IEEE 1547 - 2018 - Major Revision of Interconnection Standard

NRECA & APA's Emerging Priorities in Energy Research Day, Anchorage, AK

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Disclaimer

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Presentation Outline

1) IEEE 1547 Background

2) Featured Changes to 1547-2018,

VAR and Voltage Control Capabilities

Voltage & Frequency Ride Through

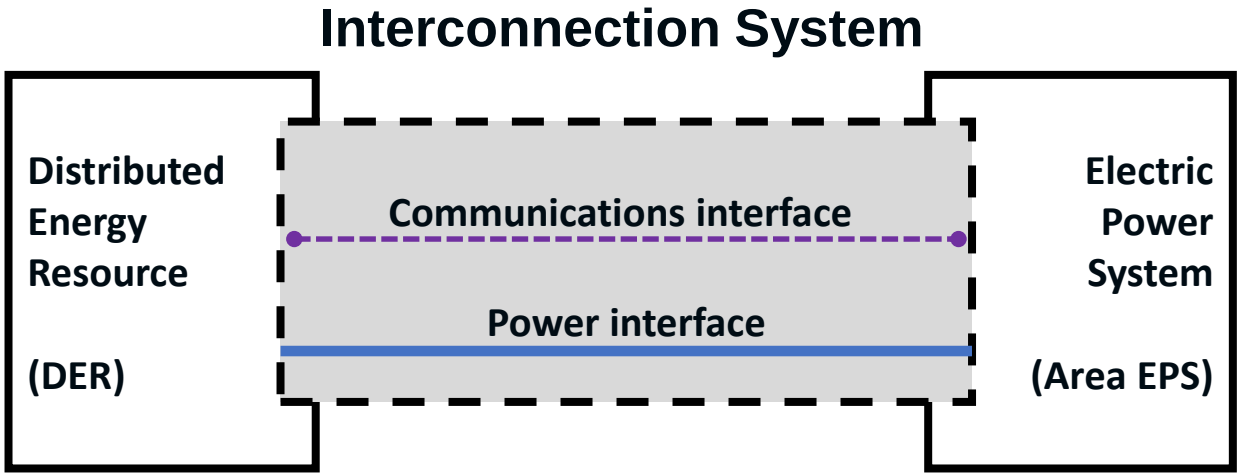
Interoperability

Intentional Islanding

IEEE 1547-2018 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 distributed energy resources (DER) with electric power systems (EPS), and associated interfaces.*



Purpose*: This document provides a uniform standard for the interconnection and interoperability of distributed energy resources (DER) with electric power systems (EPS). It provides requirements relevant to the interconnection and interoperability performance, operation, and testing, and, safety, maintenance and security considerations.*

Interconnection system: The collection of all interconnection equipment and functions, taken as a group, used to interconnect DERs to an area EPS. Note: In addition to the power interface, DERs should have a communications interface.

Interface: A logical interconnection from one entity to another that supports one or more data flows implemented with one or more data links.

IEEE 1547 Evolution of Grid Support Functions

IEEE 1547-2003

- Shall NOT actively regulate voltage
- Shall trip on abnormal voltage/frequency

IEEE 1547a-2014
(Amendment 1)

- **May** actively regulate voltage
- **May** ride through abnormal voltage/frequency
- **May** provide frequency response[1] (frequency-droop)

IEEE 1547-2018

- **Shall be capable of** actively regulating voltage
- **Shall** ride through abnormal voltage/frequency
- **Shall be capable of** frequency response[2]
- **May** provide inertial response[3]

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 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

for IEEE

IEEE 1547-2018 Document Outline

1. Normative references
2. Definitions and acronyms
3. General specifications and requirements
4. **Reactive power, voltage/power control *[normal operation conditions]***
5. **Response to Area EPS abnormal conditions**
6. Power quality
7. **Islanding**
8. Distribution secondary grid and spot networks
9. **Interoperability**
10. Test and verification
11. Seven new annexes (Informative)

Active Voltage Regulation Requirements Normal Operation Conditions

Capability required for all DER – (Cat A, B)

- Constant power factor mode
- Constant reactive power mode (“reactive power priority”)
- 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 shall specify the required voltage regulation control modes and the corresponding parameter settings.

Grid Support Requirements - Abnormal Operating Conditions

Ride-through

Required

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

Other allowed capabilities

- Inertial response[3]

[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

Interoperability Requirements

externally exchange and readily use information securely and effectively

Mandatory communications capability

A DER **shall have provisions for** a local DER interface capable of communicating…

Information to be exchanged:

Nameplate: as-built characteristics of the DERs (read

Configuration: present capacity and ability of the DERs to perform functions (read/write)

Monitoring: present operating conditions of the DERs (read)

Management: information to update the functional and mode settings for the DERs (read/write)

Communication performance requirements:

Availability of communication (DER is operating in continuous or mandatory operation region)

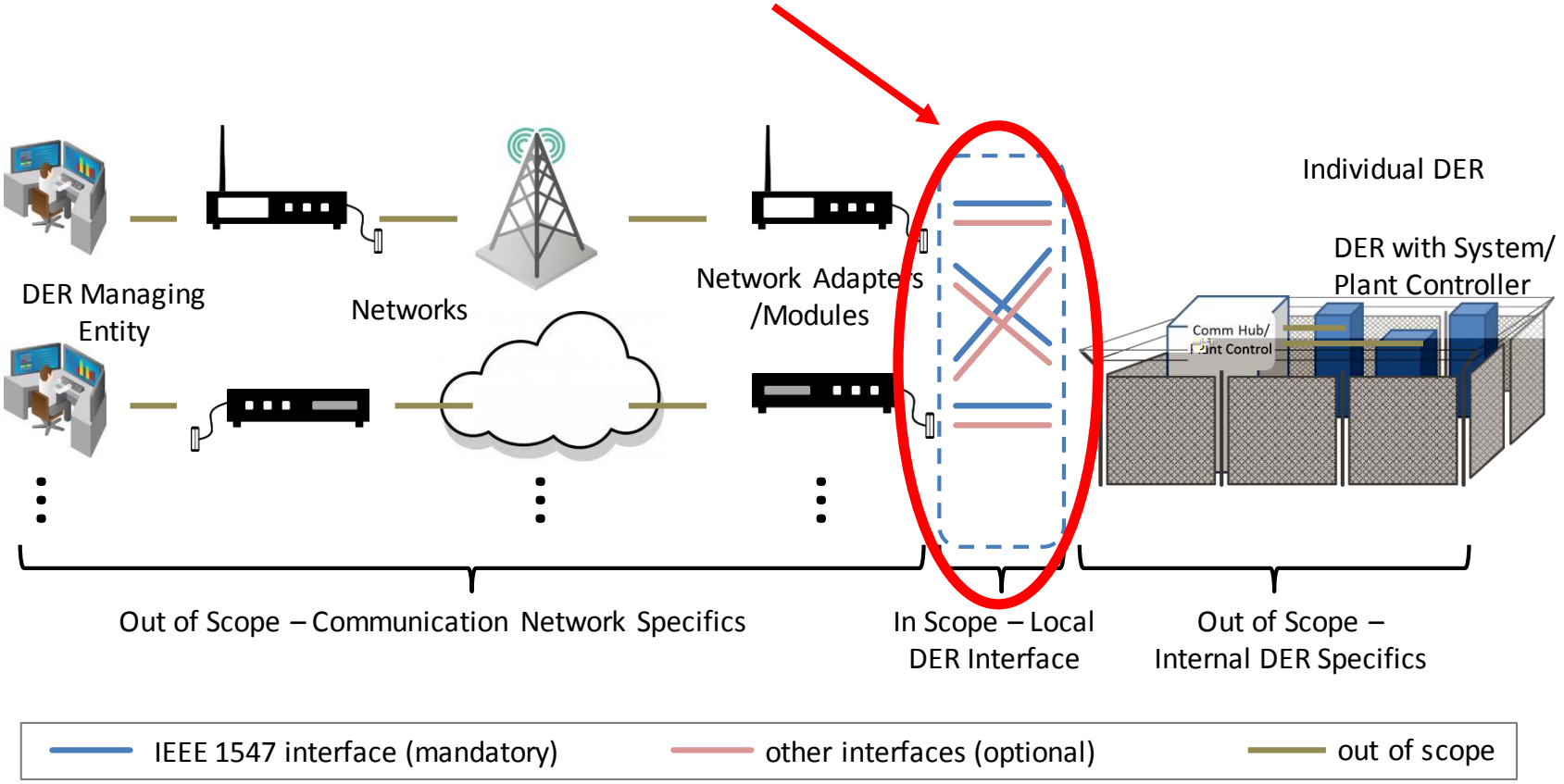
Information read response times (≤ 30 s, maximum amount of time to respond to read requests)

Communication protocol requirements:

Shall support at least one of three protocols: IEEE Std 2030.5(SEP), IEEE Std 1815(DNP3.0), SunSpec-Modbus

Interoperability Scope

Scope of IEEE 1547-2018 Interoperability Requirements



Intentional Islands: what's in-scope?

An intentional island that contains any part of the Area EPS is in-scope.

Intentional island behavior at the PCC, and impacts on the Area EPS, are in-scope.

What happens "behind the meter" within a microgrid that does *not* include any Area EPS elements is out-of-scope.

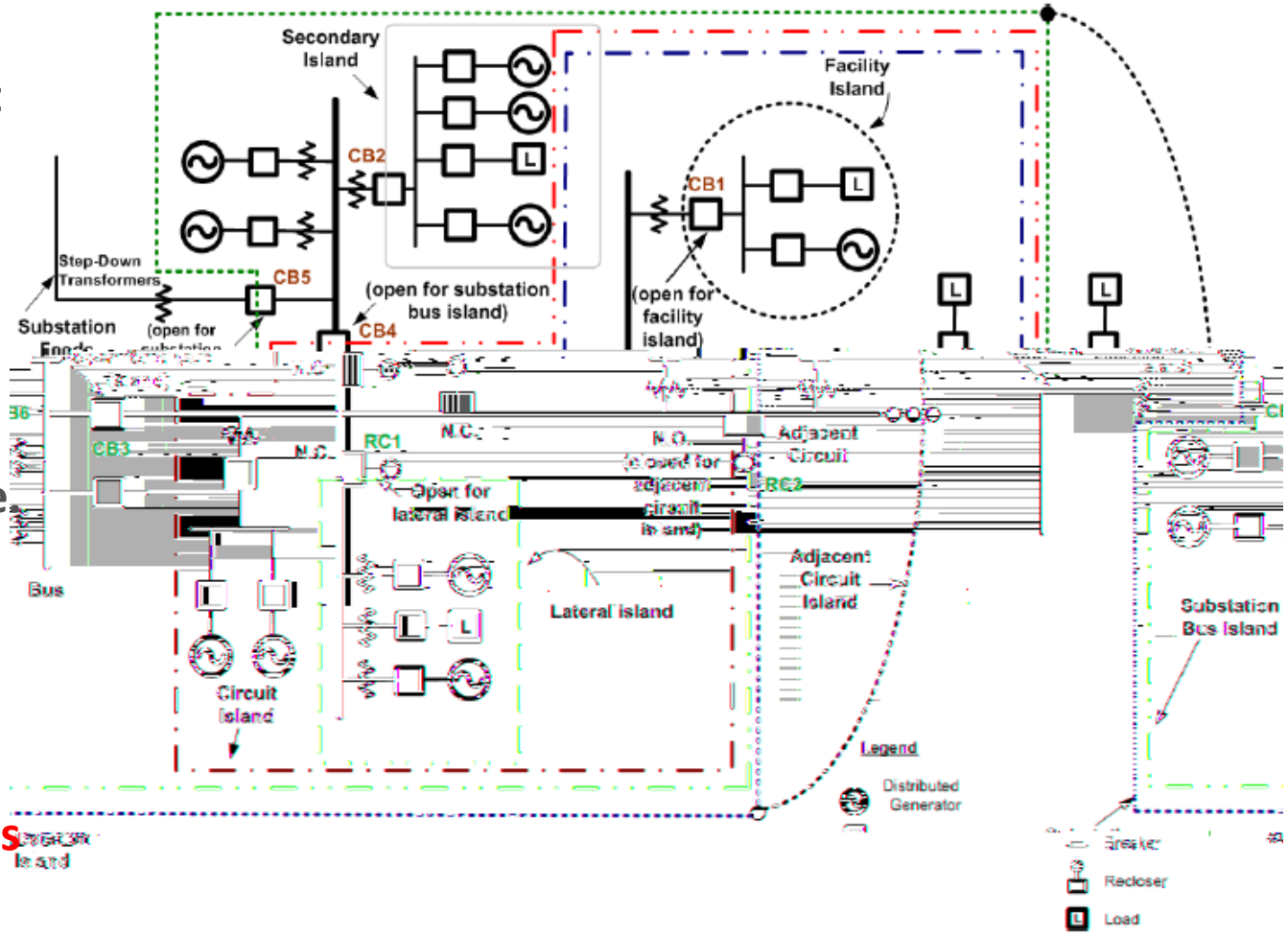


Figure C-1—Examples of DR island systems from IEEE Std 1547.4-2011

1547-2018 and intentional Islands (II)

- Two types of transitions into II mode (on-grid to off-grid): scheduled and unscheduled.
  - Scheduled: initiated by manual action or dispatch.
  - Unscheduled: automatically initiated due to abnormal Area EPS conditions.
- Power systems designated by the AHJ as Emergency, Legally Required, or Critical Operations are exempted.

1547's Island Terminology

- Intentional Island: one that is planned, has a defined boundary, and has V/F regulation controls. Types:
  - Microgrid
  - Emergency/standby power supply
  - Island power system (as in, on an actual island)
  - Remote community grid
  - Military bases
  - Remote resource extraction operations
- Unintentional island: one that isn't planned and doesn't have V/F regulation control.

Thanks!

Questions?

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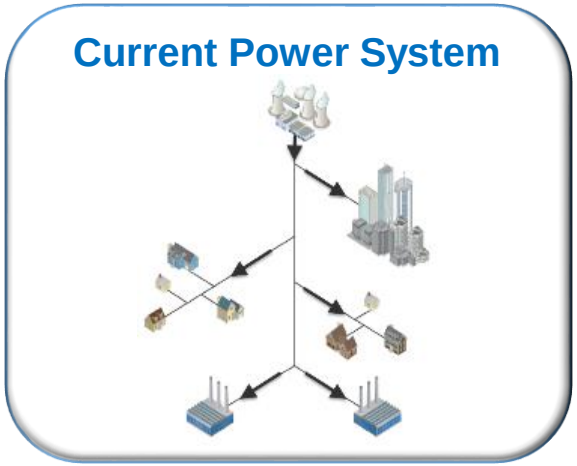
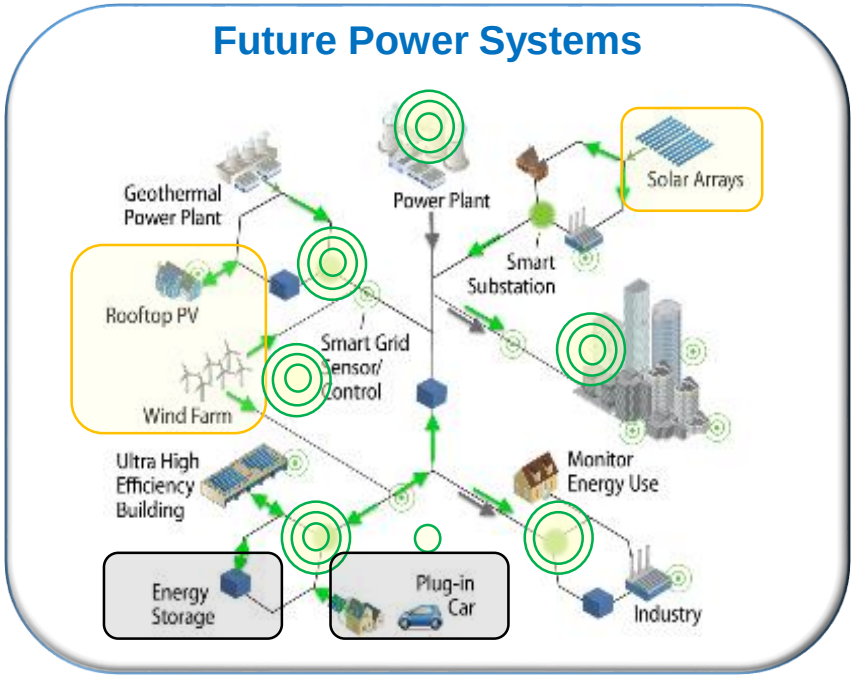
BACKUP SLIDES

Background- Evolution of the Grid



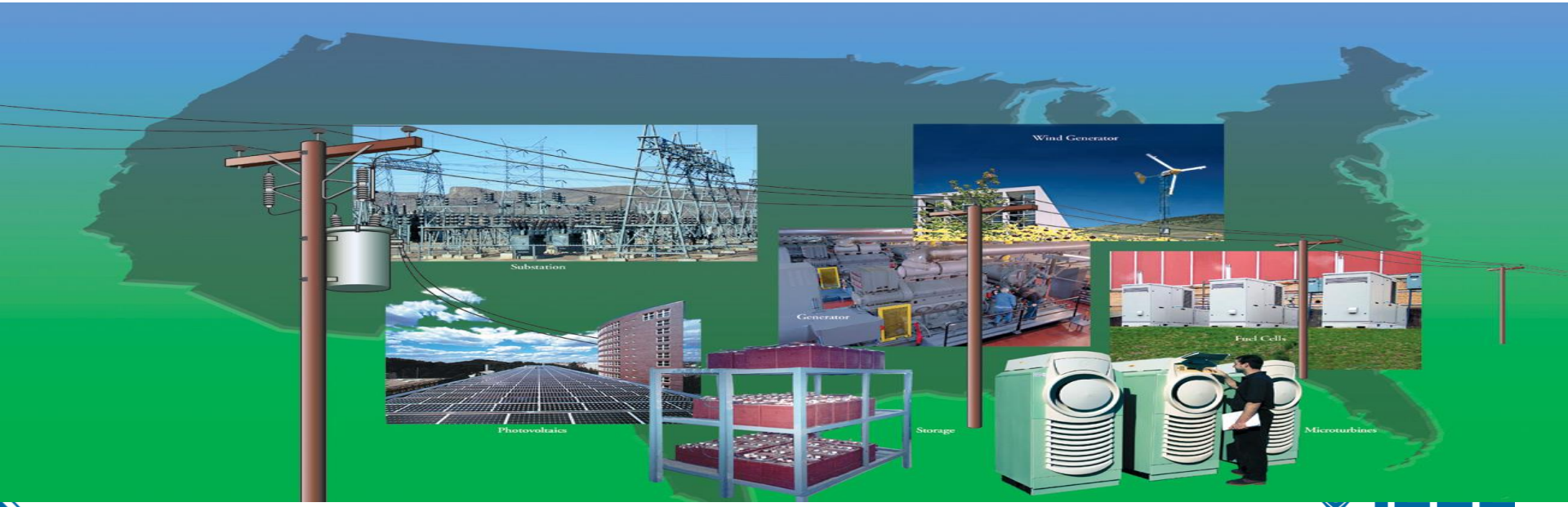


New Challenges

- New energy technologies and services
- Penetration of variable renewables in grid
- New communications and controls (e.g., Smart Grids)
- Electrification of transportation
- Integration of distributed energy storage
- Regulatory Advances

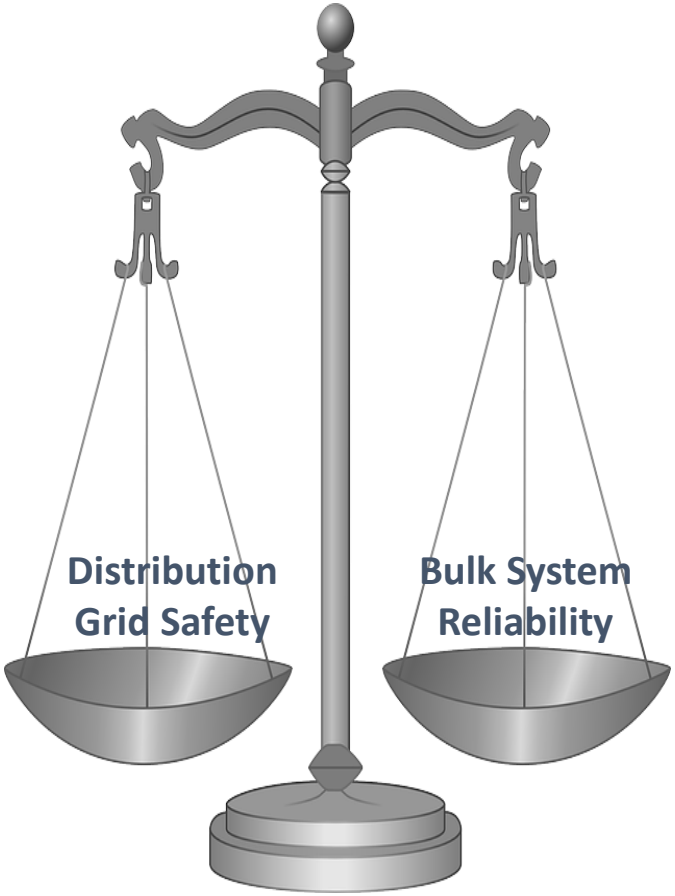
Importance of IEEE 1547

- Energy Policy Act (2005) Cites and requires consideration of IEEE 1547 Standards and Best Practices for Interconnection; all states use or cite 1547.
- Energy Independence and Security Act (2007) IEEE cited as a standards development organization partner to NIST as Lead to coordinate framework and roadmap for Smart Grid Interoperability standards and protocols {IEEE 1547 & 2030 series being expanded};
- Federal ARRA (2009) Smart Grid & High Penetration DER projects {use IEEE stds}.

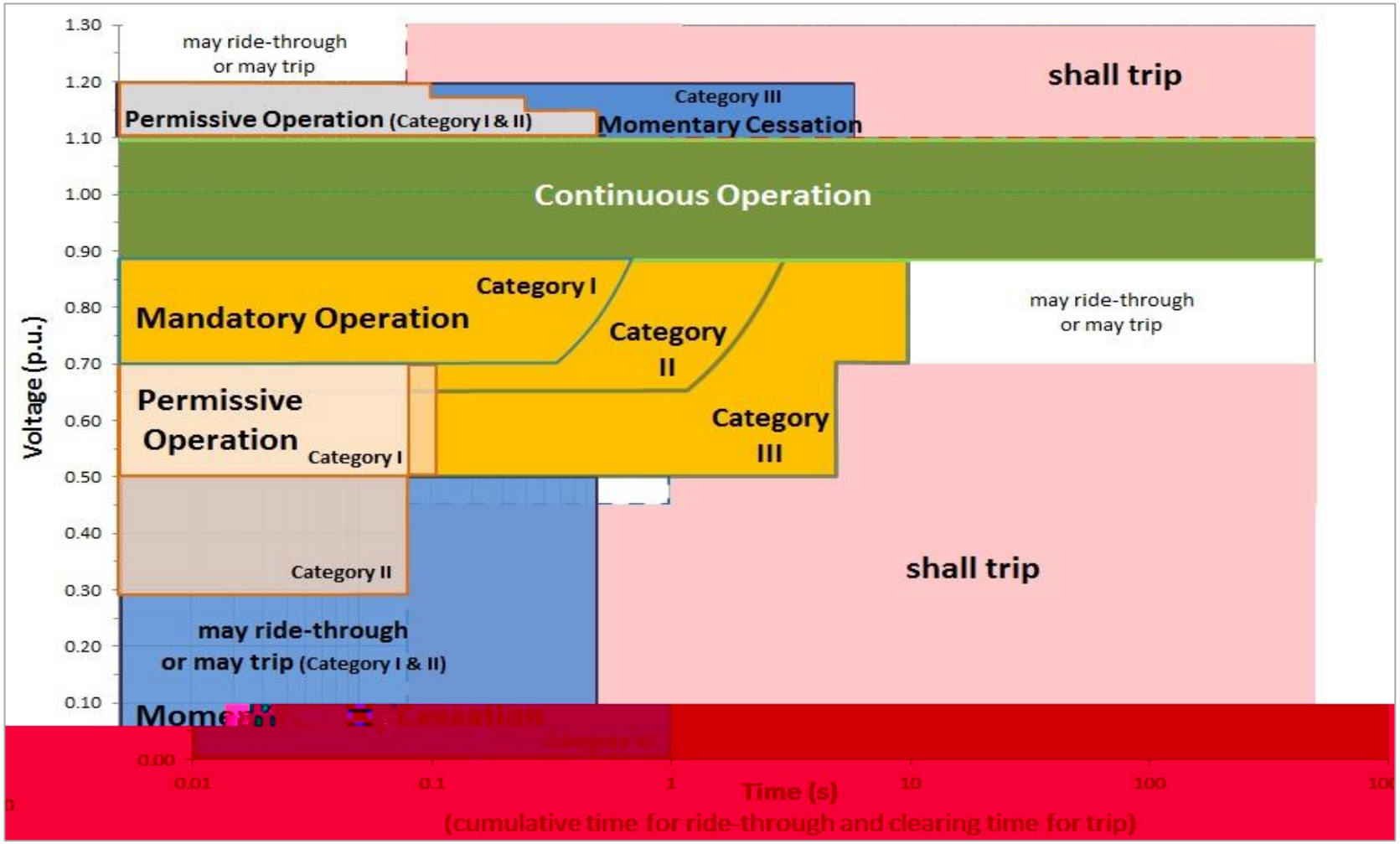


Striking a new balance

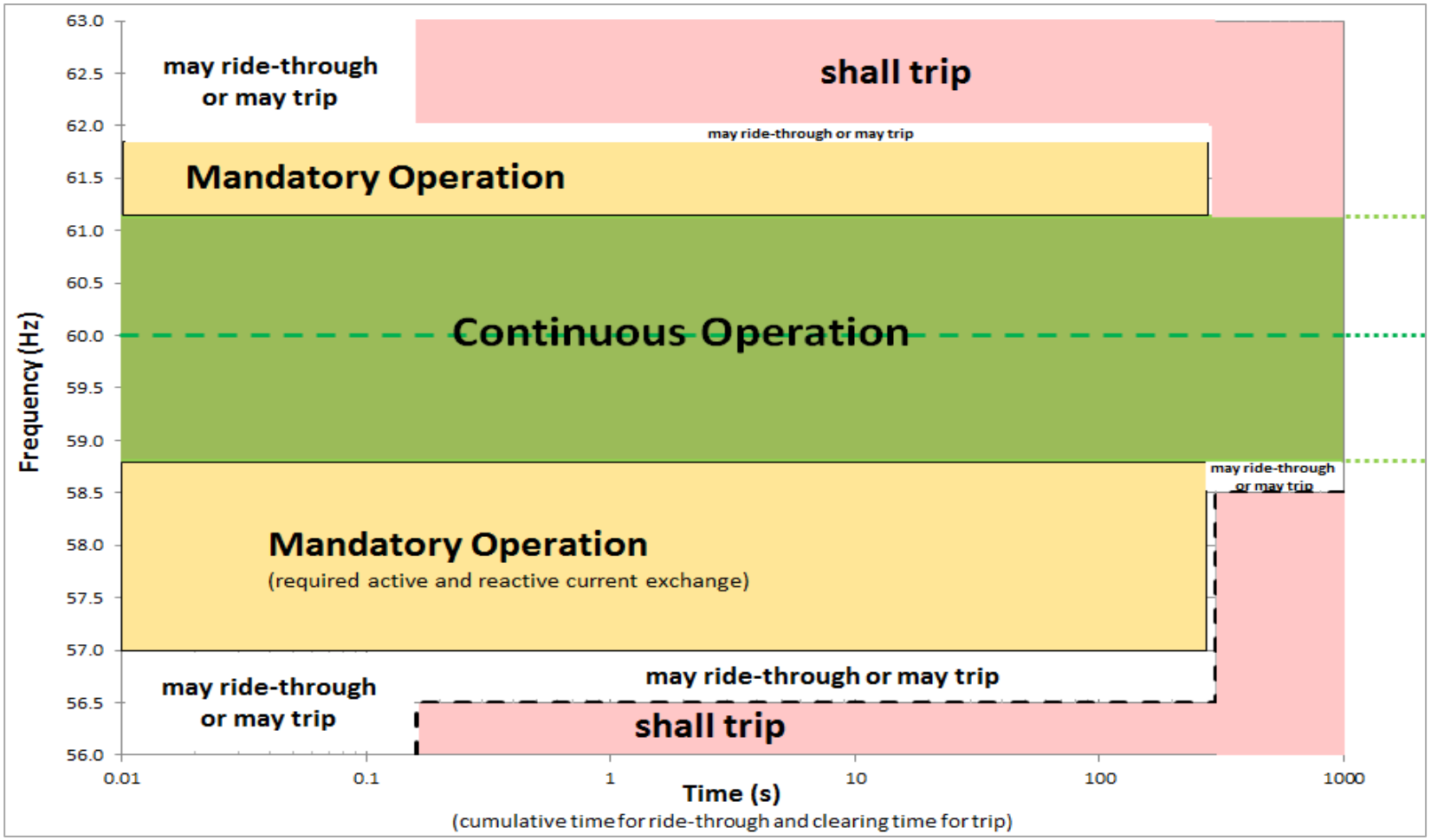
- IEEE 1547-2018 mandates BOTH:
  - Tripping requirements, and
  - Ride-through requirements
- Ride-through is not a “setting”, it is a minimum of the DER
  - _____
  - I.e., it is the minimum required DER robustness to withstand voltage and frequency disturbances
  - May or may not be fully utilized, or it may be exceeded
- Trip thresholds and clearing times are maximum operational
  - _____
  - May differ from and are adjustable over a ‘range of allowable settings’
  - Specified ranges do not allow DER tripping to seriously compromise bulk power system reliability
  - Tripping points specified by the distribution utility may account for utility-specific practices but may also be constrained by the ***regional reliability coordinator***



Voltage Ride-Through
(All Categories)

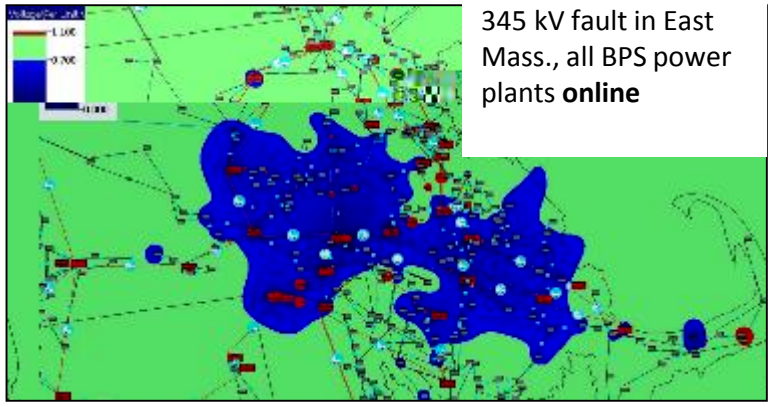


Frequency Ride-Through
(Default Values for All Categories)



Based on IEEE -2018

Driver for new ride-through requirements - Potential for widespread DER tripping (Cont)



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

Source: ISO-New England

- System frequency is defined by balance between load and generation
- Frequency is the same across entire interconnection; all DER may trip simultaneously during disturbance
- Impact 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

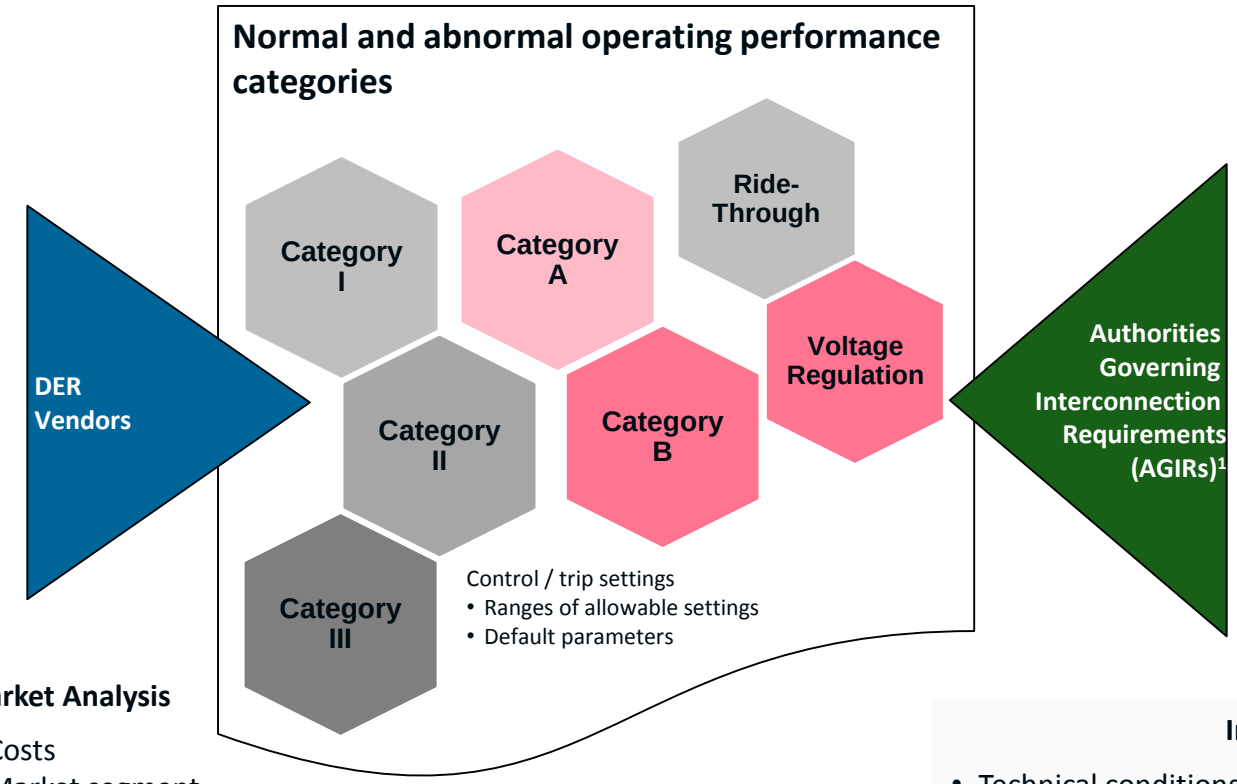
Tripping points are adjustable over an allowable range

- Range does not allow DER tripping to seriously compromise BPS security
- Tripping points specified by the Area EPS Operator (utility) within constraints of the regional reliability coordinator

Specific Performance Terminology

- **Trip** – cessation of output without immediate return to service; not necessarily disconnection
- **Cease to energize** – no active power delivery, limitations to reactive power exchange; Does not necessarily mean physical disconnection. Can be either a
  or a
- **Permissive operation** – DER may either continue operation or may cease to energize, at its discretion
- **Mandatory operation** – required active and reactive current exchange
- **Momentary cessation** – cessation of energization for the duration of a disturbance with rapid recovery when voltage or frequency return to defined range
- **Return to service** – re-entry of DER to service following a trip
- **Restore output** – DER recovery to normal output following a disturbance that does not cause a ***trip***.

Assignment of new IEEE 1547 Performance Categories



Stakeholder Engagement

- Distribution utilities.
- Bulk system operators & planners.
- DER developers.
- Others.

Market Analysis

- Costs
- Market segment
- Etc.

Impact Assessment

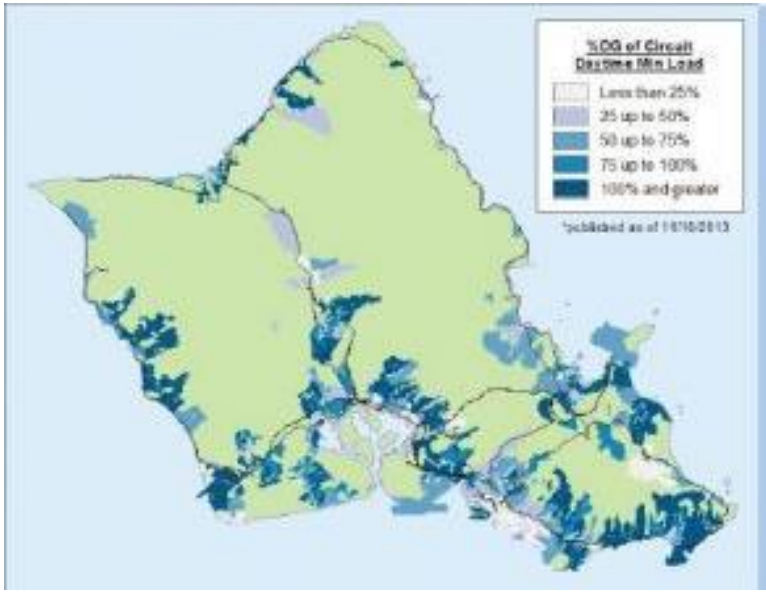
- Technical conditions: type & capacity & future penetration of DER, type of grid configuration, etc.
- Non-technical issues: DER use case, impacts on environment, emissions, and sustainability, etc.

[1] Regulatory agencies, public utility commissions, municipalities, cooperative governing boards, etc.

Importance Of Interoperability Functions
- Hawaii Case Study

- In 2014, Hawaii was headed for a repeat of Germany's "50.2 Hz problem"
  - Inverters could trip en masse due to frequency excursion, worsening excursion and potentially blacking out grid
- In February 2015, Enphase remotely reprogrammed 800,000 inverters (154 MW) in Hawaii to enable frequency ride-through
- Required close coordination between utility and inverter manufacturer

Oahu feeder PV penetration

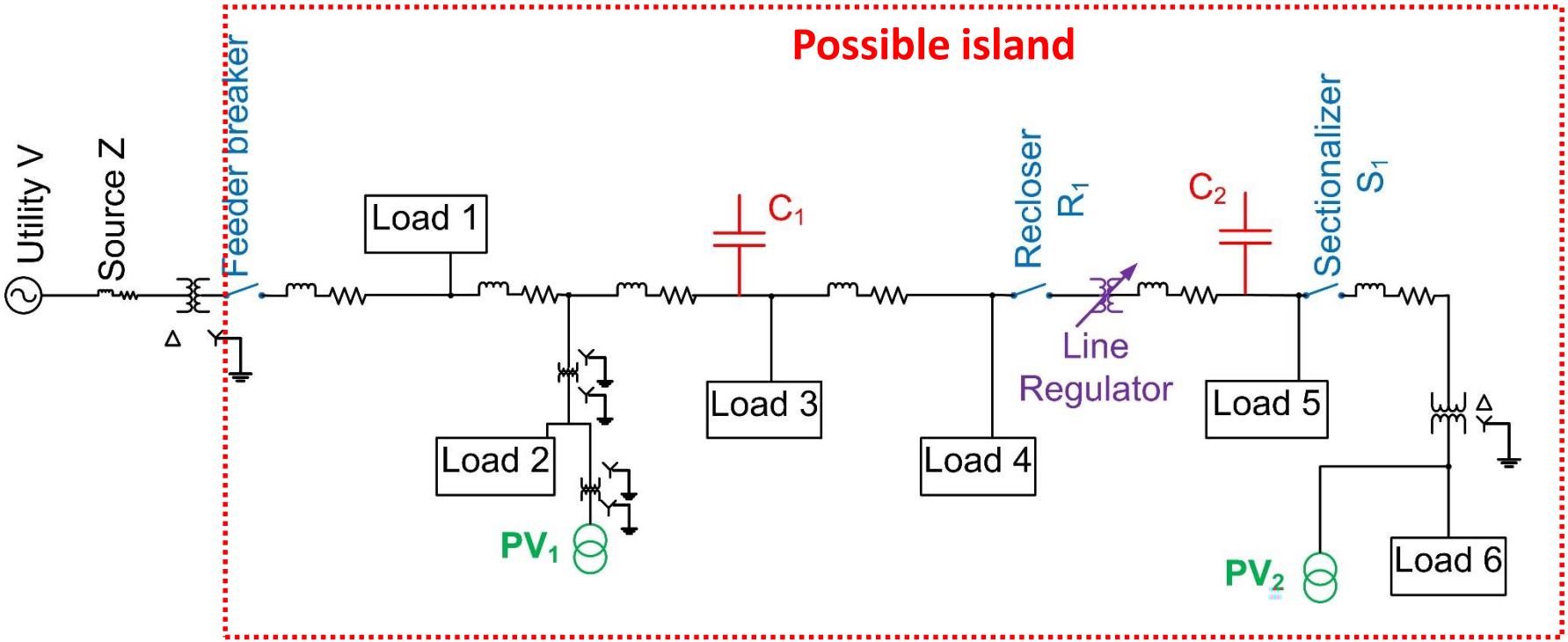


Enphase inverter locations

Figure credit: https://www.greentechmedia.com/articles/read/enphase-to-help-hawaii-ride-its-solar-energy-wave#gs.4gZ7w1Q

What is an island?

- An electric power island is a section of a power system with its own sources and loads, so that it can self-power or “self-excite”.



When can an II leave the grid?

- When conditions are met that are mutually agreed-to by the Area EPS and DER operators;
- If any of the abnormal voltage or frequency trip conditions is met; or
- If an unintentional island is detected.

For these latter two cases, one may substitute entry into intentional island mode for tripping.

Limits on Area EPS impact when leaving the Area EPS

- If an II disconnects from the Area EPS for any of the reasons listed on the previous slide, it shall do so without causing a voltage fluctuation greater than ±5% of the nominal voltage at any PCC between the Area EPS and the intentional island.
- There are two exceptions to this requirement:
  - If the II "takes its load with it"—i.e., when the II leaves the grid, it causes an amount of load equal to 90% to 110% of its rating to leave the grid also;
  - The II is an emergency or standby generator that is on-grid for testing purposes only.

Limits on an II coming back onto the Area EPS

- An II can reconnect when the “return-to-service” requirements of Clause 4.10 are met (basically, the voltage and frequency are within defined limits).
- When the II reconnects, the requirements of Clause 4.10.4 (“synchronization”, which defines how well synched to the grid the II must be in both voltage and frequency).