Interconnection Standards

Net Metering and Interconnection Standards Information Seminar

Mississippi Public Service Commission, Jackson MS

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July 22, 2011
Smart Grid Interconnection and Interoperability Standards Development

Objective
To facilitate the evolution of the existing electric power system into a smart grid by supporting the development of standards and best practices.

Technical Scope
Development of national and international standards and best practices for electric power system interfaces, interconnection and interoperability requirements

Interconnection Standards presentation for the 7/22/11 Information Seminar by the Mississippi Public Service Commission, Jackson MS.
Benefits of Standards

- Facilitates standardized designs, engineering implementation, interoperability, and installation – lower cost.
- Simplifies conformance assessment (to standards, permitting, and rules)
- Assists increased system quality and reliability achievement
- Promotes advanced communication and software platforms
- Enables enhanced grid intelligence
- Safeguards against hazards
- Fosters quality design and manufacture
- Increases competitiveness in industry
- Creates and expands markets
- Facilitates Trade and Commerce
- Assurance is provided when products meet quality standards, then users need not be concerned with further testing or evaluation of the product
OUTLINE

• Background
  Electricity infrastructure and interconnection
• Introduction of interconnection rules
  (includes shared slides RAP/NREL)
• Interconnection Rules
  - Technical Standards
  - Testing and Certification
  - Interconnection Procedures
• Background Slides
# The Electricity Grid

<table>
<thead>
<tr>
<th>Generation</th>
<th>Transmission</th>
<th>Subtransmission</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generating Station</td>
<td>Transmission Substation</td>
<td>Transmission Lines</td>
<td>Subtransmission Substation</td>
</tr>
</tbody>
</table>

- **Generation**: 13,200 volts
- **Transmission**: 345,000 volts
- **Subtransmission**: 69,000 volts
- **Distribution**: 13,200 volts

**Electrical One-Line Diagram**

- Generator
- Transformer
- Transmission Line
- Subtransmission Line
- Distribution Substation Transformer
- Distribution Line
- Distribution Transformer
- Loads
The overall power system is traditionally viewed in terms of 7 layers; each layer performing its function ranging from central station generation supplying power outward to customers.
Interconnection Rules

• Technical Standards
• Testing and Certification
• Interconnection Procedures
  e.g., Application Forms and Processes, Agreements, Screens, Timelines, Fees, Insurance, Dispute Resolution, etc.
Interconnection Rules, Jurisdiction, etc.

Bulk System Guidelines
NERC, FERC
IEEE, ANSI, IEC
NESC

Plenty of technical and jurisdictional overlap, confusion, contradiction...

Distribution System Guidelines
IEEE 1547, PUC/PRC
IEEE, ANSI, IEC
NEC
Interconnection Implementation Challenge:

*Putting the Pieces Together*
Introduction to Interconnection Rules

(Details on technical standards and procedures this afternoon)

Goals for best practice include:

– Transparency – Requirements fully stated
– Consistency – With consensus industry technical standards
– Certainty – System can be interconnected if standards are met and procedures are followed
– Uniformity – Requirements are the same across utilities (at least all regulated utilities)
– Timely interconnection – Standard timeframes that enable an estimate of expected on-line date and mitigate delays
– Reasonable fees – Uniform and cost-based
Only States Have Authority Over State-Jurisdictional Interconnections

- FERC interconnection procedures and agreements do *not* apply to state-jurisdictional interconnections like PURPA and net metering.

- If states do not act, uncertainty, higher costs and delays may pose significant barriers to state’s distributed generation goals.

- State (PSC in this case) can adopt technical standards and procedures for interconnections under its jurisdiction.
  
  - For net-metered systems, technical standards and procedures can be: 1) part of net metering rule, or 2) covered in a stand-alone rule for small generators for all state-jurisdictional interconnections (including net metering and PURPA).

- In addition, PSC can require utilities to file interconnection applications and agreements for approval or develop standard form documents through rulemaking or other docket.
Jurisdictional Issues Between States & FERC Can Be A Complicating Factor

• FERC Has Jurisdiction for Distributed Resource Interconnections That Participate in Wholesale Markets (even if Interconnected at Distribution Level)

• All Retail Interconnections Fall Under Jurisdiction of State PUCs, e.g. Net Metering

• Ideally, Wholesale and Retail Interconnection Requirements Should Be Similar
Components of an Interconnection Rule  

Technical standards

– Provide consistent, transparent requirements for interconnecting with utility systems
– Uniformly applied (at least for regulated utilities in the state)
– Use accepted industry standards
  • Institute of Electrical and Electronics Engineers (IEEE) Standard 1547 series for Interconnecting Distributed Resources with Electric Power Systems
  • American National Standards Institute (ANSI) standard code for electricity metering
  • Underwriters Laboratories (UL) 1741 - Inverters, Converters, and Controllers for Use in Independent Power Systems
– Require compliance with applicable building codes, national electrical code (NEC), national electrical safety code (NESC), and, related siting and permitting mandates.
Components of an Interconnection Rule

Standard Interconnection Procedures

- Ensure consistency with IEEE 1547 standards
- Include specified timelines for each step toward an interconnection agreement with the utility
- Use technical screens to: 1) allow net metering facilities that do not require review beyond information in the application to be approved quickly (small, UL-certified) and 2) ensure other systems receive appropriate evaluation
  - Typically 3 (or 4) “levels” or “ tiers”
  -Deal with issues like penetration of distributed generation on the feeder and other local grid parameters
- Provide expedited review for certified equipment
  - An equipment package certified by a nationally recognized test lab (NRTL, e.g., UL, CSA, TUV) for continuous interactive operation with an electric distribution system in compliance with applicable standards; no further product review, testing or additional equipment required for that product
  - Installation and commissioning testing may be waived
Standard Applications and Agreements

**Application** – Provides information to utility about proposed net metering facility, level of interconnection review sought, contractor, equipment certification, anticipated date facility will be operational, etc.

**Agreement** – Governs connection of net metering facility to utility system and ongoing operation of facility.
Interconnection Fees & Dispute Resolution

Fees for reviewing interconnection application
- Typically no fee or nominal fee (e.g., $100) for level 1-eligible systems
- Specified, higher fees for other systems – e.g., $50 + $1 per kW of net metering facility’s capacity for level 2; $100 + $2 per kW for level 3
- *Plus* reasonable hourly fee for any additional engineering work and reasonable cost of any required modifications to utility system (utility provides cost and time estimates in advance and charges actual cost)

Uniform technical standards and procedures minimize disputes over interconnection requirements, timelines and fees
Specify in rule that dispute resolution will be through standard Commission complaint procedures or a specified process for interconnection disputes
  Oregon – OAR 860-082-0080 at [http://arcweb.sos.state.or.us/rules/OARS_800/OAR_860/860_082.html](http://arcweb.sos.state.or.us/rules/OARS_800/OAR_860/860_082.html)
Interconnection Rules

- **Technical Standards**
- **Testing and Certification**
- **Procedures,** e.g., Application Forms and Processes, Agreements, Screens, Timelines, Fees, Insurance, Dispute Resolution, etc.
## Technical Standards and Practices Can Be a Barrier

### PJM-NREL Interconnection Standards Audit Results

(*Blue Font underlined indicates IEEE 1547 requirements that may be pre-certified*)

<table>
<thead>
<tr>
<th>IEEE Std 1547 Clause</th>
<th>IEEE Std 1547 Requirement</th>
<th>PJM / TO Std Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 General Requirements</td>
<td>(heading only)</td>
<td>N/A</td>
</tr>
<tr>
<td>4.1.1 Voltage Regulation</td>
<td>DR shall not actively regulate voltage; not cause the Area EPS voltage at other PCCs to go outside requirements of ANSI C84.1 Range A.</td>
<td>No</td>
</tr>
<tr>
<td>4.1.2 Integration with Area EPS grounding</td>
<td>Grounding scheme shall not cause overvoltages that exceed rating of the equipment connected to the Area EPS</td>
<td>No</td>
</tr>
<tr>
<td>4.1.3 Synchronization</td>
<td>Shall not disrupt coordination of Area EPS ground fault protection</td>
<td>Yes</td>
</tr>
<tr>
<td>4.1.4 Inadvertent Energization of the Area EPS</td>
<td>Shall not energize a de-energized Area EPS</td>
<td>Yes</td>
</tr>
<tr>
<td>4.1.5 Monitoring</td>
<td>Aggregate gen &gt; 250 kva shall have provisions for monitoring (connection status, KW, KVAR, &amp; voltage) at the DR connection</td>
<td>Yes, but size varies (often more data required by TO)</td>
</tr>
<tr>
<td>4.1.7 Isolation Device</td>
<td>When required by TO, shall provide readily accessible, lockable, visible-break isolation device</td>
<td>Yes</td>
</tr>
<tr>
<td>4.1.8 Interconnect Integrity</td>
<td>(heading only)</td>
<td>N/A</td>
</tr>
<tr>
<td>4.1.8.1 EMI</td>
<td>EMI withstand shall meet C37.90.2</td>
<td>No</td>
</tr>
<tr>
<td>4.1.8.2 Surge Withstand</td>
<td>Shall meet C62.41.2 or C37.90.1 V&amp;I withstand capability</td>
<td>No</td>
</tr>
<tr>
<td>4.1.8.3 Paralleling Device</td>
<td>Shall be capable of withstanding 220% of system rated V</td>
<td>No</td>
</tr>
<tr>
<td>4.1.9 DR on distribution secondary grid and spot networks. (heading only)</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>4.1.9.1 Distribution secondary grid networks. (Under consideration for future revisions of std.</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>4.1.9.2 Distribution secondary spot networks (multiple requirements in 1547)</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

### Summary

Conclusions

Requirements vary from utility to utility

Requirements not transparent

Requirements not uniformly applied

Many additional requirements probably not needed
Standards and Codes – Which Apply?

Relevant Standards

- IEEE 1547 - Interconnection of DR to Utilities
- IEEE 1547.1 – Test Procedures for Interconnection
- UL 1741 - Standard for Interconnection Equipment including Inverters

Important Codes

- NEC - National Electrical Code (Home and Business)
- NESC - National Electrical Safety Code (Utility Safety)
- Applicable building, site, and other related codes
Standards and Codes – Where Do They Apply?

*PCC – point of common coupling is where 1547 requirements apply

1-2-3 Overview, Definitions, References

4.0 Interconnection Technical Specifications and Requirements:

- General Requirements
- Response to Area EPS Abnormal Conditions
- Power Quality
- Islanding

5.0 Test Specifications and Requirements:

- Design Tests
- Production Tests
- Interconnection Installation Evaluation
- Commissioning Tests
- Periodic Interconnection Tests
IEEE Std 1547.1 (2005; reaffirmed 2011)

...Standard for Conformance Test Procedures... specifies the type, production, and commissioning tests that shall be performed to demonstrate that interconnection functions and equipment of a distributed resource (DR) conform to IEEE Std 1547.

![Diagram](image-url)

Figure 1 - Boundaries between the interconnection system, EPS and DR.
**UL 1741:** UL Standard for Safety for Inverters, Converters, Controllers and Interconnection Equipment for Use With Distributed Energy Resources

- NREL contracted UL to update 1741 (2005) to include all DR interconnections.

- For utility interactive equipment, **UL 1741** supplements and is to be used in conjunction with **IEEE 1547** and **IEEE 1547.1**;
  - Construction, Materials, wiring, component spacing, etc.
  - Protection against risks of injury to persons
  - Output Characteristics and utility compatibility
    (This section includes requirements from IEEE 1547)
  - Rating, Marking
  - Specific DR Tests for various technologies
    (PV, Wind, Microturbine, Fuel Cell, Engine)
NESC Requirements

NESC Code

NESC Requirements for De-energized Work

- Section 444 of the NESC details requirements
- Isolate - operate switches, disconnects and lockout/tag
- Test for voltage
- Install protective grounds on each side of the work location
Interconnection Rules:

• Technical Standards
• Testing and Certification
• Procedures,
  e.g., Application Forms and Processes, Agreements, Screens, Timelines, Fees, Insurance, Dispute Resolution, etc.
Testing and Certification

Use, and Validate Conformance to, Technical Stds
- Institute of Electrical and Electronics Engineers (IEEE) Standard 1547 series for Interconnecting Distributed Resources with Electric Power Systems
- American National Standards Institute (ANSI) standard code(s) for electricity metering
- Underwriters Laboratories (UL) 1741 - Inverters, Converters, and Controllers for Use in Independent Power Systems

Use, and Validate Conformance to, Applicable Codes
- e.g., building codes, national electrical code (NEC), national electrical safety code (NESC), and, related siting and permitting mandates

Require Accredited Test Labs

Require Installation-Evaluation/Commissioning Witnessing or Approval (typically as per above standards and codes; similar to existing approaches for like-products/systems)
IEEE 1547 Interconnection Standards Use:
Federal, Regional, State and Local Authorities/Jurisdictions

**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)

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**PJM Interconnection, Inc.**
**Small Generator Interconnection Standards**
**FERC approved**
(0-to<10MW and 10-to-20 MW; incorporate 1547 and 1547.1)

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

• Technical Standards
• Testing and Certification
• Procedures,

  e.g., Application Forms and Processes; Agreements; Screens, Timelines, and Fees; Relationship of Parties: Insurance, Dispute Resolution, Curtailment of Service, etc.

  - MADRI and FERC used to illustrate example issues or criteria
  - Also, see *Freeing The Grid* that provides an illustrative list of topical considerations to be addressed in procedures and agreements
Interconnection Procedures and Agreements

- Establish common processes and agreements for interconnection
- Consider different levels (screens) of review for proposed interconnection (based on power level and some grid technical parameters where it is to be interconnected)
- Fees
- Timelines for different levels, e.g.,
  -- Standard Process
  -- Fast Track Process
- Type Testing/Equipment Certification
Additional Interconnection Procedures and Agreements Topics

Relationships of Parties
- Insurance
- Dispute Resolution
- Relationship to Other Services:
  – Does not cover standby, backup, distribution charges, etc.
  – Some states have prohibition against utility using knowledge of project to offer discount rates or competing technology to keep customer on regular service
- Rights of curtailment and disconnection
Typical Interconnection Process (FERC-like)

1. Applicant submits completed application form and fee
2. Request complete?
   - YES: DG Facility ≤ 2 MW?
     - YES: Apply the screens for “Fast Track” interconnection
       - YES: Project passes the fast track screens
         - YES: Sign interconnection agreement
           - YES: Construction, commissioning and testing; operation
         - NO: Withdraw interconnection request
     - NO: Study Process
   - NO: More information provided?
     - YES: NO
     - NO: DG customer agrees to pay for any needed upgrades?
       - YES: Withdraw interconnection request
       - NO: NO
Foster regional consistency among states’ small generator interconnection procedures across Mid-Atlantic region.

Two Key Considerations:

• Technical Standards (establish common requirements for DG interconnection)
• Implementation Procedures (establish common processes and agreements for interconnection)
MADRI Procedures Overview

- Four Categories of Review (up to 10 MVA)
  - Level 1 <10kVA Inverter Based/Certified
  - Level 2 <2 MVA Inverter Based/Certified
  - Level 3A – DG Does Not Export Power
  - Level 3 – Up to 10 MVA

- Reference to PJM Small Generator Technical Requirements (IEEE 1547 Based)

- Procedures to Connect to Area Networks

- Criteria for Testing & Certification

- Two Standard Interconnection Agreements
  - 10 KVA and Less
  - > 10 KVA to 10 MVA

- Multiple DG Units – interconnection request evaluated based on total aggregate capacity

- Increase in Capacity for Existing System — new agreement based on total aggregate capacity
- Level 1 is for certified, inverter-based systems equal to or less than 10 kVA.

- Level 2 is for certified, inverter-based systems that are equal to or less than 2 MVA or systems that did not pass a Level 1 review.

- Level 3 is for systems equal to or less than 10 MVA which do not qualify for or did not pass the Level 1 or Level 2 reviews.

- Level 3A if for systems that do not qualify for Level 1 or Level 2 review and do not export power to the system.
Application Process: FERC small gen interconnection process

– “Fast Track Process” for systems not larger than 2 MW and

– “10 kW Inverter Process” for small inverter-based systems.

– The “Fast Track Process” includes an “Initial Review” and a “Supplemental Review” process.

– Projects not meeting screens of the Fast Track Process or of the 10 kW Inverter Process” move into the “Study Process” which includes provisions for a “System Impact Study” and a “Facilities Study”
Screening Studies

At higher screening levels, studies include:

- **Scoping Study** - A meeting to discuss the interconnection request and review existing studies

- **Feasibility Study** - Determines if there are obvious adverse impacts identified before additional studies are undertaken

- **System Impact Study** - Identifies the electric system impacts that would result if the proposed distributed generation project were interconnected without project or utility electric system modifications, focusing on adverse system impacts identified in feasibility study

- **Facilities Study** - Determines the specific equipment and costs needed to mitigate adverse system impacts
Non-FERC Example
Level 1 Detailed Procedures

Interconnection Customer submits a Level 1 Interconnection Request with appropriate fees.

- Is the application complete?
  - Yes
  - No

Interconnection Customer provides more complete information.

- Does the proposed interconnection qualify for Level 1 Review?
  - Yes
    - No

Interconnection Customer installs equipment provides 20 days notice for commissioning test and returns Certificate of Completion.

- EDC does not conduct an optional Witness Test within 10 days of notice of commissioning test
  - Yes
  - No

Interconnection Request is "deferred" approved.

12-18 rev.

Interconnection Customer has the option of resubmitting the Interconnection Request for consideration under a Level 2, Level 3 or Level 4 Review.
Non-FERC Example
Level 2 Detailed Procedures
Non-FERC
Example
Level 3 Detailed Procedures

[Flowchart diagram showing the process of interconnection review, including steps such as:
- Interconnection Customer submits an interconnection request with appropriate fees.
- Does the proposed interconnection qualify for Level 3 Review?
- Does the interconnection pass Level 2 impact screens?
- EDC provides Standard Interconnection Agreement.
- Customer signs Interconnection Agreement within 30 days.
- Construction is completed.
- EDC conducts an optional Witness Test within 10 days of commissioning test.
- Interconnection Request is reviewed.
- EDC determines interconnection is safe.
- Interconnection Customer installs equipment and provides 30 days notice for commissioning test and returns Certificate of Completion.
- Time limit hits.
- 12-18 rev.
]
Non-FERC Example Level 4 Detailed Procedures

Diagram of interconnection procedures:

1. Interconnection Customer submits interconnection request.
2. Is the interconnection request complete?
   - Yes: Proceed to the next step.
   - No: Interconnection Customer provides more information.
3. Is the interconnection request complete?
   - No: Interconnection Customer provides more information.
4. Scoping meeting (if necessary).
5. Is a feasibility study needed?
   - Yes: Does the feasibility study show that interconnection affects safety and reliability?
   - No: Continue to the next step.
6. Does the feasibility study show that interconnection affects safety and reliability?
   - Yes: Continue to the next step.
   - No: Continue to the next step.
7. Is a system impact study needed?
   - No: Continue to the next step.
   - Yes: Perform system impact study.
10. Interconnection Customer agrees to pay for any necessary interconnection facilities and upgrades to the electric system?
    - Yes: Continue to the next step.
    - No: Follow Level 2 procedures starting with "EDC provides standard Interconnection Agreement".
11. Withdraw interconnection request.

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THANK YOU!

Additional Background Slides Follow

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NREL (National Renewable Energy Laboratory)
Electricity, Resources and Building Systems Integration Center
Distributed Energy Systems Integration Group

* NREL  http://www.nrel.gov
  1617 Cole Blvd. MS5202  Golden, CO  80401-3393

And,
Vice Chair for IEEE Standards Coordinating Committee 21 (SCC21) for
Fuel Cells, Photovoltaics, Dispersed Generation, & Energy Storage
http://grouper.ieee.org/groups/scc21/

  - IEEE 1547 Series of Smart Grid Interconnection and IEEE PV standards,
    and IEEE 2030 series of Smart Grid interoperability standards
Example Interconnection Considerations for Photovoltaic Systems
Utility Concerns for PV System Installations
- Are They Valid?

“PV Installation Must be Studied”

- Generally, should not be necessary with residential PV
- Necessary with larger systems
- State Rules (or utility policies) may waive requirements or limit cost
- What are the proposed costs of the study? Are the proposed costs reasonable?
Utility Concerns for PV System Installations

“The utility system must have upgrades”

- Service Transformer
  - DG sized larger than existing transformer?
- Utility Distribution Lines
  - Capacity of line insufficient? Unlikely for other than very large DG systems
- Protective Equipment (Fuses, Reclosers, Breakers)
  - Modifications or additions of new PE unlikely unless high penetration or larger DG systems
- Substation Level and beyond
  - Very unlikely, but would involve detailed studies and high costs. PUC approval required
Utility Concerns for PV System Installations

“The penetration of PV is too high”

– Rules may prohibit PV interconnection on feeders with high penetration (greater than X%?)
– Solutions may not be practical or necessary
– High penetration PV is being studied by NREL, Utilities, other organizations
– Guidelines must be developed for High Penetration PV deployment – minimize expensive and lengthy studies
– PV Penetration must be redefined!
Required Information for Permit

Site plan showing location of major components on the property. This drawing need not be exactly to scale, but it should represent relative location of components at site (see supplied example site plan). PV arrays on dwellings with a 3’ perimeter space at ridge and sides typically would not need fire service approval.

Electrical diagram showing PV array configuration, wiring system, overcurrent protection, inverter, disconnects, required signs, and ac connection to building (see supplied standard electrical diagram).

Specification sheets and installation manuals (if available) for all manufactured components including, but not limited to, PV modules, inverter(s), combiner box, disconnects, and mounting system.
# IEEE 1547 Series Standards

<table>
<thead>
<tr>
<th>Standard Code</th>
<th>Description</th>
<th>Reaffirmed/Updated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1547-2003</strong></td>
<td>Standard for Interconnecting Distributed Resources (DR) with Electric Power Systems (EPS)</td>
<td><strong>Reaffirmed in 2008</strong></td>
</tr>
<tr>
<td><strong>1547.1-2005</strong></td>
<td>Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems</td>
<td><strong>Reaffirmed in 2011</strong></td>
</tr>
<tr>
<td><strong>1547.2-2008</strong></td>
<td>Application Guide for IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems</td>
<td></td>
</tr>
<tr>
<td><strong>1547.3-2007</strong></td>
<td>Guide for Monitoring, Information Exchange and Control of DR</td>
<td></td>
</tr>
<tr>
<td><strong>1547.4-2011</strong></td>
<td>Guide for Design, Operation, and Integration of Distributed Resources Island Systems with Electric Power Systems</td>
<td><strong>{“Microgrids”}</strong></td>
</tr>
<tr>
<td><strong>P1547.5</strong></td>
<td>Draft Guidelines for Interconnection of Electric Power Sources Greater Than 10 MVA to the Power Transmission Grid</td>
<td></td>
</tr>
<tr>
<td><strong>1547.6-2011</strong></td>
<td>Recommended Practice for Interconnecting Distributed Resources With Electric Power Systems Distribution Secondary Networks</td>
<td></td>
</tr>
<tr>
<td><strong>P1547.7</strong></td>
<td>Draft Guide to Conducting Distribution Impact Studies for DR Interconnection</td>
<td></td>
</tr>
<tr>
<td><strong>P1547.8</strong></td>
<td>Draft Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Std 1547</td>
<td></td>
</tr>
</tbody>
</table>
IEEE 1547 IS:

IEEE 1547.1 IS:
Test Procedures
Conformance to 1547

IEEE 1547 Is NOT:

- **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.
- **Should be sufficient** for most installations.

- 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.
INTRODUCTION

1.0 OVERVIEW
1.1 Scope
1.2 Purpose – Uniform standard requirements
1.3 Limitations – 10 MVA or less

2.0 REFERENCES

3.0 DEFINITIONS
IEEE 1547 Definitions

- **Distributed Resource (DR)** – sources of electric power that are not directly connected to a bulk power transmission system
- **Electric Power System (EPS)** – facilities that deliver power to a load
- **Interconnection** – the result of the process of adding a DR unit to an area EPS
- **Interconnection Equipment** – individual or multiple devices used in an interconnection system
- **Interconnection System** – the collection of all interconnection equipment, taken as a group, used to interconnect a DR unit(s) to an area EPS
- **Point of common coupling (PCC)** - the point where a Local EPS is connected to an Area EPS.
1547 Interconnection Terms

Area Electric Power System (EPS)

PCC

Point of Common Coupling (PCC)

Load

DR unit

Local EPS 1

Local EPS 2

Local EPS 3

Note: There can be any number of Local EPSs.
IEEE Std 1547: Interconnection system requirements & specifications, and test requirements & specifications; generally, the 1547 requirements apply at the point of common coupling however the equipment or devices to meet the requirements may be located elsewhere.
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
4.0 Interconnection Technical Specifications and Requirements

4.1 General Requirements

- Voltage Regulation
- Integration with Area EPS Grounding
- Synchronization
- DR on Secondary Grid and Spot Networks

- Inadvertent Energizing of the Area EPS
- Monitoring Provisions
- Isolation Device
- Interconnect Integrity
4.2 Response to Area EPS Abnormal Conditions

- Area EPS Faults
- Area EPS Reclosing Coordination
- Voltage

- Frequency
- Loss of Synchronism
- Reconnection to Area EPS
4.3 Power Quality

- Limitation of DC Injection
- Limitation of Voltage Flicker Induced by the DR
- Harmonics

4.4 Islanding

- Unintentional Islanding
- Intentional Islanding
5.0 INTERCONNECTION TEST SPECIFICATIONS AND REQUIREMENTS

5.1 Design Test

- Abnormal voltage and frequency
- Synchronization
- Interconnection integrity

- Unintentional islanding
- Limitation of DC injection
- Harmonics
5.2 Production Tests

Meet requirements of:
- response to abnormal voltage and frequency
- synchronization
- may be performed at the factory or at time of commissioning

5.3 Interconnection Installation Evaluation

- Grounding Integration with area EPS
- Isolation Device
- Monitoring provisions
- Area EPS faults
- Area EPS reclosing coordination
5.4 Commissioning Tests

- Visual Inspection
- Operability test on the isolation device
- Unintentional islanding functionality test
- Cease to energize functionality test

5.5 Periodic Interconnection Tests

- All interconnection-related protective functions and associated batteries

Annex A. Bibliography
IEEE Std 1547.2 (application guide to IEEE 1547)

... background and rationale of {IEEE 1547} technical requirements are discussed...
Presented ... are technical descriptions, schematics, applications guidance, and interconnection examples to enhance the use of IEEE 1547...

Figure A.1 – Functional diagram of an interconnection system
IEEE Std 1547.3 MIC for DR

... guidelines for MIC (monitoring, information exchange, and control) for DR (distributed resources) interconnected with electric power systems (EPS).

4. General information about monitoring, information exchange and control (MIC)
   4.1 Interoperability
   4.2 Performance
   4.3 Open Systems Approach
   4.4 Extensibility

5. Data exchange guidelines based on 4.1.6 of IEEE Std 1547

6. Business and operation processes

7. Information exchange model

8. Protocol Issues

9. Security guidelines for DR implementation
   Annexes (informative)
... guidelines for monitoring, information exchange, and control (MIC) for distributed resources (DR) interconnected with electric power systems (EPS).

### 1547.3 Figure 1
Reference diagram for information exchange.
IEEE Std 1547.4 (micro-grids/planned DER Islands)

E.g., DER (generation and energy storage) technologies are integrated with all others including the grid technologies to form **Micro-grids (planned islands)**; includes – load management, voltage & VAR control, active participation, etc.

Figure 1 – Examples of DR island systems
• Describes **criteria, scope, & extent for engineering studies** of the impact of DR on distribution system.
• **Methodology for performing** engineering studies.
• Study scope and extent described as functions of **identifiable characteristics of**:
  - the distributed resource,
  - the area electric power system, and
  - the interconnection.
• **Criteria described for determining the necessity** of impact mitigation.
• Guide allows a described methodology for:
  - **When** impact studies are **appropriate**, 
  - **What data** is required,
  - **How** studies are **performed**, and
  - **How** the study **results are evaluated**.
P1547.8 Recommended Practice … to Extend Use of 1547

• Need for P1547.8 is to address industry driven recommendations and NIST smart grid standards framework recommendations (e.g., NIST priority action plans).

• Example considerations include: voltage ride thru; volt-ampere reactive support; grid support; two-way communications and control; advanced/interactive grid-DR operations; high-penetration levels and multiple interconnections; interactive inverters; energy storage; electric vehicles; DR (and aggregates) greater than 10 MVA; etc.