Distributed PV and DER Interconnection Requirements

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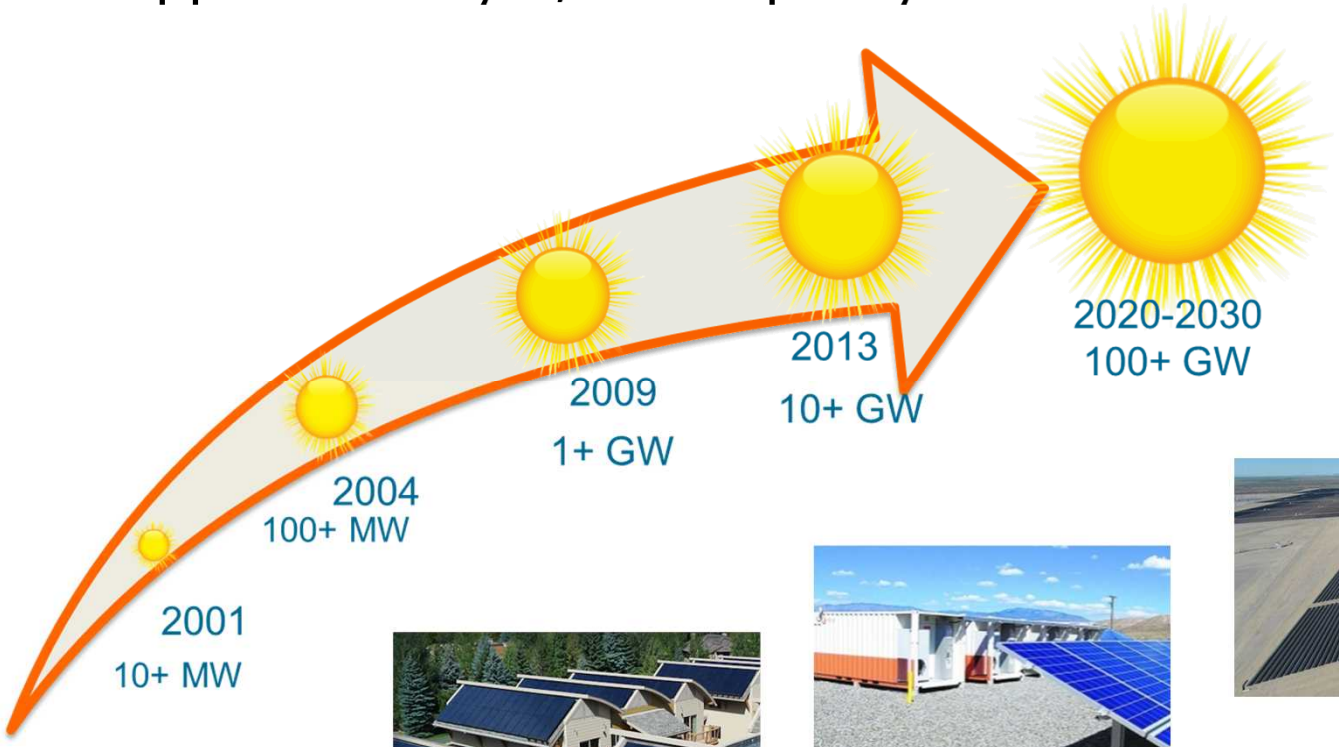
Outline

- Motivation for updating standards for PV
- DER Standards Development with focus on P1547
  - Voltage and reactive power
  - Frequency and voltage tolerance
  - Other areas
- Concluding remarks
- Q&A

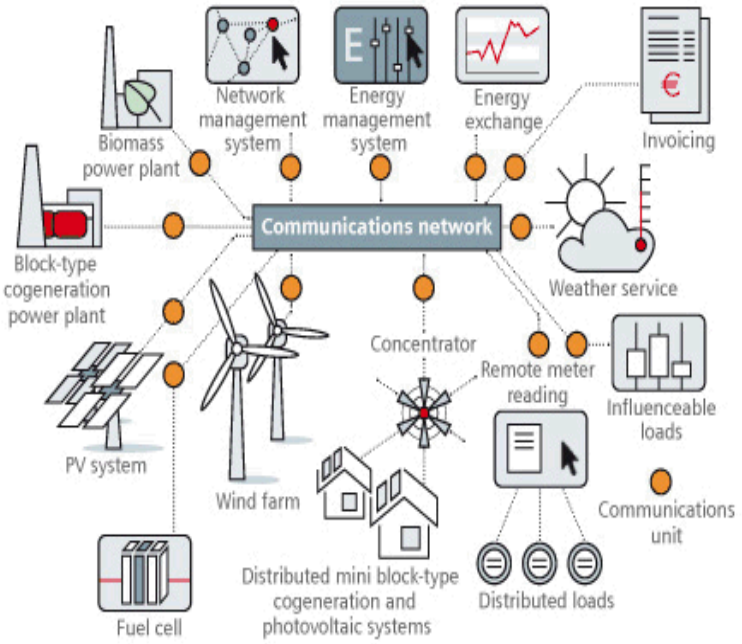
Racing toward large-scale PV deployment…

- Installed PV capacity in the U.S. is growing fast, and future potential is very high
  - Approximately 1/3 of capacity distribution-connected



Distributed PV and System Reliability

- High penetration of Distributed PV and other DER can affect grid reliability
- In the future, distributed PV and other DER will need to support grid reliability
- Clear, comprehensive and appropriate interconnection standards are in the best interest of all stakeholders
  - T&D interconnection standards revisions are underway
  - Focus on DER



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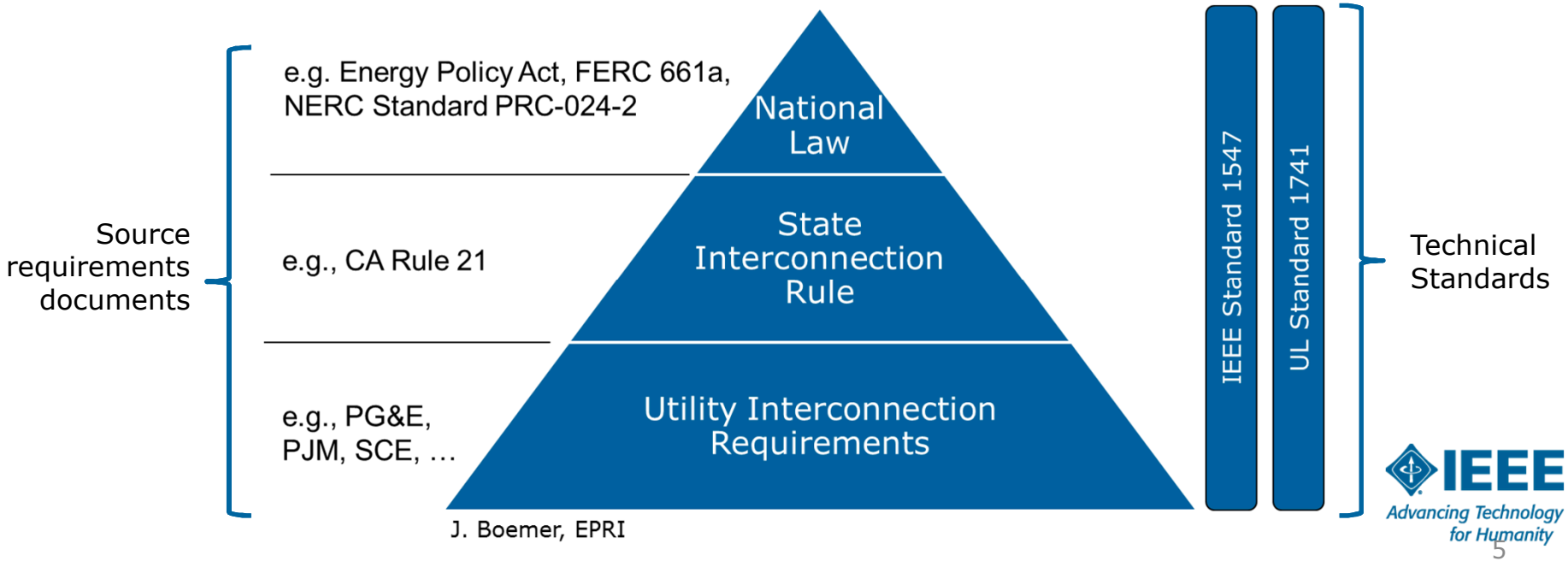
Standards harmonization and coordination is a challenge

- Transmission and (or Vs.) distribution needs
- Different generation technologies
- Different jurisdictions
  - Interdependent Standards, Rules and Requirements



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DER Standards Timeline

- IEEE 1547 (Ca. 2003)
  - Not designed for high penetration DER
  - No V/FRT, tight trip limits, voltage regulation not allowed
- CA Rule 21 and HI Rule 14H Updates (Ca. 2014)
  - Focused on inverters
- IEEE 1547a (Ca. 2014)
  - DR *may* respond to voltage & freq.; trip limits may be wider
  - Did not establish a minimum performance requirement
- P1547 and P1547.1 (ongoing, 2017?)
  - Response to CA and HI experience, BES concerns

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CA Rule 21 DER (Inverter) Functions

Appendix	Function or Communication Verification	Rule 21 Name	Central or Dist. Control
1	Anti-Islanding Protection (AI)	R21-1-AI	D
2	Low/High Voltage Ride-through (L/HVRT)	R21-1-L/HVRT	D
3	Low/High Frequency Ride-through (L/HFRT)	R21-1-L/HFRT	D
4	Volt-Var Mode with Watt-Priority	R21-1-VV11	D
5	Ramp Rates	R21-1-RR	D
6	Fixed Power Factor	R21-1-INV3	D
7	Soft Start	R21-1-SS	D
14	Monitor Alarms	R21-3-A	C
15	Monitor DER Status and Output	R21-3-DS93	C
16	Limit Maximum Real Power	R21-3-INV2	C/D
17	Connect/Disconnect	R21-3-INV1	C
18	Provide DER Information at Interconnection/Startup	R21-3-INFO	C
19	Initiate Periodic Tests of Software and Patches	R21-3-TEST	C
20	Schedule Output Limits at PCC	R21-3-WSchd	C
21	Schedule DER Functions	R21-3-Schd	C
22	Schedule Storage	R21-3-SSchd	C
23	Frequency-Watt Mode	R21-3-FW	D
24	Voltage-Watt Mode	R21-3-VW	D
25	Dynamic Current Support	R21-3-TV31	D
26	Limit Maximum Real Power	R21-3-Wlim	C
27	Set Real Power	R21-3-INV4	C
28	Smooth Frequency Deviations	R21-3-Ffix	D
29	Backup Power	R21-3-BP	C
30	Imitate Capacitor Bank Triggers	R21-3-CAP	C/D
31	Operate within an Islanded Microgrid	R21-3-I	C
32	Provide Low Cost Energy	R21-3-COST	C
33	Provide Low Emissions Energy	R21-3-LEE	C
34	Provide Renewable Energy	R21-3-RE	C
35	Execute Schedules	R21-3-ES	C
36	Issue Generation and Storage Schedules	R21-3-S	C
37	Provide Black Start Capabilities	R21-3-BS	C
38	Participate in Automatic Generation Control	R21-3-AGC	C
39	Provide Spinning or Operational Reserve	R21-3-R	C
40	Real Power Response to Demand Response Price Signals	R21-3-PS	C/D
41	Ancillary Service Response to Demand Response Signals	R21-3-INV5	C/D
42	Registration (Automated DER Discovery)	R21-3-REG	C

Phase 1
Autonomous Functions

Phase 2:
Communication capability—add data model, cybersecurity, etc.

Phase 3:
Communications-enabled functions—status reporting, connect/disconnect, limit active power, etc.

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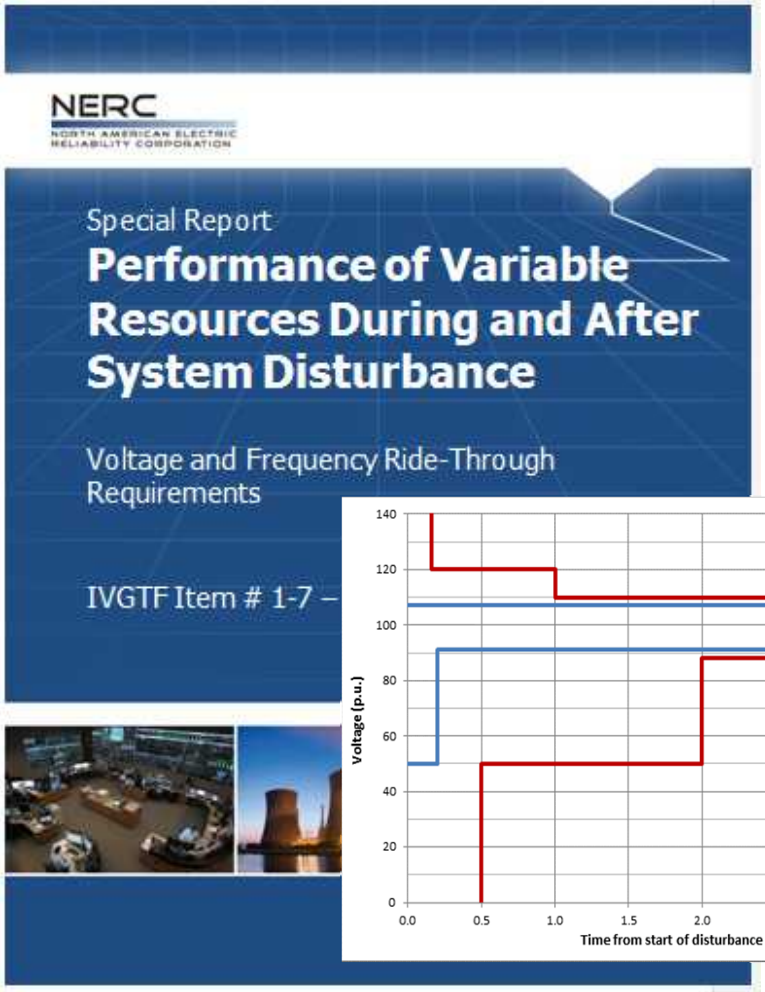
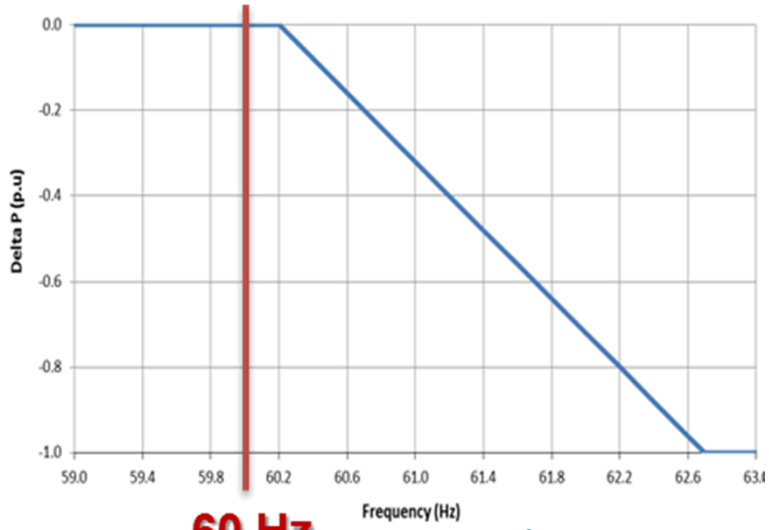
NERC And BES Perspective



- NERC IVGTF 1.7 recommendations to DER interconnection standards
  - Require *V/FRT requirement*
  - Require *high-frequency droop*
  - Minimum *default* settings



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IEEE 1547 Revision (201?)

- Clause 4.2 – Response to abnormal conditions
  - Defines V/FRT requirement, frequency droop, and dynamic current injection for 3 performance categories
  - Remotely and/or field adjustable parameters
  - Emphasizes reclosing coordination
  - Defines exemptions for intentional islanding, equivalent load tripping, and testing of standby generators
- Performance Categories
  - **Cat I:** Addresses essential BES stability/reliability
  - **Cat II:** All BES reliability/stability needs
  - **Cat III:** For very high penetration scenarios (HI, CA R21)
  - Area EPS operator to specify applicable category

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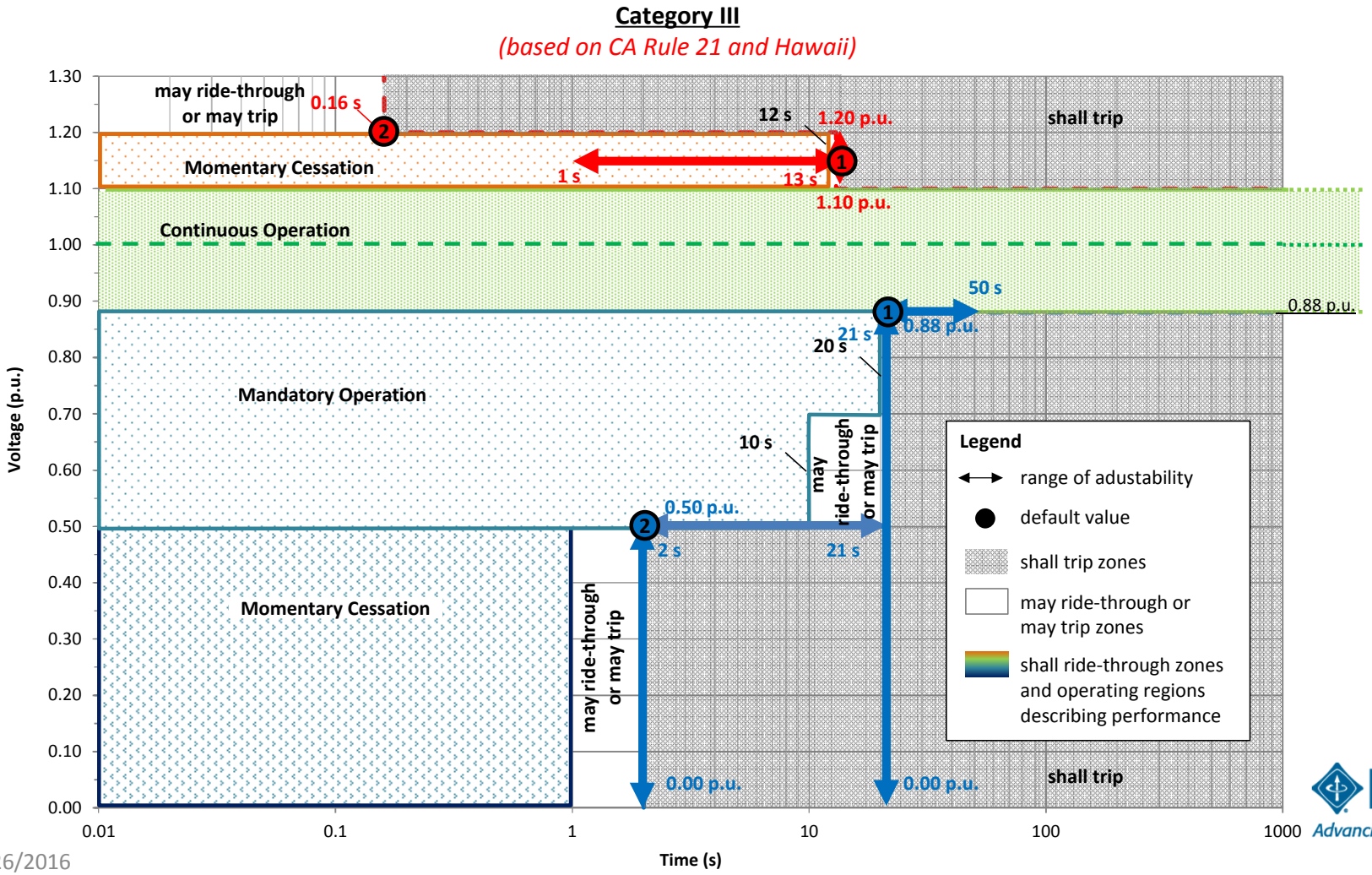
IEEE 1547 Revision (201?)

- VRT Operating Modes
  - Continuous Operation
  - Mandatory Operation: RT and must inject power
  - Momentary Cessation: RT but must not inject power
  - Permissive Operation: RT, may or may not inject power

- "Cease to Energize" requirements still applies
  - Over and under voltage, Over and under frequency thresholds harmonized with V/FRT requirements
  - Tripping or Momentary Cessation count

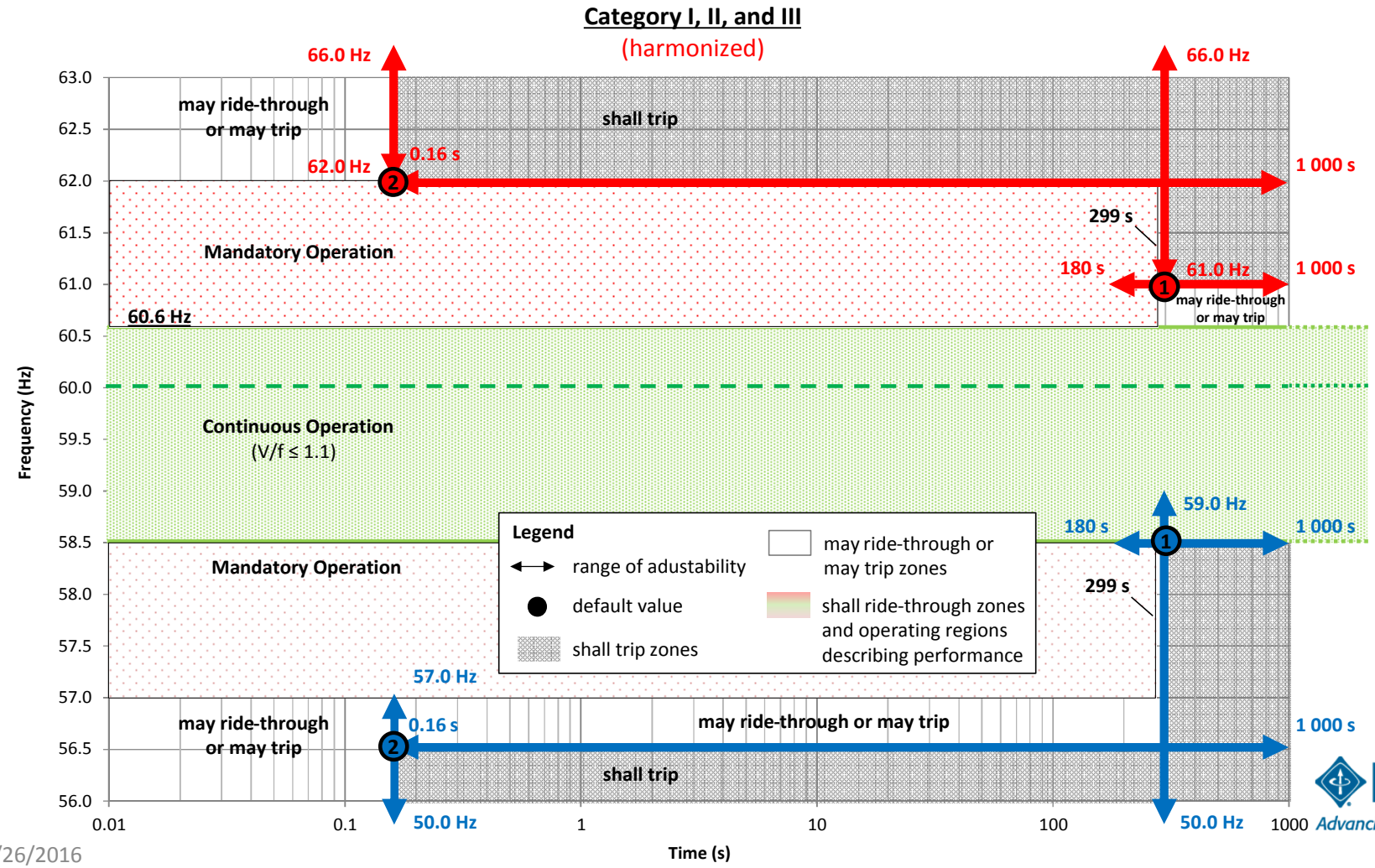
IEEE 1547 Revision (201?)

- Proposed VRT requirement for Cat III



IEEE 1547 Revision (201?)

- Proposed FRT requirement for all categories



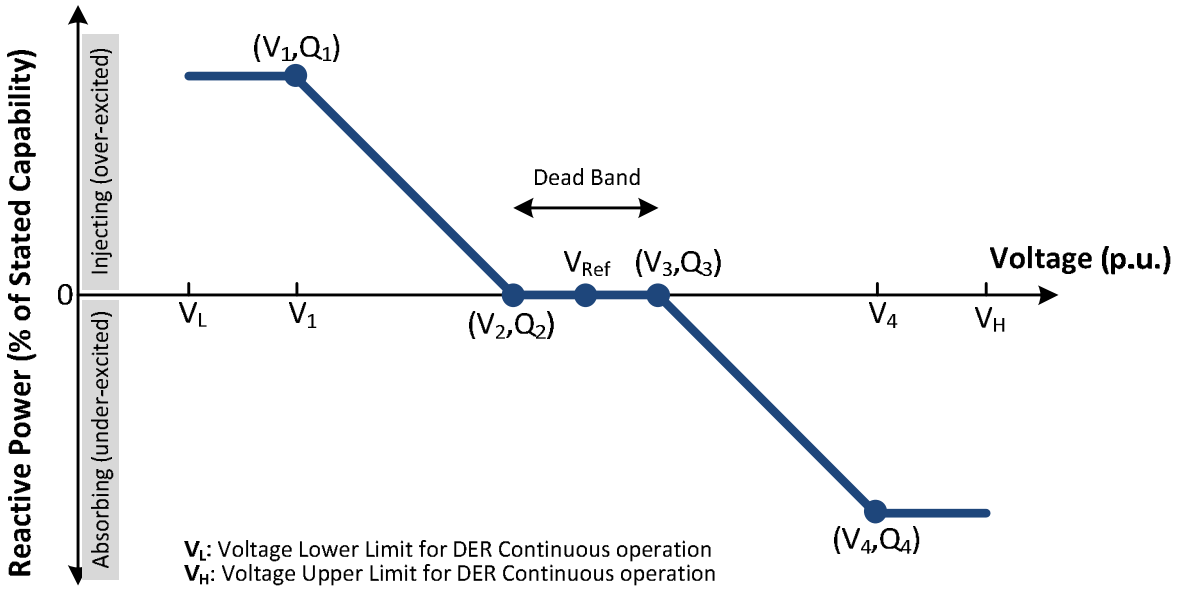
IEEE 1547 Revision (201?)

- Clause 4.1 – Voltage and reactive power
  - Defines reactive power capability for 2 perf. categories
  - Voltage and reactive power control: PF (default), Volt-var, watt-var, Q, dynamic injection (Cat B.)
  - Other control modes permitted
  - Precedence of voltage and reactive power control modes
- Performance categories
  - **Cat A:** Minimum capability for local voltage regulation, should be attainable by all state-of-the-art DER
  - **Cat B:** Additional requirements to mitigate local voltage variations due to resource variability
  - Area EPS operator to specify applicable category

IEEE 1547 Revision (201?)

DER Category	Injection Capability
A	0.90 PF injecting 0.97 PF absorbing
B	0.90 PF injecting 0.90 PF absorbing

Minimum Reactive Power Capability at Rated kVA



Volt-var control specification

IEEE 1547 Revision (201?)

- Other changes expected before ballot…
- Clause 4.3 – Power quality: forming stage
  - Harmonic distortion, flicker (maximum voltage change)
  - TR-OV, T-OV and GF-OV
- Communications, interoperability: some progress
  - Trying to expand on existing requirements
- Simulation and modeling: storming stage
  - Specification of SC behavior? Dynamic models?
- Microgrids: early stage
- P1547.1 testing standard: just started!

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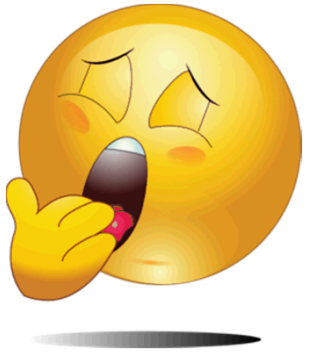
Still more work to be done

- High stakes
  - Rapid PV and DER deployment, grid reliability
- Implementation takes a long time…
  - Consensus process to develop and approve
  - NRTL certification process
  - Adoption by Sate PUC/PRC



- It is a balancing act!
  - Harmonization with BES reliability standards
  - Different types of DER, different local needs, different PV deployment stages

- Stay tuned! Better yet, engage!

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