

IEEE 1547 Standard for Interconnection of Distributed Resources with Electric Power Systems, Overview and Current Activity

Northwest Energy Systems Symposium

April 27, 2016

Charlie Vartanian

IEEE P1547 Committee Secretary and Treasurer



PRESENTATION OUTLINE

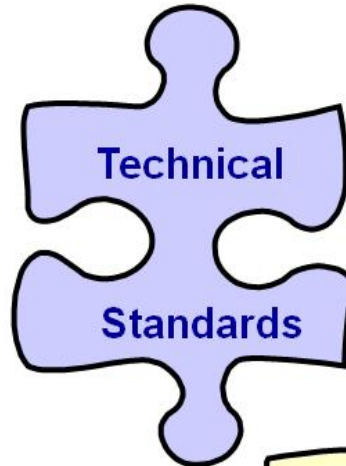
- 1) IEEE STANDARDS BACKGROUND
- 2) PUBLISHED IEEE 1547 & 1547.X STANDARDS
- 3) ACTIVE REVISION OF IEEE 1547
- 4) GETTING INVOLVED

Putting the Pieces Together:

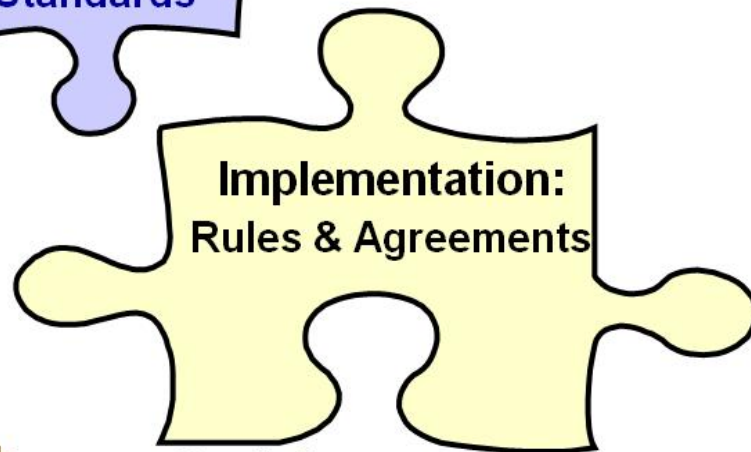
Standards, Testing, and Implementation



Controlled/quality: processes, facilities, equipment personnel. Lab accreditation.
Manufacturer quality. Test @ cradle-to-grave.



Consensus driven.
Defined scope & purpose.
Proven/validated.
Maintained/updated.

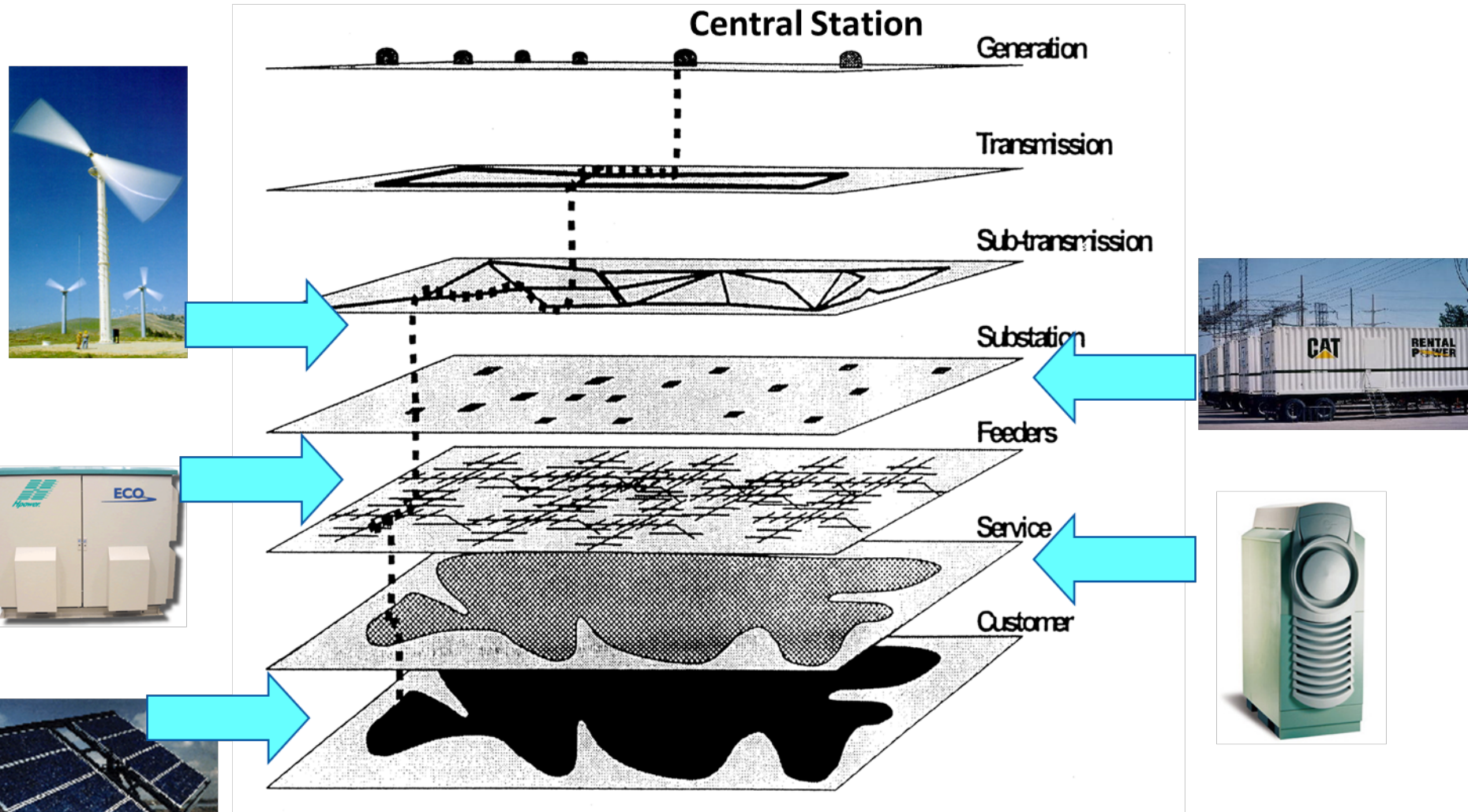


Goals/purposes.
Which standards & programs?
Authority having jurisdiction.
Dispute resolution.

IEEE Standards are Classified As:

- **Standards**: documents specifying mandatory requirements (**shall**)
- **Recommended Practice**: documents in which procedures and positions preferred by the IEEE are presented (**should**)
- **Guide**: documents that furnish information -- e.g., provide alternative approaches for good practice, suggestions stated but no clear-cut recommendations are made (**may**)

Interconnecting Distributed Energy Resources



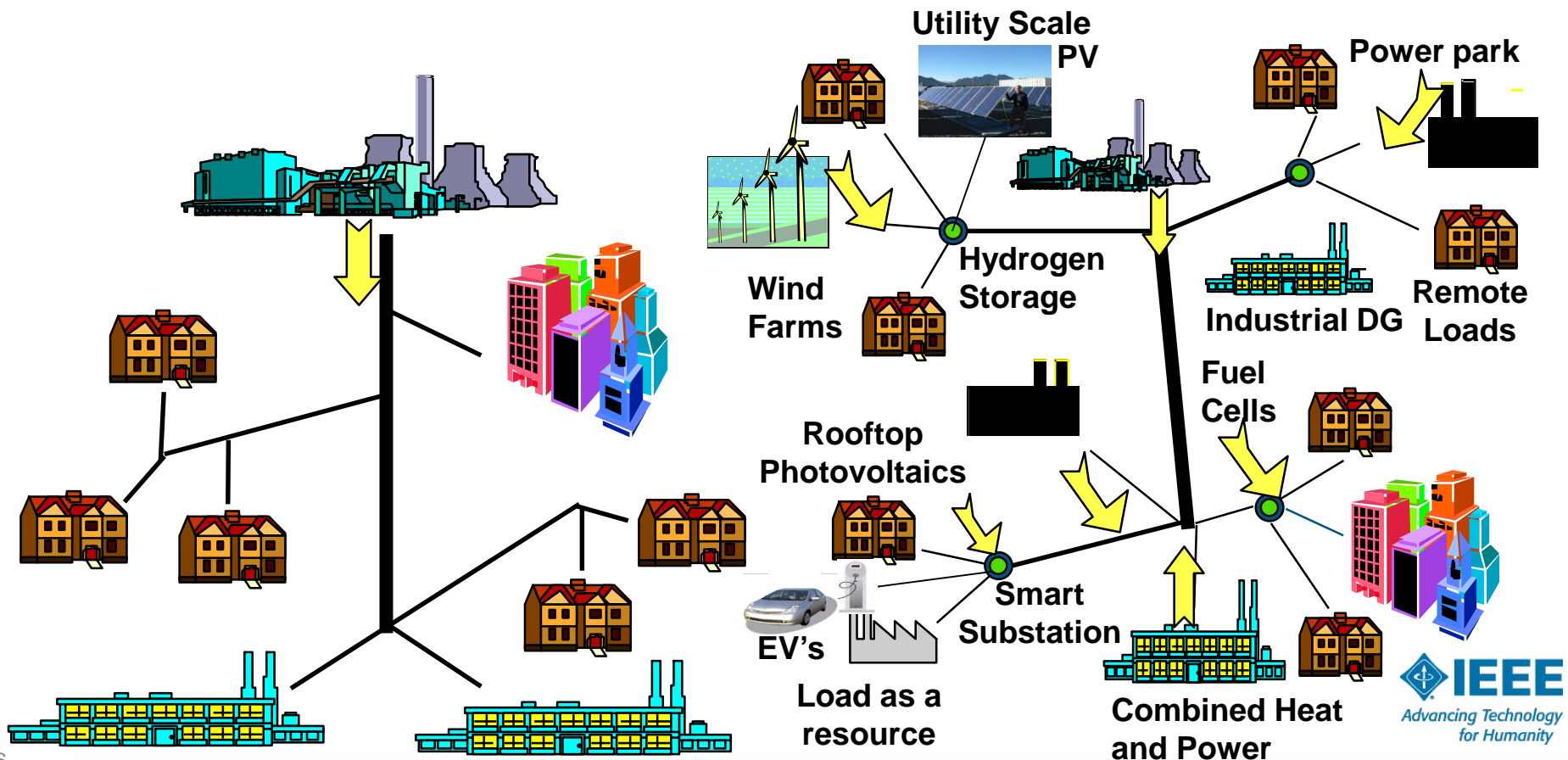
Traditionally the power system was viewed as vertically layered; each performing its function from central station generation supplying power out to customers/loads.

Grid Modernization

*Traditional
Electric Grid...*



*Modern Electricity
Choices ...*



- 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*}.



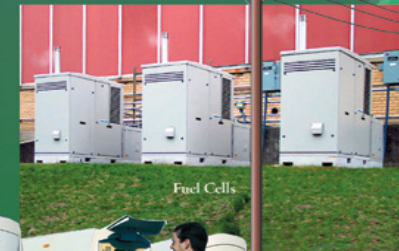
Substation



Wind Generator



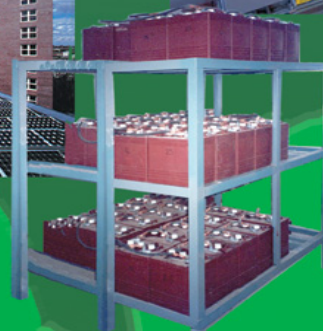
Generator



Fuel Cells



Photovoltaics



Storage



Microturbines

IEEE SCC21 1547 Series of Standards*

IEEE Std 1547™(2003 and 2014 Amendment 1) Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std P1547™(full revision) Draft Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE Std 1547.1™(2005 and 2015 Amendment 1) Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

IEEE Std P1547.1 (full revision) Draft Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces

IEEE Std 1547.2™(2008) Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std 1547.3™(2007) Guide for Monitoring Information Exchange, and Control of Distributed Resources with Electric Power Systems

IEEE Std 1547.4™(2011) Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems

IEEE Std 1547.6™(2011) Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks

IEEE Std 1547.7™ (2013) Guide to Conducting Distribution Impact Studies for Distributed Resource Interconnection

IEEE Std P1547.8™ Draft Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Std 1547-2003

* Colored background designates IEEE published standard; clear background is draft standard work in progress.

1547: Interconnection Is The Focus

IEEE Std 1547 covers:

- INTERCONNECTION TECHNICAL SPECIFICATIONS & REQUIREMENTS
- INTERCONNECTION TEST SPECIFICATIONS & REQUIREMENTS

**Distributed
Resource
(DR)
unit**

Interconnection System

**Note: P1547 full revision started in
year 2015 is also addressing
interoperability and interfaces**

**Area
Electric
Power
System
(EPS)**

IEEE 1547 Interconnection Standards Use in USA

IEEE 1547 **Interconnection System and Test Requirements**

- Voltage Regulation
- Grounding
- Disconnects
- Monitoring
- Islanding
- etc.

IEEE 1547.1 **Interconnection System Testing**

- O/U Voltage and Frequency
- Synchronization
- EMI
- Surge Withstand
- DC injection
- Harmonics
- Islanding
- Reconnection

UL 1741* **Interconnection Equipment**

- 1547.1 Tests
- Construction
- Protection against risks of injury to persons
- Rating, Marking
- Specific DR Tests for various technologies

NEC**

Article 690 PV Systems;

Article 705:
interconnection
systems (shall
be suitable per
intended use
per UL1741)

PJM Interconnection, Inc. ***Small Generator Interconnection Standards*** **FERC approved**

*(0-to<10MW and 10-to-20 MW;
incorporate 1547 and 1547.1)*

* UL 1741 supplements and is to be used in conjunction with 1547 and 1547.1

**** Articles:** 480 Storage Batteries ;
692 Fuel Cell Systems;
694 Wind Electric Systems
(NEC info. based on NEC 2011)

IEEE 1547

IS:

- A Technical Standard – Functional Requirements For
 - the interconnection itself
 - the interconnection test
- Technology neutral, e.g., does not specify particular equipment nor type
- A single (whole) document of mandatory, uniform, universal, requirements that apply at the PCC.
- Should be sufficient for most installations.

IEEE 1547

Is NOT:

- a design handbook
- an application guide
- an interconnection agreement
- prescriptive, e.g., does not address DR self-protection, nor planning, designing, operating, or maintaining the Area EPS.

IEEE 1547.1 is:

Test Procedures for
Conformance to 1547

IEEE Std 1547 {2003/2014}

4.0 INTERCONNECTION TECHNICAL SPECIFICATIONS AND REQUIREMENTS

4.1 General Requirements

4.2 Response to Area EPS Abnormal Conditions

4.3 Power Quality

4.4 Islanding

5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS

5.1 Design Test

5.2 Production Tests

5.3 Interconnection Installation Evaluation

5.4 Commissioning Tests

5.5 Periodic Interconnection Tests

ANNEX A (INFORMATIVE) BIBLIOGRAPHY

IEEE Std 1547a – Amendment 1, May 2014

(Amendment 1: revisions to 4.1.1, 4.2.3, and 4.2.4)

4.1.1 Voltage Regulation

... DER allowed to change its output of active and reactive power.

4.2.3 (*Response to abnormal grid ...*) Voltage

.... DER allowed to “ride through” abnormalities of grid voltage;

... grid and DER operators can mutually agree to other voltage trip and clearing time settings

4.2.4 (*Response to abnormal grid ...*) Frequency

... DER allowed to provide modulated power output as a function of frequency

... .. grid and DER operators can mutually agree to other frequency trip and clearing time settings

IEEE P1547 (Full Revision) Project Authorization

Approved by the IEEE SASB on March 27, 2014

Title: Draft 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.

Note: Interfaces and interoperability and related terms are defined and described in IEEE Std 2030

P1547 Revision: Draft *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.*

- *Build from existing Std 1547 document structure*
- *Incorporate revisions based on existing 1547 series*
- *Address additional criteria and requirements based on approaches of Std 2030 and P2030.2, including interoperability, and, associated interfaces*

Scope: This standard establishes criteria and requirements for interconnection of distributed **energy** resources (DER) with electric power systems (EPS), **and associated interfaces.**

Note: Interfaces defined in IEEE 2030: “a logical interconnection from one entity to another that supports one or more data flows implemented with one or more data links.

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.**

Std P1547 Full Revision: Work in Progress Topics

Updates to many 1547 (2003) requirements, and new requirements, e.g.,

Voltage regulation (F2)

Reactive Power Capability of the DER

... capable of injecting and absorbing minimum reactive power ...

Voltage and Reactive Power Control

... capabilities of modes of reactive power control functions:

Power factor; Volt-Var; Active-power power-factor; Reactive power

Voltage & Frequency Ride Through (F3)

3 classes (parameter ranges)

Interoperability Requirements (F4)

Special Interconnection Requirements (F5) e.g.,

- Energy Storage
- Islanding/Microgrids
- Distribution Secondary Networks

Power Quality/Harmonics (F7)

P1547 Example New Reactive Power Requirements (Work In Progress)

The DER shall provide the capabilities of the following modes of reactive power control functions:

1. Adjustable Constant Power factor mode – The capability is mandatory for categories A and B
2. Voltage-reactive power (Volt-var) mode – The capability is mandatory for categories A and B
3. Active power-reactive power mode (watt-var) – The capability is optional for category A and mandatory for categories B
4. Reactive power mode – The capability is mandatory for categories A and B
5. Dynamic reactive current? Still in progress

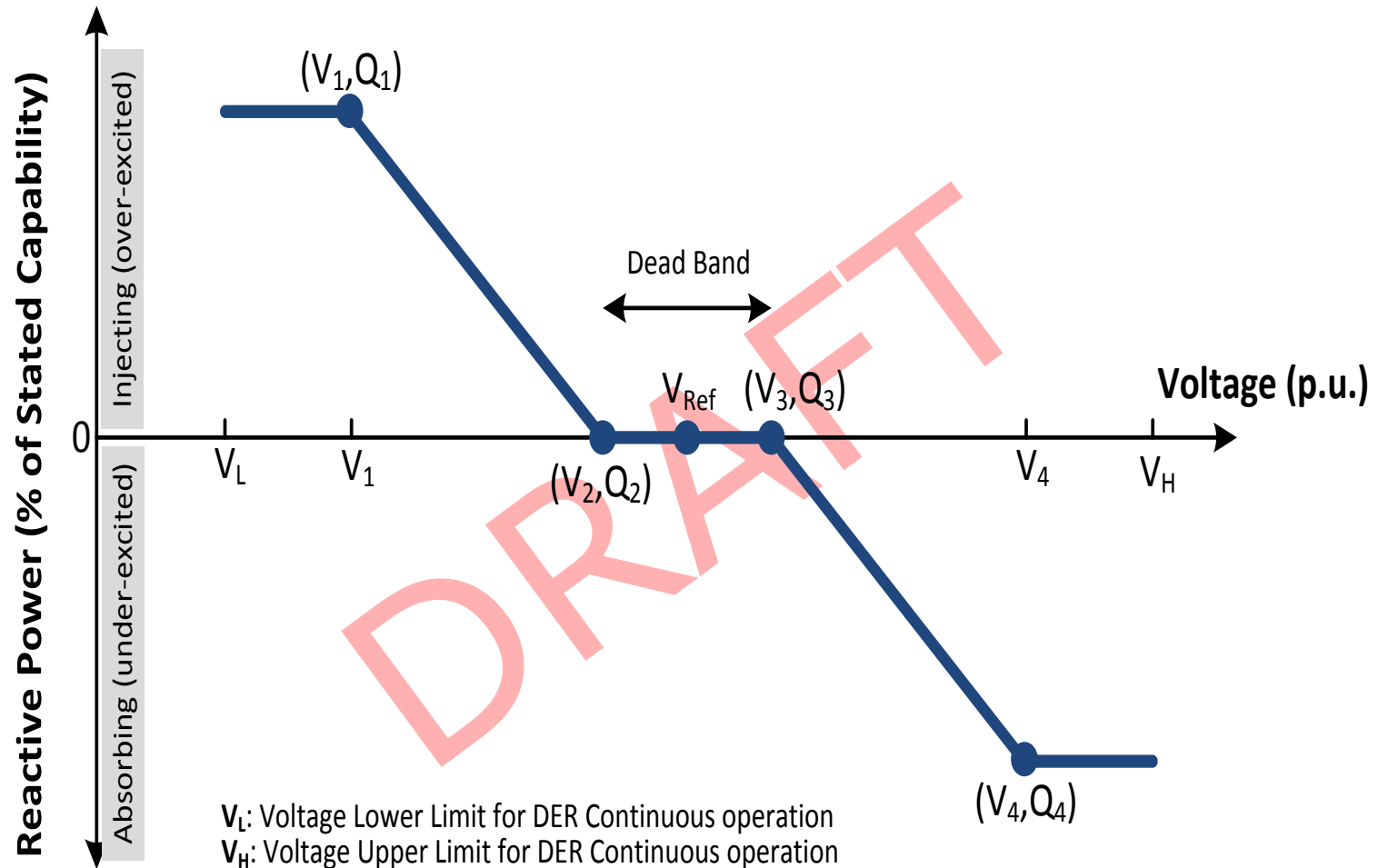
P1547 Example New Reactive Power Requirements (Work In Progress)

The DER shall be capable of injecting reactive power (over-excited) and absorbing reactive power (under-excited) equal to the minimum reactive power (kVar) corresponding to the value given in Table TBD at all active power output equal to 20% to 100% of nameplate active power rating (kW).

Table TBD – Minimum Reactive Power Injection and Absorption Capability

Category	Injection Capability as % of Nameplate Apparent Power (kVA) Rating $Q_{min_{inj}}$	Absorption Capability as % of Nameplate Apparent Power (kVA) Rating $Q_{min_{abs}}$
A (at DER rated voltage)	44 Full load PF=0.9	25 Full load PF=0.97
B (at ANSI range A)	44 Full load PF=0.9	44 Full load PF=0.9

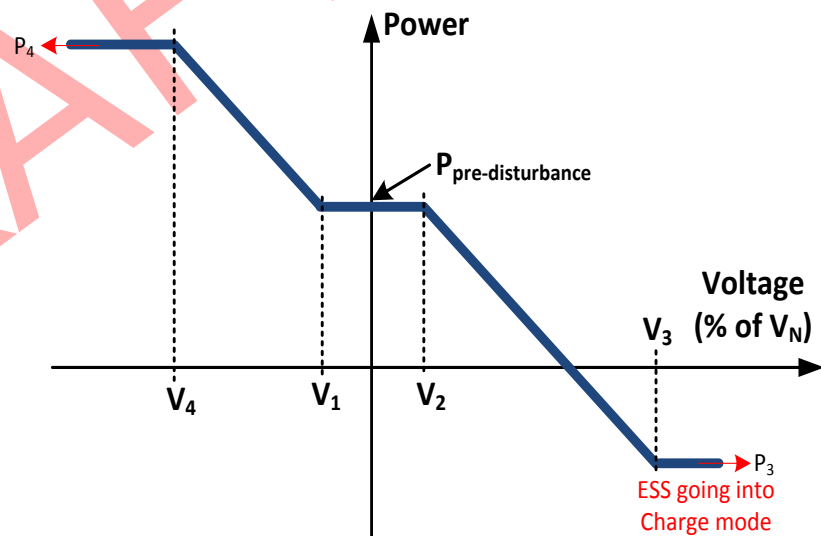
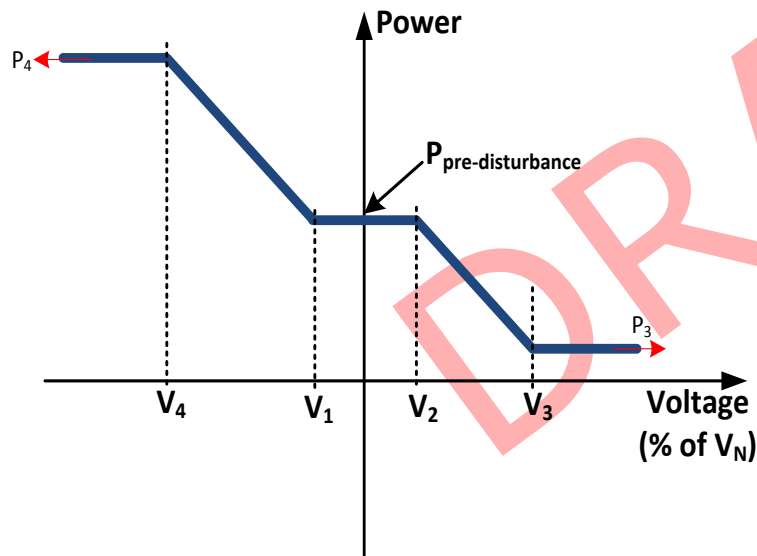
P1547 Example New Reactive Power Requirements (Work In Progress)



P1547 Example New Reactive Power Requirements (Work In Progress)

Voltage-Real Power (Volt-Watt) Mode

When in this mode, the DER shall actively control the real output power as a function of the system voltage following a target voltage – active power (volt-watt) characteristic curve.



P1547 Example New Requirements for Ride Through (work in progress)

Ride through operation and tripping zones defined:

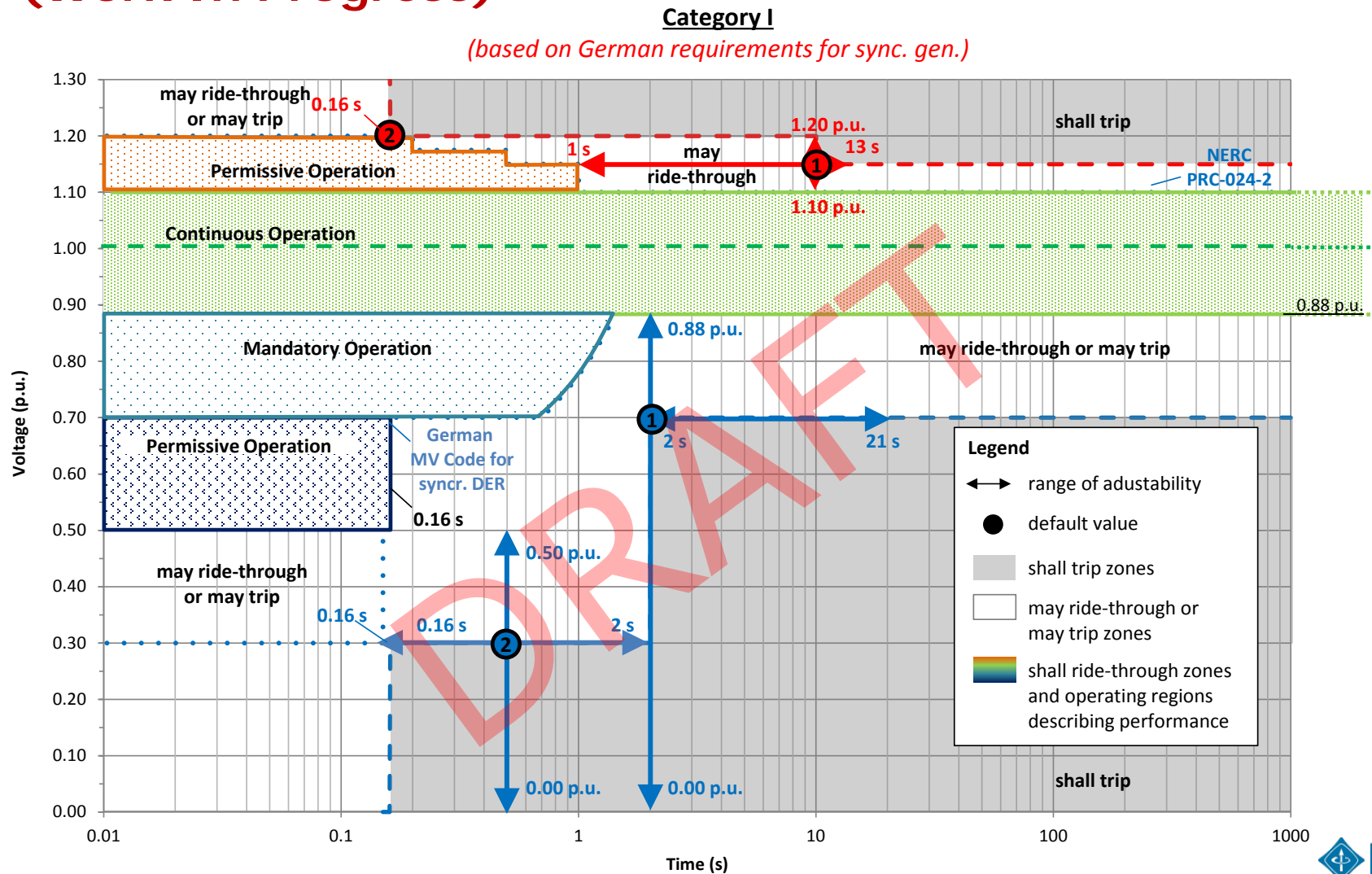
- **Continuous operation** – Area EPS normal operating voltage range
- **Mandatory operation** – DER shall remain operating for area EPS reduced voltage up to a second or so
- **Permissive Operation** – DER may operate for area EPS further reduced voltage or small overvoltages for up to 10 cycles
- **Momentary Cessation** – DER stops producing at area EPS low voltages but does not trip
- **Shall trip** - For area EPS overvoltages and undervoltages that extend beyond 10 cycles to 2 seconds or more

P1547 Ride Through (work in progress)

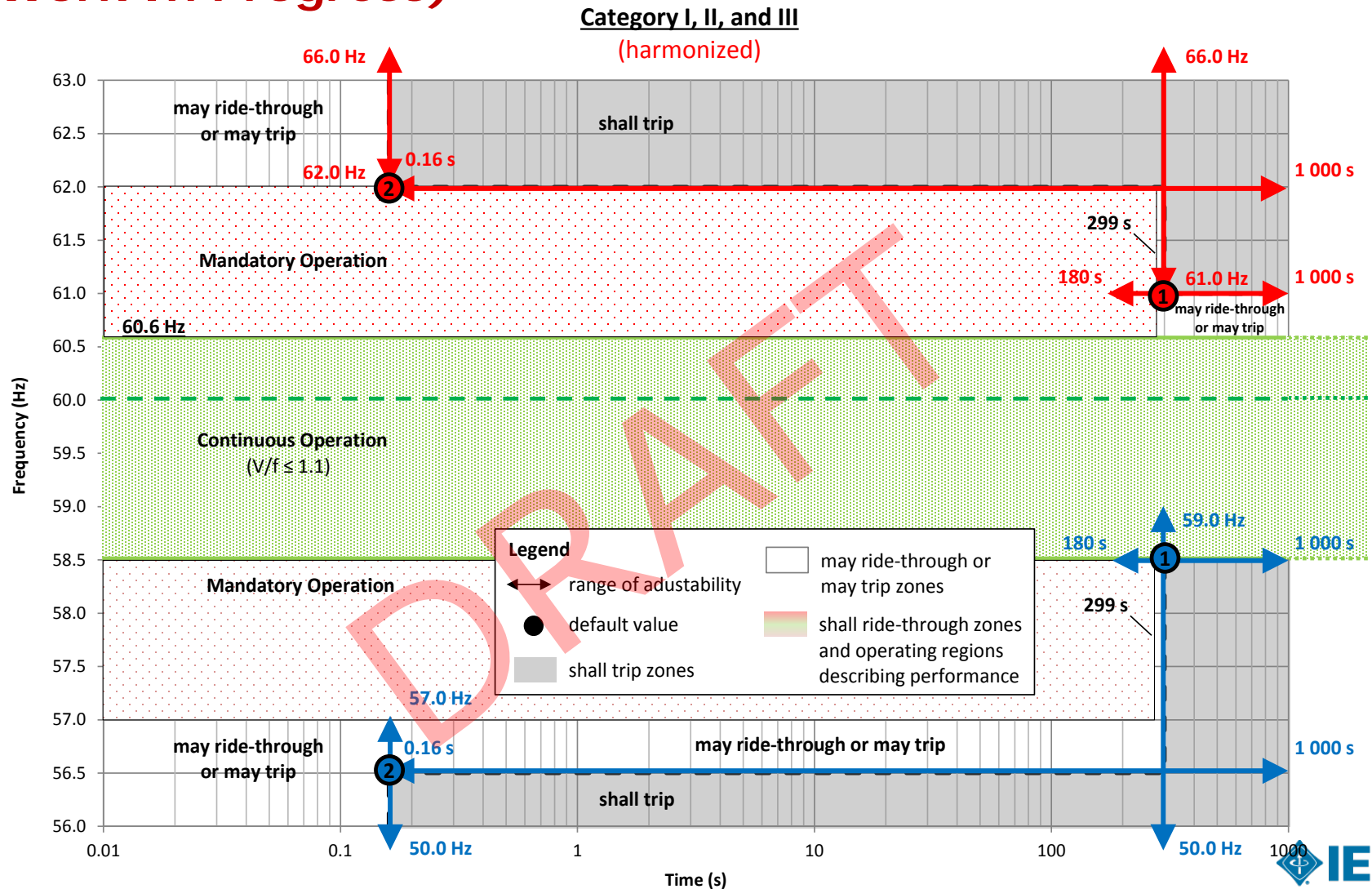
- Three Categories of DER Operational Responses to Support the Grid -- Based on Local and Farther Reaching Grid Requirements and DER

Requirement	Category	Foundation	Justification
Voltage Ride-Through	Category I	German grid code for medium voltage-connected synchronous generator-based DER	<ul style="list-style-type: none"> <i>Essential</i> bulk system needs. Attainable by all state-of-the-art DER technologies.
	Category II	NERC PRC-024-2 but w/o stability exception, extended LVRT duration for 65-88% V_{nom} ➤ based on EPRI White Paper (May 2015)	<ul style="list-style-type: none"> All bulk system needs. Coordinated with existing reliability standards. Considering fault-induced delayed voltage recovery.
	Category III	CA Rule 21 and Hawaii, minor modifications	<ul style="list-style-type: none"> All bulk system needs. Considering fault-induced delayed voltage recovery. Distribution system operation.
Frequency Ride-Through	All Categories (harmonized)	CA Rule 21 and Hawaii, exceeds PRC-024-2 ➤ based on EPRI White Paper (May 2015)	<ul style="list-style-type: none"> All bulk system needs. Low inertia grids.

P1547 Example New VRT Requirements (Work In Progress)



P1547 Example New FRT Requirements (Work In Progress)



P1547 Example New Intentional Islanding (Work In Progress)

4.4 Islanding

4.4.1 Unintentional islanding

For an unintentional island in which the DR energizes a portion of the Area EPS through the PCC, the DR interconnection system shall detect the island and cease to energize the Area EPS within two seconds of the formation of an island.¹²

4.4.2 Intentional islanding

This topic is under consideration for future revisions of this standard.

Intentional island systems are EPSs that: (1) have DER and load, (2) have the ability to disconnect from and parallel with the area EPS, (3) include the local EPS and may include portions of the area EPS, and (4) are intentionally planned.
[X, cite 1547.4 in Bibliography Annex]

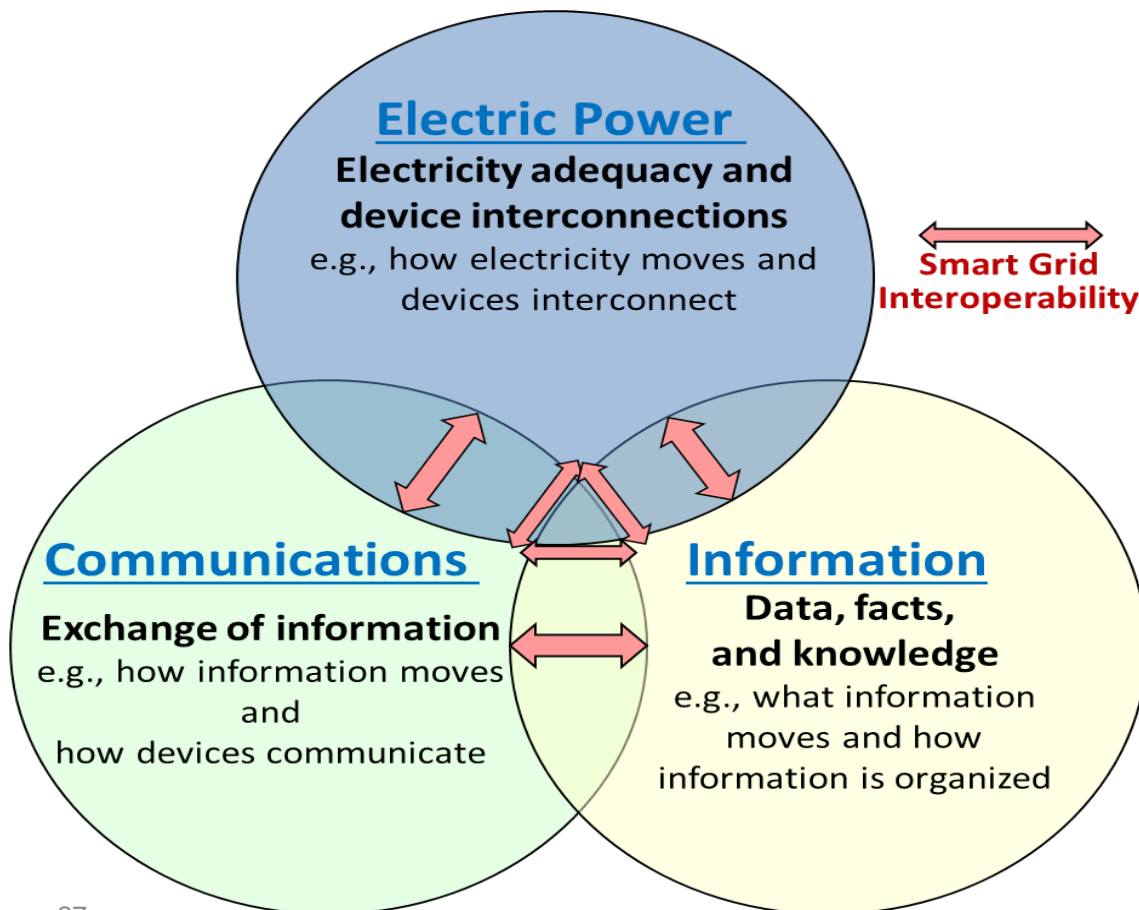
Intentional island systems that include any portion of the Area EPS while islanded shall be designed and operated in coordination with the Area EPS operator.

P1547 Example New Requirements for Communications, Information Models and Protocols (work in progress)

- Cyber Security Requirements
 - DER systems and DER proxy systems shall use standardized cyber security policies, procedures, and technologies
- Protection Communication Requirements
 - Communications between Local EPS and Area EPS protection schemes for coordination purposes shall be supported if mutually agreed upon between the Local and Area EPS operators.
- Information Model & Communication Protocol Requirements
 - The information models and communication protocols used for the information exchanges shall be standards mutually agreed upon by the Local and Area EPS operators

Smart Grid Interoperability

Smart Grid: the integration of power, communications, and information technologies for an improved electric power infrastructure serving loads while providing for an ongoing evolution of end-use applications. (Std 2030)



Interoperability: the capability of two or more networks, systems, devices, applications, or components to **externally exchange and readily use information securely & effectively**. (Std 2030)

IEEE P1547

IEEE Grouper web pages, Getting Involved

http://grouper.ieee.org/groups/scc21/1547_revision/1547revision_index.html

- **First Step**, Sign up for P1547 ListServe
- **Next Step**, Participate in Working Group. Identify yourself to Folder Subgroup Leads to get connected and involved in specific Folder subgroup for notices of activity and participation

Opportunity to Get Involved: Next IEEE P1547 Meetings

- **June 14-15, 2016**
 - Meeting sponsored by and location,
Portland General Electric, Portland OR
- **October, 2016**
 - Meeting sponsored by and location,
Commonwealth Edison, Chicago IL

P1547 Ballot in 2016; P1547.1 Co-located Meeting

<u>Meeting</u> (2/year? 3 in 2016)	<u>Meeting Location</u> (<u>Sponsor</u>)	<u>Meeting Duration</u> { 3 days }	<u>Meeting Format</u> (Breakouts and full WG)
April 23 – 25, 2014	Las Vegas NV	2-1/2 days	One group
June 26-27, 2014	Las Vegas NV	1-1/2 days	One group
Nov 4-7, 2014	Atlanta GA (NERC)	3 days	breakouts
Feb 10 - 12 2015	Arlington VA (NRECA)	3 days	One group
June 1-3, 2015	Nat'l Grid, Waltham, MA	3 days	One group
Fall 2015 Oct 27-29	AZ (Salt River Project)	3 days. 2 ½ 1547 Rev, ½ 1547.1 Rev Work Shop	One group
			Below: Co-located 1547 & 1547.1
Winter 2016, Mar8-10	NextEra Energy, Juno Beach FL (James H.)	2 days 1547, 1 day for 1547.1	One group. Possible breakout space.
June 14-16, 2016	Portland General Electric (Janette S.) confirmed	2 days 1547, 1 day 1547.1	One group. Possible breakout space – check.
October 2016, dates?	ComEd, PENDING confirmation (via Mark Siira, Justin O.) Backup locations, DVP, Nat'l Grid, IEEE NJ WG complete final draft to IEEE for ballot	2 days 1547, 1 day 1547.1	TBD

THANK YOU!

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626-818-5230

End of Tutorial

References and Backup slides follow

References

Using IEEE 1547

- <http://www.hydroone.com/Generators/Pages/TechnicalRequirements.aspx>
- <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/2007-172e.pdf>
- https://www.sce.com/NR/sc3/tm2/pdf/Rule21_2004.pdf
- <http://www.gosolarcalifornia.ca.gov/equipment/inverters.php>
- <http://www.energy.ca.gov/sb1/index.html>
- <http://www.cpuc.ca.gov/PUC/energy/rule21.htm>

IEEE Reference Materials and Standards

- IEEE standards for sale <http://www.techstreet.com/ieee/>
- IEEE SCC21 Standards web site, <http://grouper.ieee.org/groups/scc21/>
- IEEE-SASB Bylaws: <http://standards.ieee.org/develop/policies/bylaws/index.html>
- IEEE-SASB Operations Manual: <http://standards.ieee.org/develop/policies/opman/>

Further Background Information

- Basso, T.; "Standards for DER -- IEEE 1547 (Interconnection) & IEEE 2030 (Interoperability)" NREL/5D00-63157; Nov. 2014; www.nrel.gov
- Siira, M. Interconnection, interoperability for integration in the Smart Grid;" Consulting-Specifying Engineer Magazine; March 2014, www.csemag.com
- Siira, M. "Best Practices In Electric Power System Testing For Improved Availability;" March/April 2014 PowerLine Magazine; www.EGSA.org

BACKUP MATERIAL

P1547 Central Desktop Folder Organization (F1 – F7)

<p>P1547 Organization: P1547 Chair – Tom Basso; Secretary/Treasurer – Charlie Vartanian</p> <p>P1547 Vice Chairs: John Berdner; Jim Daley; Babak Enayati; Mark Siira</p> <p>Note: each SG considers their specific inputs to testing, interoperability, and other cross-cutting aspects.</p>	<p>Subgroup Leaders: P1547 Vice Chairs & Sect’y. WG Subgroup Facilitators: see below</p>
<p><u>F1 OD: Overall Document structure/contents/harmonization; new Annexes (informative as well as normative)</u> Existing 1547 clauses 1-2-3, glossary, new Annex(es). 1.3 “Limitations”; security/reliability?</p>	<p>Tom Basso, Lead; Charlie Vartanian, Alt Lead. WG Facilitators: 1.3 <u>Bob Cummings & David Forrest;</u></p>
<p><u>F2 (GR1): General Requirements 1 (GR1), -- Voltage regulation, potential new requirements</u></p> <p>4.1.1 Voltage regulation; and possible new general requirements.</p>	<p>Babak Enayati, Lead; John Berdner, Alt. Lead. <u>WG Facilitators:</u> 4.1.1 Aminul Huque;</p>
<p>F7 (PQ): 4.3 Power quality (4.3.1, 4.3.2, and 4.3.3)</p>	<p>F7 (Power Quality) Babak Enayati, Lead, <u>WG Facilitator:</u> Tom McDermott MG’s</p>
<p><u>F3 (GR2): General Requirements 2 (GR2), Response to abnormal grid conditions,</u></p> <p>4.0; 4.1 (not 4.1.1 V-regulation; not distribution secondary networks); 4.2.1; 4.2.2; 4.2.3; 4.2.4; 4.2.5; 4.2.6) Includes voltage and frequency ride through</p>	<p>John Berdner, Lead; Babak Enayati, Alt. Lead. <u>WG Facilitators:</u> VRT & FRT Reigh Walling and Jens Boemer</p>

<p><u>P1547 Organization: P1547 Chair – T. Basso; Secretary/Treasurer – C. Vartanian</u></p>	
<p><u>F4 (IIAMS): Interoperability, Analysis, Modeling and Simulation?</u> 4.1.6 Monitoring provisions (information, SCADA, etc.); Interoperability/new; modeling and simulation/new?</p>	<p>Mark Siira, Lead; Tom Basso, Alt. Lead. <u>WG Facilitators:</u> Frances Cleveland, Wayne Stec, Mike Ropp</p>
<p><u>F5 (SI): Special Interconnections (special EPS's and special DER-EPS considerations)</u> 4.4 islanding; Microgrids (MG)/new; 4.1.4 Secondary distribution networks; special EPSs/new</p>	<p>Charlie Vartanian, Lead; Tom Basso, Alt. Lead; <u>WG Facilitators:</u> - 4.1.4 Networks Mike Coddington & Dan Musogovan; - 4.4 Islanding Leo Casey, Storage Richard Bravo; Microgrids Babak Enayati</p>
<p><u>F6 (IST): Interconnection/Interoperability Test Specifications and Requirements</u> all of existing 5; new 5.1.7 DER short circuit response; and new 5.1.8 DER response to Loss of load; modeling and simulation/new; and, this "Testing" folder needs to be filled from all of previous topical areas.</p>	<p>Tom Basso, Interim Lead; Mark Siira, Alt. Lead. <u>WG Facilitators:</u> NEEDED, -5.1.7 & 5.1.8</p>

IEEE-SA Standards Board

- Encourages and coordinates the development and revision of all IEEE standards
- Approves the initiation of IEEE standards projects
- Reviews IEEE standards projects for consensus, due process, openness, and balance
- Gives final approval to IEEE standards prior to publication and processes all necessary appeals.

Standards Coordinating Committees (SCC)

IEEE-SA Standards Board will establish its own standards developing committees (SCC's) when necessary, e.g., when the scope of an activity is too broad to be encompassed in a single IEEE Society, an SCC may be formed.

An SCC reports directly to the Standards Board;
there are over 15 SCC committee's.

SCC21 has been operating since 1981

IEEE Standards Association Standards Board **Standards Coordinating Committee 21 (SCC 21)**

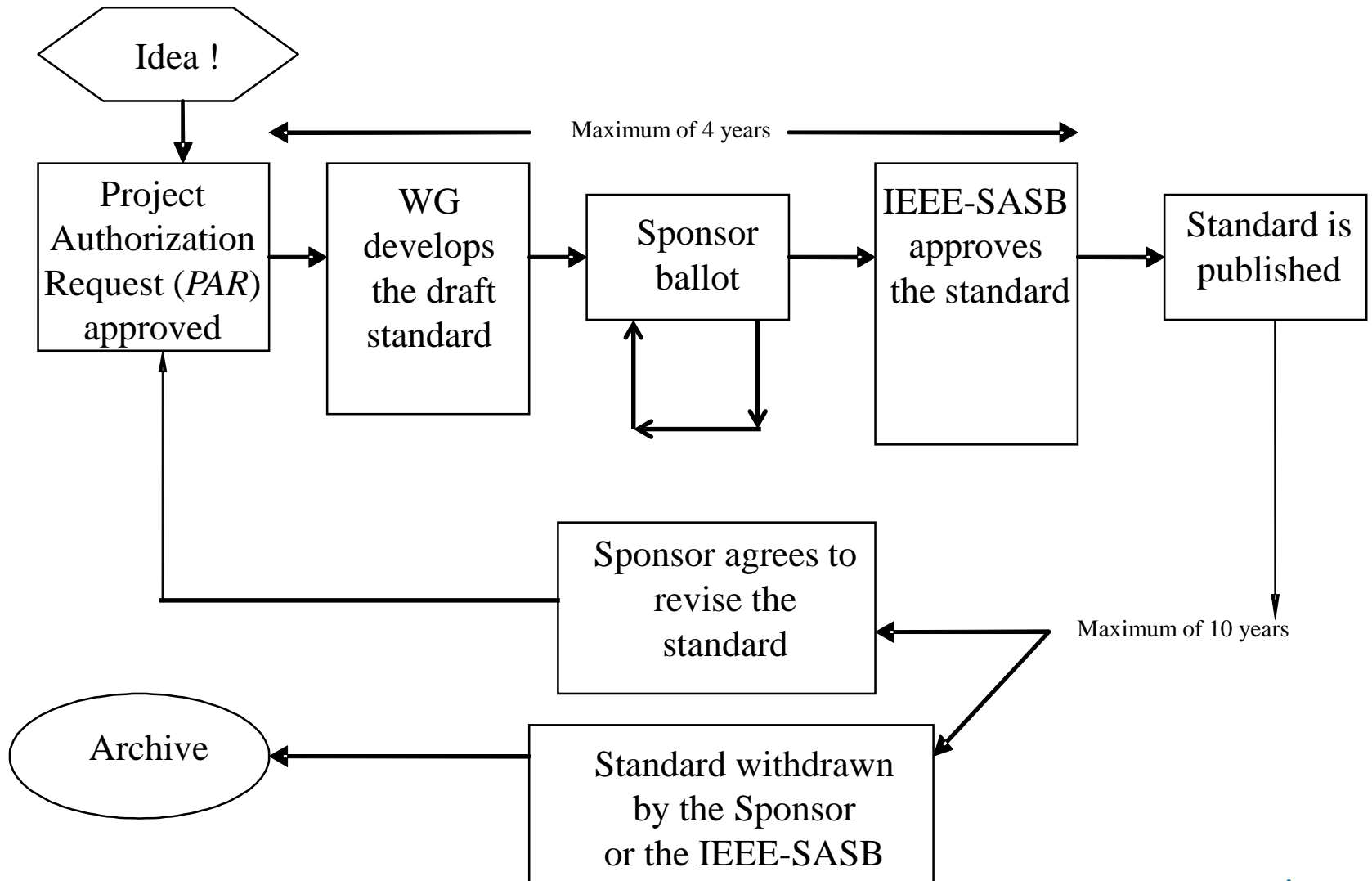
Fuel cells, Photovoltaics, Dispersed Generation, and Energy Storage (operating since 1981)

IEEE SCC21 – Scope and Purpose

The IEEE Standards Coordinating Committee 21 oversees the development of standards in the areas of fuel cells, photovoltaics, dispersed generation, and energy storage, and coordinates efforts in these fields among the various IEEE societies and other affected organizations to insure that all standards are consistent and properly reflect the views of all applicable disciplines.

Reviews all proposed IEEE standards in these fields before their submission to the IEEE-SA Standards Board for approval and coordinates submission to other organizations.

IEEE Standards Development Lifecycle



IEEE SCC21 Standards Historical Highlights

- Developed first Photovoltaic (PV) standards (1980's); subsequently promulgated worldwide.
- Published (late 1980's) IEEE Std 929 (Interconnection Recommended Practice) in response to PURPA (1978).
- Incorporated SCC23 activities (e.g., IEEE Std 1001 *Guide for Distributed Generators*) into SCC21 in 2000.
- Established IEEE 1547 in 2003 in response to deregulation and interconnection needs sought by distributed generation and utility industries;
- Created IEEE 2030 series (early 2000's); published IEEE Std 2030 (year 2011) *Guide to Smart Grid Interoperability-- 1st/only Smart Grid Interoperability Reference Model*.
- Currently: establishing new, and liaising for a host of, modern grid integration standards, e.g., DER concurrent interconnection/interoperability requirements.