IEEE P1547 Update

What we can learn from Germany when revising interconnection standards for Distributed Energy Resources

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Energy and Environment Seminar
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Disclaimer

This presentation and discussion here on IEEE P1547 are individual’s views and are not the formal position, explanation or position of the IEEE.
Abstract

This lecture will explore lessons learned from Germany about interconnection and integration of massive amounts of distributed energy resources (DERs) into the distribution grid and related impacts on bulk system stability.

Germany has experienced an unprecedented, and unexpected, deployment of small-scale, roof-top solar systems in the past decade and is now serving about one third (!) of its annual electricity consumption by renewable energy from wind, solar, biomass, hydro, etc. In the transitioning process of its power system, called “Energiwende”, Germany has made a number of unfortunate mistakes that can be useful for the U.S. to learn from.

The main interconnection standard for DERs in North America, IEEE Std 1547, is currently being revised and the lecturer who is with the Electric Power Research Institute (EPRI) is involved in a leadership position in that revision process. Revisions to the standard include reactive power capability and voltage control requirements, voltage and frequency ride-through, interoperability and communication capability requirements as well as testing and verification requirements. This lecture will provide an informal report on the status of the revision of IEEE Std 1547 and explain how interested parties may get involved in the process and voting.
Agenda

1. Background and Context
2. Lessons learned from Germany
3. Major Changes in IEEE P1547 in a Nutshell
4. Draft Interconnection and Interoperability Requirements (selected)
   - VAR and VAR-control capability
   - Voltage & Frequency Ride-Through
   - Interoperability and Communication
5. Test and Verification of Requirements
6. How to Get Involved?
Background and Context

Data Source: GTM/SEIA's U.S. Solar Market Insight Report Q1 2015

Cumulative Capacity in U.S. (MWdc)

Year (2015-2020 are forecasts)

Number of PV installations increases dramatically.
Background and Context
The Reality: Development of Renewable Energy Sources in Germany.

Share of Renewables in Gross Annual Electricity Consumption

Installed Nameplate Capacity of Renewables
Background and Context
The Grid Planning & Operation Challenge with Distributed Energy Resources

- Voltage/Reactive Power
- Power quality: voltage limits/power factor/harmonics

- Frequency/Active Power
- Stability
- Health & Safety: protection coordination/anti-islanding
Background and Context
The Grid Planning & Operation Challenge with Distributed Energy Resources

- Voltage/Reactive Power
- Power quality: voltage limits/power factor/harmonics
- Frequency/Active Power
- Stability
- Health & Safety: protection coordination/anti-islanding

Interconnection requirements for DERs should adequately address transmission and distribution system needs.
Background and Context
Which standards apply after the transitioning period? (Example: California)

Period after IEEE Stds 1547 and 1547.1 Update

- IEEE Std 1547.1-20xx
- IEEE Std 1547-20xx
- UL 1741-20xx (Listing / Certification Test)
- NERC / FERC
- State/PUC Utility Laws (CA Rule 21-20xx)
- Individual Utility Generator Connection Agreements

Harmonizing Requirements in IEEE Std. 1547 for the Future.

- DER interconnection and system integration focus.
- Technology-agnostic.
- Widely accepted.
- Performance-based requirements.
- Leading technological development and innovation of DER performance.
Lessons learned from Germany

Understanding the transitioning process of the power system as a collaborative learning process.

1. Things may go much faster than you'd expect.
   - Good solutions from the past may not hold in the future.

2. You cannot plan for everything.
   - 2009: German incentive program for improved grid integration of wind power plants.
   - 2012: German legislation to retrofit DERs with (basic) remote control capability.
   - 2012: German legislation to retrofit PV systems with improved frequency settings (so-called “50.2 Hz problem”).
   - 201x: German legislation to retrofit other DERs with improved frequency settings (so-called “49.5 Hz problem”).
   - 2016: It is easy to miss the end point of 'market introduction' of (distributed) renewables (“duck curve problem”).

3. Expect mistakes and make the system flexible:
   - Require communication capability.
Major Changes in IEEE P1547 in a Nutshell

CA Rule 21 and UL 1741(SA) are leading the way for IEEE Stds 1547 and 1547.1

- **Shall** trip in response to abnormal voltage/frequency condition
- **Shall not** actively regulate voltage or frequency
- **May** ride through abnormal V/F
- **May** actively regulate voltage by changing real/reactive power
- **May** change real power in response to frequency deviations
- **Shall** have communication interface?
- **DER Unit Level:** Type Test, Production Test
- **DER Facility Level:** Design Evaluation, Installation Evaluation, Commissioning Test, Periodic Tests
- **DER to provide ancillary grid services** – capability VS. provision

<table>
<thead>
<tr>
<th>Year</th>
<th>Change Event</th>
</tr>
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<tbody>
<tr>
<td>2000</td>
<td>California Rule 21</td>
</tr>
<tr>
<td>2003</td>
<td>FERC SGIP (Small Generator Interconnection Procedure)</td>
</tr>
<tr>
<td>2005</td>
<td>Updated California Rule 21 (consistent with IEEE 1547-2003)</td>
</tr>
<tr>
<td>2011</td>
<td>IEEE 1547a-2014</td>
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<tr>
<td>2014</td>
<td>Updated California Rule 21 (more prescriptive than IEEE 1547a-2014)</td>
</tr>
<tr>
<td>2015</td>
<td>Amended UL 1741 (SA) (inverter certification driven by CA Rule 21)</td>
</tr>
<tr>
<td>2017/18</td>
<td>IEEE 1547rev-20lx</td>
</tr>
<tr>
<td>2018/19</td>
<td>IEEE 1547.1rev-20lx</td>
</tr>
</tbody>
</table>

Interconnection Agreements / Markets / etc.
Major Changes in IEEE P1547 in a Nutshell

Draft Applicability of Requirements

The reference point has implications for testing & conformance requirements in IEEE P1547 & P1547.1 !!!
Major Changes in IEEE P1547 in a Nutshell

IEEE P1547 Performance Category Approach

IEEE Std. 1547rev

Category I

Category II

Category III

Category A

Ride-Through

Voltage Regulation

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.

Authority Governing Interconnection Agreements

DER Vendors

Market Analysis

• Costs
• Market segment
• Etc.

1 State Regulator, Area EPS or bulk system operator, etc.
VAR and VAR-control capability

Draft Reactive Power Capability Requirements

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 the Table below at all active power output equal to 20% to 100% of nameplate active power rating (kW).

Minimum Reactive Power Injection and Absorption Capability

<table>
<thead>
<tr>
<th>Category</th>
<th>Injection (Over-Excited) Capability as % of Nameplate Apparent Power (kVA ) Rating</th>
<th>Absorption (Under-Excited) Capability as % of Nameplate Apparent Power (kVA ) Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (at DER rated voltage)</td>
<td>44</td>
<td>25</td>
</tr>
<tr>
<td>B (at ANSI range A)</td>
<td>44</td>
<td>44</td>
</tr>
</tbody>
</table>
VAR and VAR-control capability
Draft Voltage Regulation Control Modes

<table>
<thead>
<tr>
<th>DER Category</th>
<th>Cat A</th>
<th>Cat B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Voltage Regulation by Reactive Power Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustable Constant Power Factor</td>
<td>Mandatory</td>
<td>Mandatory</td>
</tr>
<tr>
<td>Voltage – Reactive Power (Volt-var)</td>
<td>Mandatory</td>
<td>Mandatory</td>
</tr>
<tr>
<td>Active Power – Reactive (Watt-Var) Mode</td>
<td>Optional</td>
<td>Mandatory</td>
</tr>
<tr>
<td>Adjustable Constant Reactive Power</td>
<td>Mandatory</td>
<td>Mandatory</td>
</tr>
<tr>
<td><strong>Voltage and Active Power Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage – Real Power (Volt-Watt)</td>
<td>Optional</td>
<td>Mandatory</td>
</tr>
</tbody>
</table>

- The DER shall be capable of activating any of these modes individually.
- Adjustable constant power factor mode with unity power factor setting shall be the default mode of the installed DER unless otherwise specified by the area EPS operator.
- The Area EPS operator 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.
Voltage & Frequency Ride-Through
Foundations for Voltage & Frequency Ride-Through Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Category</th>
<th>Foundation</th>
<th>Justification</th>
</tr>
</thead>
</table>
| Voltage Ride-Through      | Category I       | German grid code for medium voltage-connected synchronous generator-based DER | • *Essential* 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)                                        | • *All* bulk system needs.  
• Coordinated with existing reliability standards.  
• Considering fault-induced delayed voltage recovery. |
|                           | Category III     | CA Rule 21 and Hawaii, minor modifications                                  | • All bulk system needs.  
• Considering fault-induced delayed voltage recovery.  
• Distribution system operation. |
| Frequency Ride-Through     | All Categories   | CA Rule 21 and Hawaii, exceeds PRC-024-2  |
|                           | (harmonized)     | based on EPRI White Paper (May 2015)                                        | • All bulk system needs.  
• Low inertia grids. |
Voltage & Frequency Ride-Through
Draft Voltage Ride-Through Requirements for Category II

Category II
(based on NERC PRC-024-2 and considering FIDVR issues to a certain extent)

Voltage & Frequency Ride-Through
Draft Frequency Ride-Through Requirements for All Categories

Definition and Applicability

Changes in the IEEE P1547 paradigm:
- The point of interconnection now includes power and communication interfaces.

Definitions from IEEE Std 2030:
- **Interoperability** – the capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively
- **Interface** – a logical interconnection from one entity to another that supports one or more data flows implemented with one or more data links.

Limited Scope of IEEE P1547

- Only the standards protocols and the hardware interface at the DER interconnection points is within the scope of P1547.
  - Internal network specifics such as the protocols utilized within communication networks are out of scope of P1547.
  - Internal DER specifics such as plant-level communications and controls are out of scope of P1547.
Test and Verification of Requirements

Key characteristics of a proposal to be discussed at the P1547 Working Group meeting October 25-26, 2016

Objectives

- Keep it *simple*.
- Maintain and create *planning security*.
- Streamline DER interconnection *processes* by providing *Authorities Governing Interconnection Agreements (AGIAs / AHJs)* with a conformance framework.

Approach

- Consider applicability of requirements, i.e., PoC vs. PCC.
- Give flexibility as to allow for meeting compliance by means of “Supplemental DER Devices” if individual DER units only partially meet the requirements.
- Use as much “plug-and-play” as possible, rely on type tests where possible, ensure interoperability.
- Prefer cost-effective “DER evaluation” over expensive commissioning test.
## Test and Verification of Requirements

The test requirements should give guidance, yet be flexible enough to consider the large variety of actual DER setups in the field:

<table>
<thead>
<tr>
<th>IEEE Std 1547 Requirement XYZ</th>
<th>Applicability of Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>DER Capability &amp; Conformance</td>
<td>Point of DER Connection (PoC)</td>
</tr>
<tr>
<td>Full</td>
<td>Type Test</td>
</tr>
<tr>
<td>no Supplemental DER Support Device needed</td>
<td></td>
</tr>
<tr>
<td>Partial</td>
<td>Type Test(s) + DER Evaluation</td>
</tr>
<tr>
<td>one or more Supplemental DER Support Device(s) needed</td>
<td></td>
</tr>
</tbody>
</table>
## How to Get Involved?
What are the next steps, is the process to get involved, the rules for voting?

<table>
<thead>
<tr>
<th>Dates</th>
<th>Event / Action</th>
<th>More information</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/25/16 - 10/26/16</td>
<td><strong>IEEE P1547 WG meeting</strong> (followed by P1547.1 WG meeting)</td>
<td>Commonwealth Edison, 1919 Swift Drive Oak Brook, IL, 60523</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Register at,</strong> <a href="http://www.cvent.com/d/pvqkcm">http://www.cvent.com/d/pvqkcm</a></td>
</tr>
<tr>
<td>11/26/16</td>
<td>Initial Pre-Ballot Draft</td>
<td>Show redline changes from Draft 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Post to iMeetCentral. Review for WG approval at Feb WG meeting</td>
</tr>
<tr>
<td>Week of Feb 27, 2017</td>
<td><strong>IEEE P1547 WG meeting</strong> (followed by P1547.1 WG meeting)</td>
<td>NERC, Atlanta GA</td>
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<tr>
<td>March 2017</td>
<td>Complete Ballot Draft of 1547 Revision</td>
<td>Begin IEEE pre-ballot editorial review process</td>
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<tr>
<td>May 2017</td>
<td><strong>Balloting</strong></td>
<td><strong>6 months estimated minimum duration</strong></td>
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<tr>
<td>Summer 2017</td>
<td><strong>IEEE P1547 WG meeting</strong> (followed by P1547.1 WG meeting)</td>
<td>National Grid, Waltham MA</td>
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</tbody>
</table>
# How to Get Involved?

**What are the next steps, is the process to get involved, the rules for voting?**

<table>
<thead>
<tr>
<th>Activity Level</th>
<th>Interested Stakeholders</th>
<th>IEEE Members</th>
<th>IEEE-SA Members</th>
<th>How to get involved?</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Participation in Working Group and SubGroups meetings and conference calls</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>1. Sign up for P1547 ListServ: send an e-mail to <a href="mailto:listserv@listserv.ieee.org">listserv@listserv.ieee.org</a> with the following command in the body of the e-mail: Subscribe stds-p1547rev lastname, firstname End 2. Contact WG and/or SubGroup Leads &amp; Facilitators refer to the next slide for further information</td>
</tr>
<tr>
<td>II. Access to WG Draft Standards in the WG repository on iMeetCentral</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>1. Meet the requirements for P1547 WG membership status, described at WG Membership (attend 2 consecutive Mtgs.) OR 1. Register for P1547 WG live meetings, where latest Drafts are provided as needed for meeting participation.</td>
</tr>
<tr>
<td>IV. Ballot (vote) on IEEE P1547</td>
<td>✗</td>
<td>(✓)</td>
<td>✔️</td>
<td>1. Sign up for IEEE SA Individual Membership OR pay for single ballot 2. Join Open Ballot Invitation on myBallot™ by use of IEEE Account</td>
</tr>
</tbody>
</table>

*IEEE 1547 is set up as an individual vote, not an entity vote!*

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Click on the links to open these websites.
Together…Shaping the Future of Electricity

Jens C. Boemer – (206) 471-1180 – jboemer@epri.com
Backup
(General)
Role of IEEE Std 1547

Product & Installation Requirements
(Standards have no inherent authority)

Grid Interconnection & Functional Requirements

Communication Certification Requirements

Tests
National Electric Code (voluntary)
UL 1741 (Listing / Certification Test)

State
State Codes/Laws (selective adoption of NEC)

Local
Local Municipal Codes

IEEE Std 1547.1
IEEE Std 1547

State/PUC Utility Laws (e.g. CA Rule 21)

Individual Utility Generator Connection Agreements

IEEE
IEEE P2030.5
IEC 61850
NRC P1815
SunSpec

Local

Standards
Which standards apply during the transitioning period? (Example: California)

- **Period prior to CA Rule 21 and UL 1741 Update**
  - IEEE Std 1547.1-2005
  - UL 1741-2010 (Listing / Certification Test)
  - NERC / FERC
  - State/PUC Utility Laws (CA Rule 21-2000)
  - Individual Utility Generator Connection Agreements

- **Period after CA Rule 21 and UL 1741 Update**
  - IEEE Std 1547.1-2005
  - UL 1741-2016 (Listing / Certification Test)
  - NERC / FERC
  - Individual Utility Generator Connection Agreements

- **Period after IEEE Std 1547 and 1547.1 Update**
  - IEEE Std 1547.1-20xx
  - UL 1741-20xx (Listing / Certification Test)
  - NERC / FERC
  - State/PUC Utility Laws (CA Rule 21-20xx)
  - Individual Utility Generator Connection Agreements
UL1741 New Supplement for Grid Support Utility Interactive Inverters

- Anti-Islanding
- L/HVRT
- L/HFRT
- Must Trip Test
- Normal Ramp Rate
- Soft-Start Ramp Rate
- Specified Power Factor
- Volt-Var Mode

- Other/ Optional
  - Frequency Watt
  - Volt Watt

Important Dates:
- Apr 11, 2016 – To UL1741 STP for ballot
- May 20, 2016 – Ballot ends
  (If obtain a consensus ballot on the first pass)
- Days/Weeks later – All comments resolved and SA published
- Recirculation of revised document early August
- Effective September 2016 (in general), June/July 2017 – Likely CA Rule 21 effective date for UL1741 SA

Source: Estimate based on informal conversation (not official UL schedule)
Background and Context
Role of IEEE Std 1547

Period prior to CA Rule 21 and UL 1741 Update

Harmony in the “Good Old Days” when Distributed Energy Resources were insignificant:

- DER interconnection focus.
- Technology-agnostic.
- Equipment standard / UL listing.
- But: “Get out of the way” principle.
Background and Context
Which standards apply during the transitioning period? (Example: California)

Period after CA Rule 21 and UL 1741 Update

Today’s Disharmony in a World of Uncertainty:

- Technology-specific requirements.
- Based on state of the art technology capabilities.
- Heavily focused on solar PV inverters.
Backup
(IEEE P1547 Draft 5)
### IEEE P1547 Working Group Organization

<table>
<thead>
<tr>
<th>Group</th>
<th>Code</th>
<th>Scope</th>
<th>Subgroup Lead, (WG Vice Chair)</th>
<th>Alt. Lead</th>
<th>Facilitator(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>OD</td>
<td>Overall Document</td>
<td><strong>D. Narang, NREL, WG Chair</strong></td>
<td><strong>C. Vartanian, MEPPI, WG Secretary</strong></td>
<td><strong>J. Boemer, EPRI</strong></td>
</tr>
<tr>
<td>F2</td>
<td>GR1</td>
<td>Voltage regulation</td>
<td><strong>B. Enayati, NationalGrid</strong></td>
<td><strong>J. Berdner, enphase</strong></td>
<td><strong>A. Huque, EPRI</strong></td>
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<tr>
<td>F3</td>
<td>GR2</td>
<td>Response to abnormal grid conditions</td>
<td><strong>J. Berdner, enphase</strong></td>
<td><strong>B. Enayati, NationalGrid</strong></td>
<td><strong>J. Boemer, EPRI</strong></td>
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<tr>
<td>F4</td>
<td>IIAMS</td>
<td>Interoperability &amp; Communication</td>
<td><strong>B. Fox, SUNSPEC</strong></td>
<td><strong>B. Seal, EPRI</strong></td>
<td><strong>F. Cleveland, W. Stec</strong></td>
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<tr>
<td>F5</td>
<td>SI</td>
<td>Special Interconnections, islanding, microgrids, storage, etc.</td>
<td><strong>C. Vartanian, MEPPI</strong></td>
<td></td>
<td><strong>L. Casey, Google</strong></td>
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<tr>
<td>F6</td>
<td>IST</td>
<td>Interconnection/Interoperability Test Specifications and Requirements, Modeling and Simulation</td>
<td><strong>M. Siira, comrent</strong></td>
<td></td>
<td><strong>W. Stec, M. Ropp, NPPT</strong></td>
</tr>
<tr>
<td>F7</td>
<td>PQ</td>
<td>Power quality, Area EPS microgrids</td>
<td><strong>B. Enayati, NationalGrid</strong></td>
<td></td>
<td><strong>J. Piekarz, NG, Chris Rowe, Enphase</strong></td>
</tr>
</tbody>
</table>

*Click on the names to contact these individuals via email.*
Major Changes in a Nutshell
Draft Figure 1 and Related Normative Definitions

- **point of common coupling (PCC)** – The point where a Local EPS is connected to an Area EPS.
  - NOTE—See Figure 1.

- **point of distributed energy resources connection (point of DER connection—PoC):**
  The point where a DER unit is electrically connected in an EPS and meets the requirements of this standard exclusive of any load present in the respective part of the Local EPS.
  - NOTE—See Figure 1.
  - NOTE—For (a) DER unit(s) that are not self-sufficient to meet the requirements without (a) supplemental DER device(s), the point of DER connection is the point where the requirements of this standard are met by DER (a) device(s) in conjunction with (a) supplemental DER device(s) exclusive of any load present in the respective part of the Local EPS.

- **supplemental DER device:**
  An equipment that is used to obtain compliance with some or all of the performance-requirements of this standard.
  - NOTE—Examples include capacitor banks, STATCOMs, harmonic filters that are not part of a DER unit, protection devices, plant controllers, etc.
  - NOTE—Communications gateways are not included in this definition.

There is a large variety of actual DER setups in the field. Figure 1 aims at illustrating five examples to explain certain concepts.
Major Changes in a Nutshell

Notes to Draft Figure 1

- **NOTE**—The example of **Local EPS 1** includes only load. Any requirements for this Local EPS are outside the scope of this standard.

- **NOTE**—The example of **Local EPS 2** includes only DER. Depending on the DER rating, requirements of this standard apply either at the PCC or the PoC. The DER unit in this example is able to meet requirements at its terminals without any supplemental DER device; the PoC coincides with the DER unit’s terminals.

- **NOTE**—The example of **Local EPS 3** includes both a DER unit and load. Depending on the DER rating and the % of average load demand, requirements of this standard apply either at the PCC or the PoC. The DER unit is able to meet requirements at its terminals without any supplemental DER device; the PoC coincides with the DER unit’s terminals.

- **NOTE**—The example of **Local EPS 4** includes a DER unit, a supplemental DER device, and load. Depending on the DER unit’s rating and the % of average load demand, requirements of this standard apply either at the PCC or the PoC. The DER unit is not able to meet requirements at its terminals without any supplemental DER device; the PoC is the point where the requirements of this standard are met by the DER unit in conjunction with the supplemental DER device exclusive of any load, if present, in the respective part of the Local EPS.

- **NOTE**—The example of **Local EPS 5** includes two (or more) DER units and a supplemental DER device but no load. Depending on the aggregate DER units’ rating, requirements of this standard apply either at the PCC or the PoC. The two (or more) DER two units are not able to meet requirements at their terminals without any supplemental DER device; the PoC is the point where the requirements of this standard are met by two (or more) DER units in conjunction with the supplemental DER device exclusive of any load, if present, in the respective part of the Local EPS.
Major Changes in a Nutshell

Use of “DER” term in IEEE P1547

- “DER” is a generic term for which performance requirements are specified in P1547.

- Its meaning may change for various DER setups:
  - DER is aggregate DER and/or supplemental units, loads, and collector system that relate to the PCC.
  - DER is a single unit in applications without multiple units or supplemental DER that relate to the PoC.
VAR and VAR-control capability

Example for Assignment of Voltage Regulation and Reactive Power Categories to DER

- Impractical for DER type to meet Cat. B?
  - Yes: SCR at PCC high?
    - Yes: Aggregate penetration of DER type expected to be low?
      - Yes: DER output constant, not frequently variable?
        - Yes: Assign Category A
        - No: Assign Category B
    - No: Assign Category B
  - No: Assign Category B
Voltage Trip Requirements
IEEE Std 1547-2003

Voltage Ride-Through Requirements
IEEE P1547 Draft 3 (January 2016) – Category II

Category II
(based on NERC PRC-024-2 and considering FIDVR issues to a certain extent)

Voltage Ride-Through Requirements
IEEE P1547 Draft 3 (January 2016) – Category III

Voltage Ride-Through Requirements

Dynamic Voltage Support

Dynamic Voltage Support

Considerations for ‘Dynamic Voltage Support’ from DER

Support *during* disturbances?
- short-circuit contribution
- dynamic reactive current injection (DRC)
- fast voltage control / fast-responding closed-loop voltage regulation
- control loops typically operate in the sub-second time frame, often within a few cycles.

![Graph showing voltage versus time]

Support *after* disturbances?
- dynamic reactive support
- control loops typically operate in the 1 s … 10 s time frame

Further research required to adequately justify and specify requirements.
Voltage & Frequency Ride-Through
Draft Frequency-Droop Capability Requirements for All Categories

![Frequency-Droop graph]

Default value of frequency deadband was reduced from 100 mHz to 36 mHz.

Table 17 – Parameters of frequency-droop (frequency/power) operation for DER of Category I, Category II, and Category III

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ranges of adjustability (not a design criteria)</th>
<th>Default settings¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Category I</td>
<td>Category II</td>
</tr>
<tr>
<td>(d_{OF}, d_{UF}) [Hz]</td>
<td>0.017 – 1.0</td>
<td>0.017 – 1.0</td>
</tr>
<tr>
<td>(k_{OF}, k_{UF}) [p.u.]</td>
<td>0.03 – 0.05</td>
<td>0.03 – 0.05</td>
</tr>
</tbody>
</table>

¹ Adjustments shall be permitted in coordination with the Area EPS operator.
What is the process to get involved, the rules for voting? - Participation in IEEE Standards

- **IEEE**
  - **IEEE Standards Association**
    - Standards Coordinating Committee 21
      - **IEEE 1547 “Series of Interconnection Standards” Working Group**
        - IEEE 1547-yyy (where yyy is the year of the revision)
        - IEEE 1547.n (where n designates one of a set of related standards and recommended practices developed by the working group)

- **Participation**
  - IEEE 1547 is based on Individual Membership
    - https://www.ieee.org/membership_services/membership/membership_standards.html
  - Voting membership in the working group is based on participation
    - “Letter ballots” are the normal process for achieving consensus within the WG
  - Sponsor Ballot – final phase of balloting, open to all IEEE-SA, not only the WG.
    - Voting on the sponsor ballot requires the individual to have IEEE-SA membership. No WG participation requirement.
    - Request to join sponsor ballot, cast vote, and submit comments at https://development.standards.ieee.org
A successful ballot requires a 75% return and 75% approval.
IEEE-SA, Standards Balloting
Backup

(EPRI Proposal for section 5, Testing & Conformance)
Revised Definitions of Test Types (revised 10/4)

- **NTRL (implementation / audit)**
  - **Type Test** – Tests of one device or combination of devices forming a system made to a certain design to show that the design meets certain specifications (performance requirements and/or communications capabilities) or provide information that can be used to verify compliance. In case of a combination of devices forming a system, this test shows that the devices are able to operate together as a system (→ interoperability).
  - **Production Test** - Tests conducted on every unit of equipment prior to customer delivery to demonstrate that they meet the design specifications and applicable standards.
Revised Definitions of Test Types (revised 10/4)

- Someone else (see next slide)
  - **DER Evaluation**
    1. **Design Evaluation** (Desk Study) – Evaluation at time of interconnection request to verify that the composite of the individual partially-compliant DERs forming a system as designed meets the interconnection and interoperability requirements at the applicable reference point, i.e. Point of DER Connection (PoC) or Point of Common Coupling (PCC). This evaluation is usually done off-site before equipment is delivered and installed.
    2. **As-built Installation Evaluation** (On-Site) - Evaluation at time of commissioning to verify that the composite of the individual partially-compliant DERs forming a system as delivered and installed meets the interconnection and interoperability requirements at the applicable reference point, i.e. Point of DER Connection (PoC) or Point of Common Coupling (PCC). This evaluation does not require testing.

- **Commissioning Test** – Tests and/or verifications on one device or combination of devices to confirm that the system as designed, delivered and installed meets the interconnection and interoperability requirements at the applicable reference point, i.e.
  - Point of DER Connection (PoC) : Basic functional test
  - Point of Common Coupling (PCC) : Sophisticated functional test

- **Periodic Test** – Tests and/or verifications, according to a scheduled time period or other criteria, that confirm that one device or combination of devices meets the interconnection and interoperability requirements at the applicable reference point, i.e. Point of DER Connection (PoC) or Point of Common Coupling (PCC).
Test and Verification of Requirements
Example Test and Verification Requirements Matrix

**Legend:**
- **F** – for **full** conformance of DER unit,
- **P** – for **partial** conformance of DER unit,
- **N/R** – Not Required

**Time**

- **Component Level (DER unit)**
  - Requirement
  - Type Test
  - Production Test
  - DER Evaluation
    - 1. Design evaluation (at time of interconnection request)
    - 2. As-build installation evaluation (at time of commissioning)

- **Local EPS Level (DER system)**
  - DER As-built Installation Evaluation
  - Commissioning Test
  - Periodic Test
  - Over lifetime or when DER is changed substantially

**Requirements**
- 4.1.1 Reactive power capability of the DER
- 4.1.2 Voltage and reactive power control
- 4.1.3 Voltage and active power control
- 4.2.3.2 Mandatory voltage tripping requirements
- 4.2.3.3 Voltage disturbance ride-through requirements
- 4.2.4 Interoperability, communication interface and protocols
- 1. Design evaluation (at time of interconnection request)
- 2. As-build installation evaluation (at time of commissioning)
Test and Verification of Requirements
Who may conduct the design & installation (field) evaluation?

Candidates
- The DER developer
- The Area EPS operator / utility
- The Authority Governing Interconnection Agreements (AGIA)
- An independent third party

Challenges
- Different business objectives among parties
- Conflicts of interest
- “System reliability” is a public good

Proposal
- Assign responsibilities in a flexible way
- Use “may” / “or” rather than “shall” language
  ➢ “Area EPS operator or DER operator or third party”

Example Germany:
Three mayor players in the certification process for grid integration.

Backup
(Interoperability and Communication)
Why is interoperability in IEEE 1547 PAR?

Supports the direction of grid transformation:

- The Integrated Grid
- Connectivity
- Billions of Distributed Energy Resources Future
- Learning from the mistakes made by Germany

➢ Standards help to reduce costs and create interoperability
  - IEEE 1547 is an “Interconnection” standard
  - The point of interconnection now includes power and communication interfaces
What is in the Current IEEE 1547 Draft (V5)

A DER shall provide interoperability support at one of the following levels:

- monitoring and management enabled
- monitoring enabled
- no interoperability support

The interoperability support level required shall be allowed to be specified by the EPS operator.

The information models and communication protocols used for the information exchanges shall be standards mutually agreed upon by the Local and Area EPS operators. Examples of such communication standards are provided in Annex MIC. For the purpose of ensuring or increasing interoperability, it is recommended that Area EPS operators develop and coordinate detailed profiles and guidelines for the implementation of the agreed upon information models, communication protocols, and the data to be exchanged.
Interoperability and Communication

Logical Combinations

- Allowing for a couple of well-defined options gives vendors more flexibility and is still achievable for aggregators/integrators.
Specifying Communication Interoperability

Multiple Layers Involved

- **OSI**
  - Physical
  - Data Link
  - Network
  - Transport
  - Session
  - Presentation
  - Application

- **Internet**
  - Network Access
  - IP Layer
  - Transport
  - Application

- **Practical Options**
  - DNP3
  - IEEE 2030.5
  - SunSpec/Modbus
  - IEC 61850
  - TCP, UDP, or Not Applicable
  - IPV4, IPV6, or Not Applicable
  - Ethernet, RS-485
  - Twisted Pair, RJ-45, CTA-2045

- Lower layers provide physical compatibility. They avoid the need for electricians onsite, custom wiring, adapters.

- Upper layers provide software compatibility. They avoid the need for protocol translation, reduce software complexity.
Interoperability and Communication

Powering Communication Devices

• Not a concern for large-scale DER
  • Electrician will go onsite
  • Dedicated cabinet, backup battery, power supply

• A major concern for small-scale DER
  • Where to get power?
  • Expense of conduit, electrician

• Communication interfaces can include power for the communication devices:

  - **USB 3.0**
    - 5V @ 900[mA]

  - **PoE**
    - 44V at 350[mA]

  - **CTA-2045**
    - AC line @ 50[mA]
    - 3.3V@750[mA]