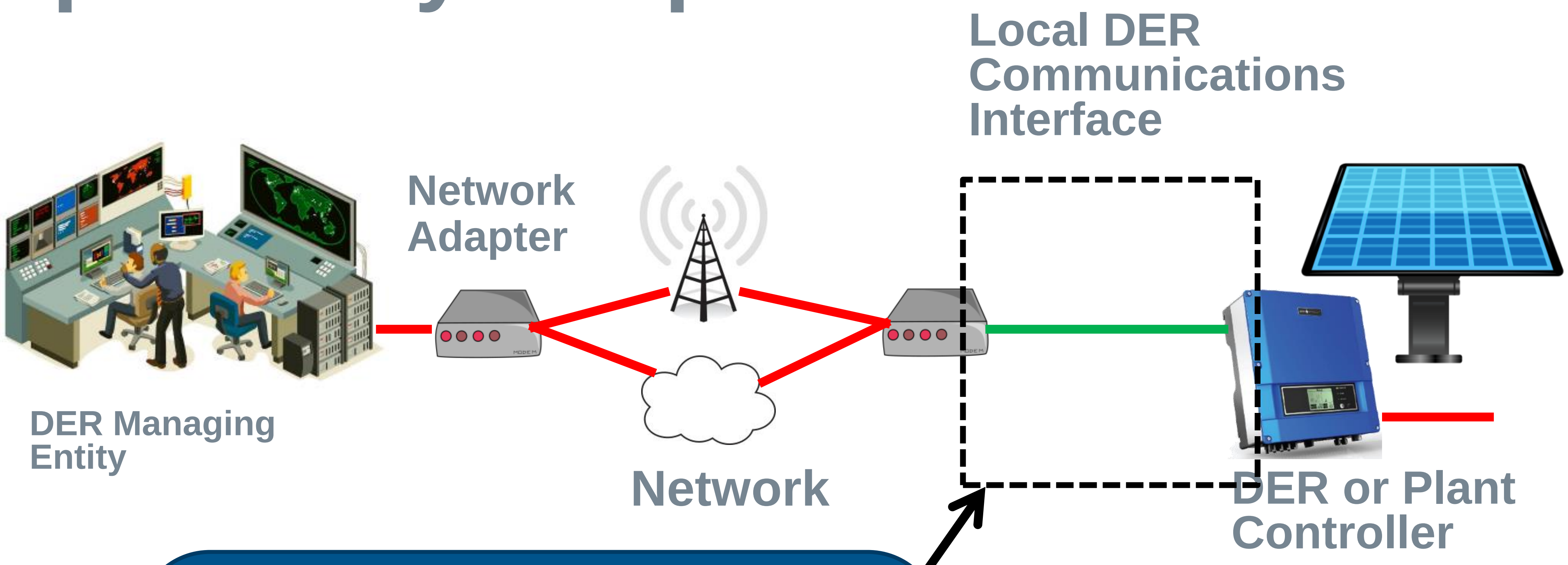


Origin of Ride-Through Requirements

Requirement	Category	Foundation	Justification
Voltage Ride-Through	**Category I**	**German grid code** for synchronous generator-based DER	• ***Essential*** **bulk system needs** • Attainable by all state-of-the-art DER technologies
	Category II	**NERC PRC-024-2** Without stability exception, Extended LVRT duration for 65-88%	• ***All*** **bulk system needs** • Considering fault-induced delayed voltage recovery (**FIDVR**)
	Category III	**CA Rule 21 and Hawaii** Minor modifications	• **All bulk system needs** • Considering fault-induced delayed voltage recovery (**FIDVR**) • **Distribution system operation**
Frequency Ride-Through	**All Categories**	**CA Rule 21 and Hawaii** Exceeds PRC-024-2	• **All bulk system needs** • **Low inertia grids**

Interoperability, Information Exchange, Information Models, and Protocols

Interoperability Scope



- **Monitoring ,Control, and Information Exchange**
- **Information Models**
- **Protocols**

Key

In Scope

Out of Scope

Use Cases for Interoperability

Monitoring of near real-time status for Operations

Remote settings changes for contingency or emergency situations

Coordination with Advanced Distribution Management System (ADMS) applications

- Distribution Voltage Optimization
- Fault Location Identification and Service Restoration

Integration in Distributed Energy Resources Management (DERMS)

- Aggregation
- Integration into Markets

Types of DER Information Exchange

Nameplate	**Configuration**

• P at unity and specified pf
• S maximum rating
• +/- Q maximum
• Performance Category
    • Normal
    • Abnormal
• Voltage Ratings
• Supported Control Modes
• Make, Model, Version
	• Each rating in the Nameplate Information Table is configurable
	• Not intended for continuous dynamic adjustment

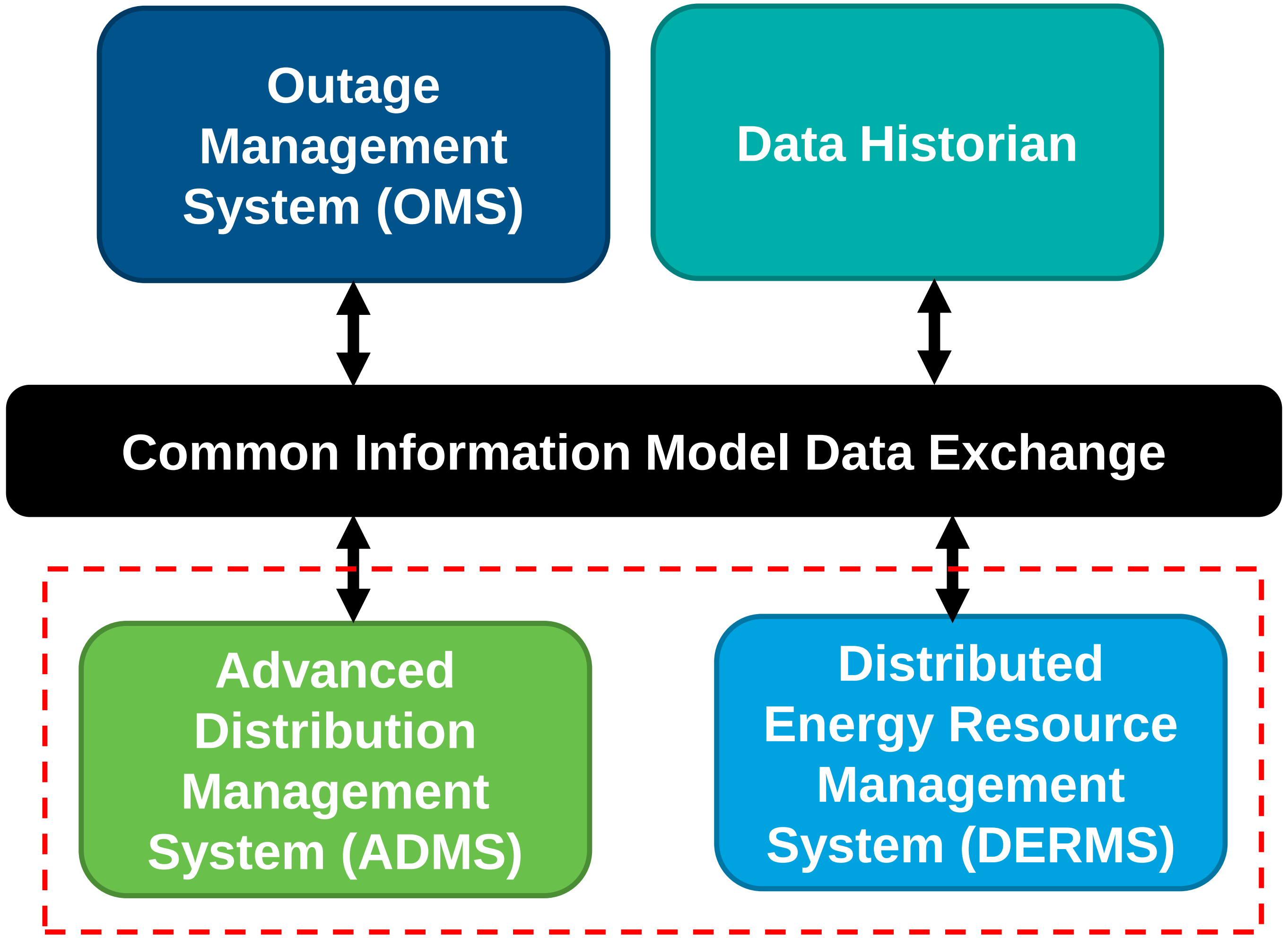
Monitoring	**Management**
• Active Power • Reactive Power • Voltage • Frequency • Operational Status • Connection Status • Alarm Status	• P and Q control mode settings • Voltage/frequency trip and momentary cessation parameters • Enter service after trip parameters • Cease to energize and trip • Limit maximum active power

Interoperability Protocol Options

Application	DNP3 (IEEE 1815)	SEP 2.0 (IEEE 2030.5)	SunSpec Modbus	
Transport	TCP/IP	TCP/IP	TCP/IP	N/A
Physical	Ethernet	Ethernet	Ethernet	RS-485

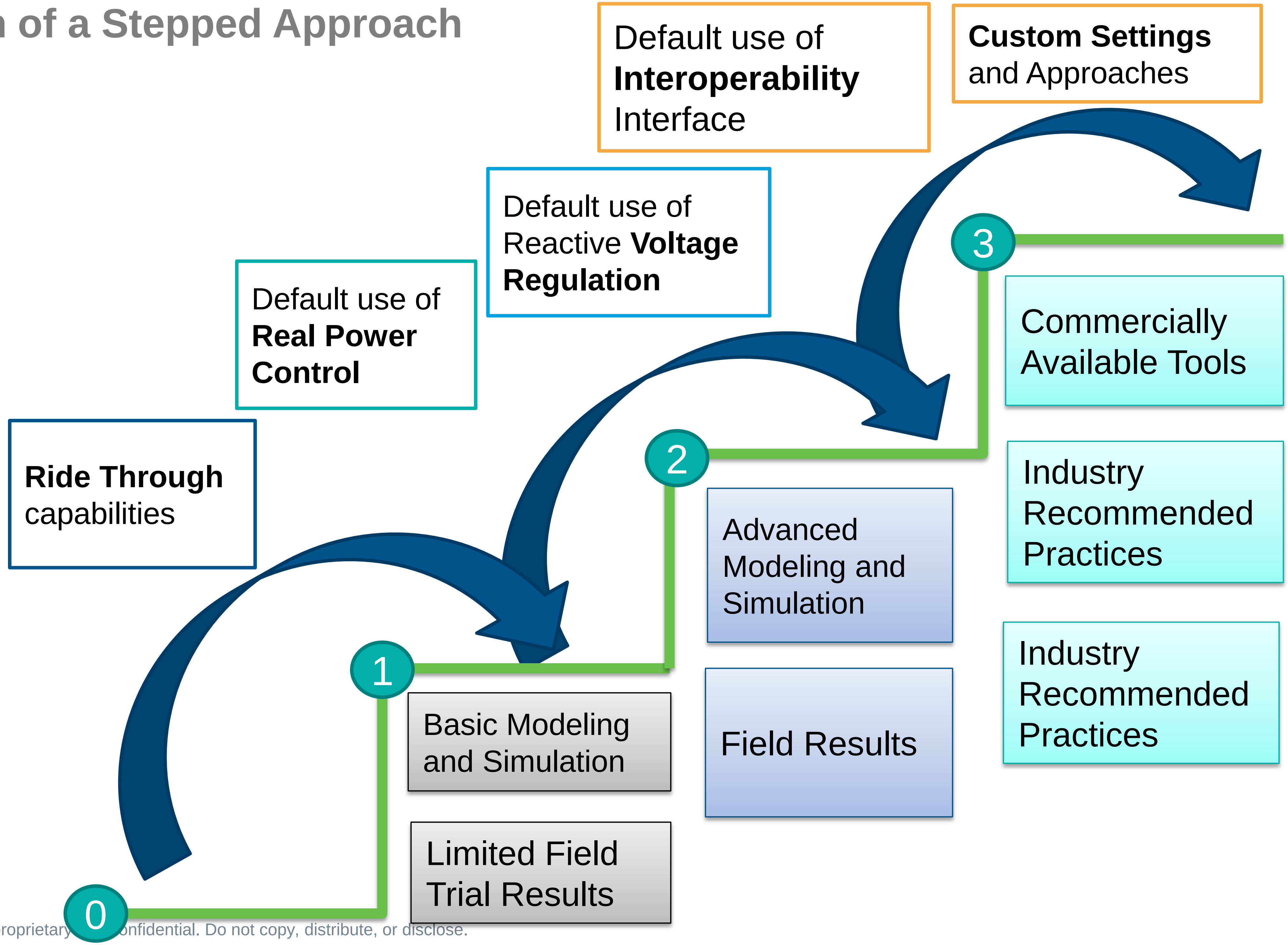
Information Models

- Communication capability shall use unified information model



Adoption of Advanced Inverter Functions

Illustration of a Stepped Approach



Summary of Standard DER Capabilities

Local System Support

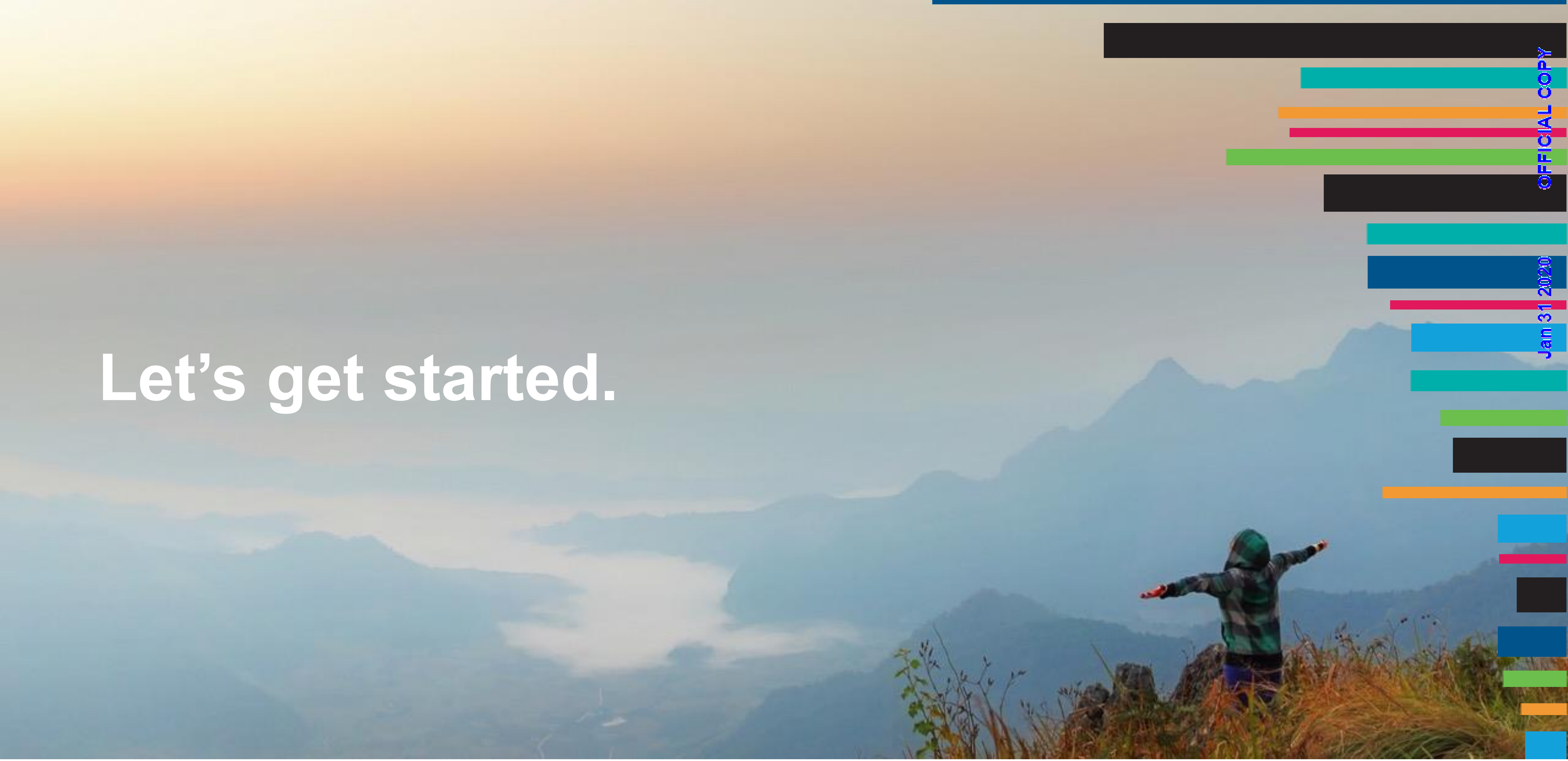
- Distribution Engineers Deeper Involvement in Control Systems
- Modeling Tools with Dynamic Simulation Capabilities
- Interaction with other Advanced Grid Efforts

Bulk System

- Statewide and Regional Coordination of Ride Through Settings
- DER Modeling Needs

Interoperability

- Define Use Cases for Capabilities
- Road Map and Architecture of Back-End Systems



Let’s get started.