Accelerating DER Development and Validation

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SIRFN DER Test Protocols Task Objectives

Build **open-source software tools, test beds, consensus test protocols, and automated scripts** to be used by DER vendors, universities, research institutions, certification laboratories, standards organizations, etc.

Inputs to **national and international standards** development has major impact on the capabilities of smart grid and DER equipment for electrical performance and communications capabilities.

Utility-Interactive Converter Functions are Smart Grid Building Blocks
Why is SIRFN doing this?

- **Interoperable DER are critical for increasing renewable energy penetrations** on the power system.
  - DER certification tests *provide grid operators confidence* that the equipment will behave as designed.

- Standards often include **multiple errors**, of varying size, which are undetected in the writing process.
  - **Standards Development Organizations (SDOs)** need more quantitative support in standards development prior to publication.
  - Where possible, SDOs incorporate field observations, industry experience, and simulation results from stakeholders.
  - Unfortunately, some certification standards are written with little or no experimental results to back test procedures, parameters, and pass/fail criteria.

- SDOs benefit significantly when they can gather results from **power system models, DER electrical testing, interoperability experiments, field demonstrations**, etc.
  - Once labs dig deep into (ideally draft) standards, they can drastically **improve the content**.
Automated DER Certification Testing

- The SIRFN community is using the open-source test platform known as **System Validation Platform (SVP)** for evaluating DER test protocols.
- It **automates the execution of tests/evaluations by communicating to laboratory equipment** as well as the Equipment Under Test (EUT) in a laboratory test setup.
- The SVP uses **abstraction layers** so the same test scripts work for all laboratory testbeds by adjusting the underlying **equipment drivers**.

![Diagram of System Validation Platform](image)
Software Development Progress

**Testbed drivers and abstraction layers (SVP Energy Lab)**
- DER protocols – SunSpec, IEEE 2030.5, IEEE 1815, Modbus
- HIL systems – Opal-RT, Hyphoon HIL
- Data Acquisition – LabVIEW, Tektronix, Yokagawa, DEWETRON
- DC Simulators – Ametek TerraSAS, Chroma, Keysight, NHR
- Grid Simulators – Ametek, Chroma, Pacific, Spitzenberger Spiess, SunRex

**Test scripts for IEEE 1547.1**
- Constant power factor, volt-var, frequency-droop, and volt-watt
- Limit active power, constant reactive power, active power-reactive power (watt-var), and prioritization of grid-support functions
- Voltage ride-through, frequency ride-through, and rate of change of frequency (ROCOF) ride-through, and voltage phase-angle change ride-through
- Interoperability for SunSpec Modbus, IEEE 2030.5, and IEEE 1815

**Test scripts for AS-NZS 4777.2**
- Constant power factor, constant reactive power, and volt-watt

**Test scripts for UL 1741 SA and UL 1741 SB**
- Normal ramp rate, soft start ramp rate
- Specified power factor, volt-var, and frequency-watt

SVP is written in Python 3.7+

https://github.com/jayatsandia/svp_energy_lab

https://github.com/jayatsandia/svp_1547.1

https://github.com/BuiMCanmet/DR_AS-NZS-Scripts

https://github.com/jayatsandia/svp_UL1741SA
Prior Work - Publications

**Compliance Protocol**: A pre-standardization Sandia test procedure for IEC TR 61850-90-7 [1], [2]
- connect/disconnect, active power curtailment, and power factor [3]
- connect/disconnect, active power curtailment, power factor, reactive power-priority volt-var [4]

**Compliance Protocol**: A SIRFN-developed test procedure for ESS devices [5]
- active power, fixed power factor, volt-var, and frequency-watt [6]

**Compliance Protocol**: UL 1741 SA
- volt-var and specified power factor [7]
- normal ramp rate, soft start ramp rate, specified power factor, volt-var, and frequency-watt [8]

**Compliance Protocol**: IEEE 1547.1-2020
- constant power factor, volt-var, frequency-droop, and volt-watt [9]
- limit active power, constant reactive power, active power-reactive power (volt-var), and prioritization of grid-support functions [10]
- voltage phase-angle change ride-through [11]
- voltage ride-through, frequency ride-through, and rate of change of frequency (ROCOF) ride-through [12]

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Example of adopting Automated DER Testing

- The test procedure based on IEEE 1547.1 is about 3,000 cases or more, which may increase time and cost.
- Verification was conducted in a facility that is also used for 500 kVA class certification testing, and it was shown that the test time could be reduced by as much as 85%.
- The test automation platform worked on at SIRFN will be applied to a large 5MVA-class test facility at AIST, Japan.

### Increased number of test cases

<table>
<thead>
<tr>
<th></th>
<th>1st Edition</th>
<th>2nd Edition</th>
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</thead>
<tbody>
<tr>
<td>1547 technical content:</td>
<td>13 pages</td>
<td>127 pages</td>
</tr>
<tr>
<td>1547.1 technical content:</td>
<td>54 pages</td>
<td>256 pages</td>
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</tbody>
</table>

### The platform will install next 5MVA facility

DER Testing and Verification - Overview of IEEE P1547.1, Anderson Hoke, Presentation at PJM Technical Workshop on DER Integration, July 30, 2019


The SVP can reduce the test time
Other SIRFN activities – Advanced Lab Testing Methods

- Encourage participation and collaboration among testing facilities focused on the identification of the next generation of advanced laboratory testing methods.
- Significantly reduces the time and cost required for evaluation and certification.
- Enables flexible construction of test environments to meet the increasingly sophisticated and complex requirements of renewable energy power sources.

**Advantage to use HIL(virtual) testing**

<table>
<thead>
<tr>
<th>Time/cost required for evaluation/certification</th>
<th>Now</th>
<th>Future</th>
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<tbody>
<tr>
<td>Full hardware testing</td>
<td></td>
<td>Full hardware testing</td>
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<tr>
<td>HIL testing</td>
<td></td>
<td>Full hardware testing</td>
</tr>
</tbody>
</table>

**Impact assessment of GFL/GFM inverter on different RE installed capacities.**

![Graph showing impact assessment](image-url)
Thank You

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Standards Development Tradeoffs

• Types of Standards
  • DER Interconnection Standards – e.g., IEEE 1547-2018
  • Certification Standards – e.g., IEEE 1547.1-2020
  • Communication Standards – e.g., IEEE 2030.5-2018
  • Cybersecurity Standards/Guides – e.g., IEEE 1547.3-2023

• National and Research Laboratory Role in Standards Development is Critical
  • Research-based, data-backed direction to standards
  • Practical, balanced solution to support industry growth
  • Long-term solutions are prioritized
  • Labs don’t have a dog in the fight
    • DER manufacturers tend to resist requirements
    • Certification labs & grid operators want more extensive requirements

Fewer Requirements
• Lower bar to market entry
• Reduced product cost
• Greater ambiguity in DER performance, communications, security requirements, etc.

More Requirements
• Higher bar to market entry
• Longer product development timelines
• Tighter tolerance in equipment response and behaviors
• Reduced ambiguity in data exchanges, DER performance, etc.
Standards Development Challenges

• Standards often include **multiple errors**, of varying size, which are undetected in the writing process.
  • **Standards Development Organizations (SDOs)** need more quantitative support in standards development prior to publication.
  • Where possible, SDOs incorporate field observations, industry experience, and simulation results from stakeholders.
  • Unfortunately, some certification standards are written with little or no experimental results to back test procedures, parameters, and pass/fail criteria.
  • Once detected, there are **amendments, revisions**, or other “refinements”

• SDOs benefit significantly when they can gather results from power system models, DER electrical testing, interoperability experiments, field demonstrations, etc.
  • **Difficult for labs** to get funding and complete the research in time to edit the draft.
  • Once labs dig deep into (ideally draft) standards, they can drastically improve the content.
Examples of Issues Uncovered by Lab Experiments

Interoperability Standards

- **Missing/incomplete definitions**
  - Does IEEE 1547-2018 require DER support six-point P/Q and P'/Q' WV curves?
  - IEEE 1547-2018 does not include a standardized unit for reactive power, preferably %VAMax.
  - Missing points, poor naming conventions, problems with scale factors, etc. in interoperability standards, e.g., SunSpec Modbus.
  - The IEEE 1815 DNP3 App Note should add Manufacturer, Model, Serial Number, and Version Data to the AI points.
  - There is no clear IEEE 2030.5 mechanism to disable controls.

- **Ambiguous statements**
  - Not clear if the IEEE 1547.1-2020 DNP3 management information tests require electrical experiments.
  - No description for how values changed in the IEEE 1547.1-2020 Configuration Data Test.
  - Missing IEEE 1547.1-2020 allowable tolerance on test results.
  - Does Reactive Power (Injected) and Reactive Power (Absorbed) Monitoring Information Operating Points indicate the active power direction or excitation in IEEE 1547.1-2020?

- **Harmonization issues** between DER interoperability standard information models
  - SunSpec includes an Anti-islanding Enable/Disable point; IEEE 2030.5/CSIP and IEEE 1815/DNP3 App Note do not.

Interconnection Standards

- **IEEE 1547.1-2020 Voltage and Frequency Ride-Through Experiments**
  - Ambiguous voltage ride-through momentary cessation test conditions resulted in inconsistent results
  - Team recommended IEEE 1547.1 precisely defined test voltages to standardize test results.
  - Error: Frequency ride-through measurement time insufficient to assess DER output power.
  - Team recommended extending the minimum recording time for FRT tests with frequency-droop response to include the response time of frequency-droop function.

- **IEEE 1547.1 Draft Active Power-Reactive Power Mode (Watt-Var)**
  - Error: Watt-Var curve was evaluated at 20% and 66% of rated EUT power, but the curtailment does not expose the characteristics of the WV curve.
  - Team recommended three sweeps of the WV curve without any active power limitation.

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