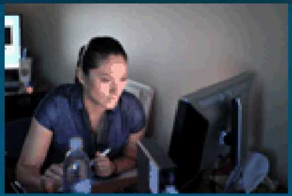
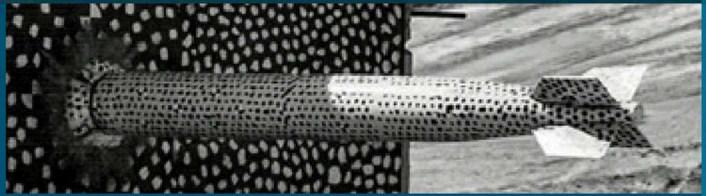
SAND2019-2996PE

Typhoon HIL

Automated Interoperable Grid-Support Function Testing in a C-HIL Environment

AUSTRIAN INSTITUTE OF TECHNOLOGY





Typhoon HIL Webinar

14 March 2019

PRESENTED BY

Jay Johnson, Sandia National Laboratories

Zoran Miletic, Austrian Institute of Technology

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Background

The context

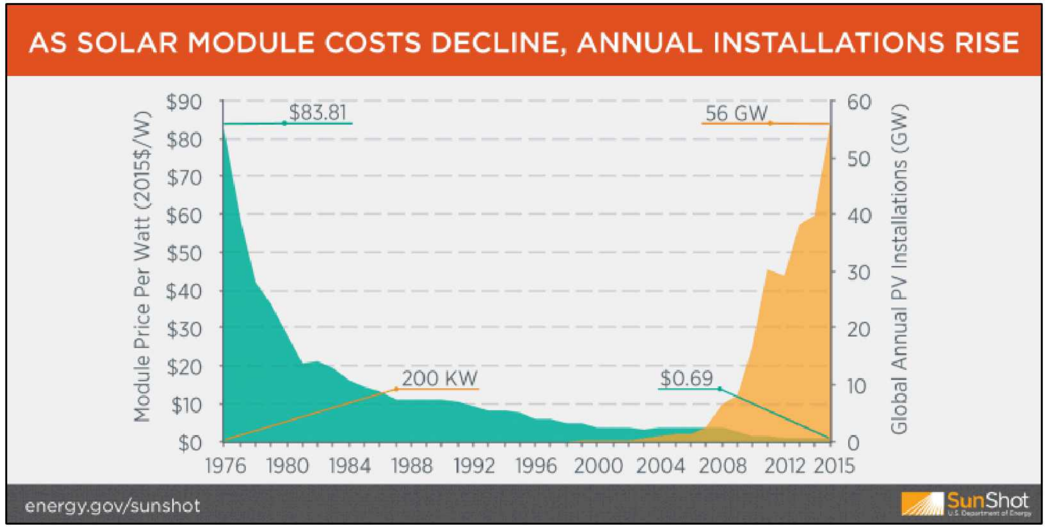
- Total installed capacity of PV is growing fast in the world
- Large growth expected in distribution systems

The problem

- Because the grid is slow to evolve, we encounter technical challenges with voltage/frequency regulation, protection, etc.
- Unless mitigated, these challenges will make it increasingly difficult and costly to continue integrating renewable energy

Advanced inverters are a big part of the solution

- Actively support voltage and frequency by modulating output
- Have high tolerance to grid disturbances
- Interact with the system via communications



...Faster than a tap changer

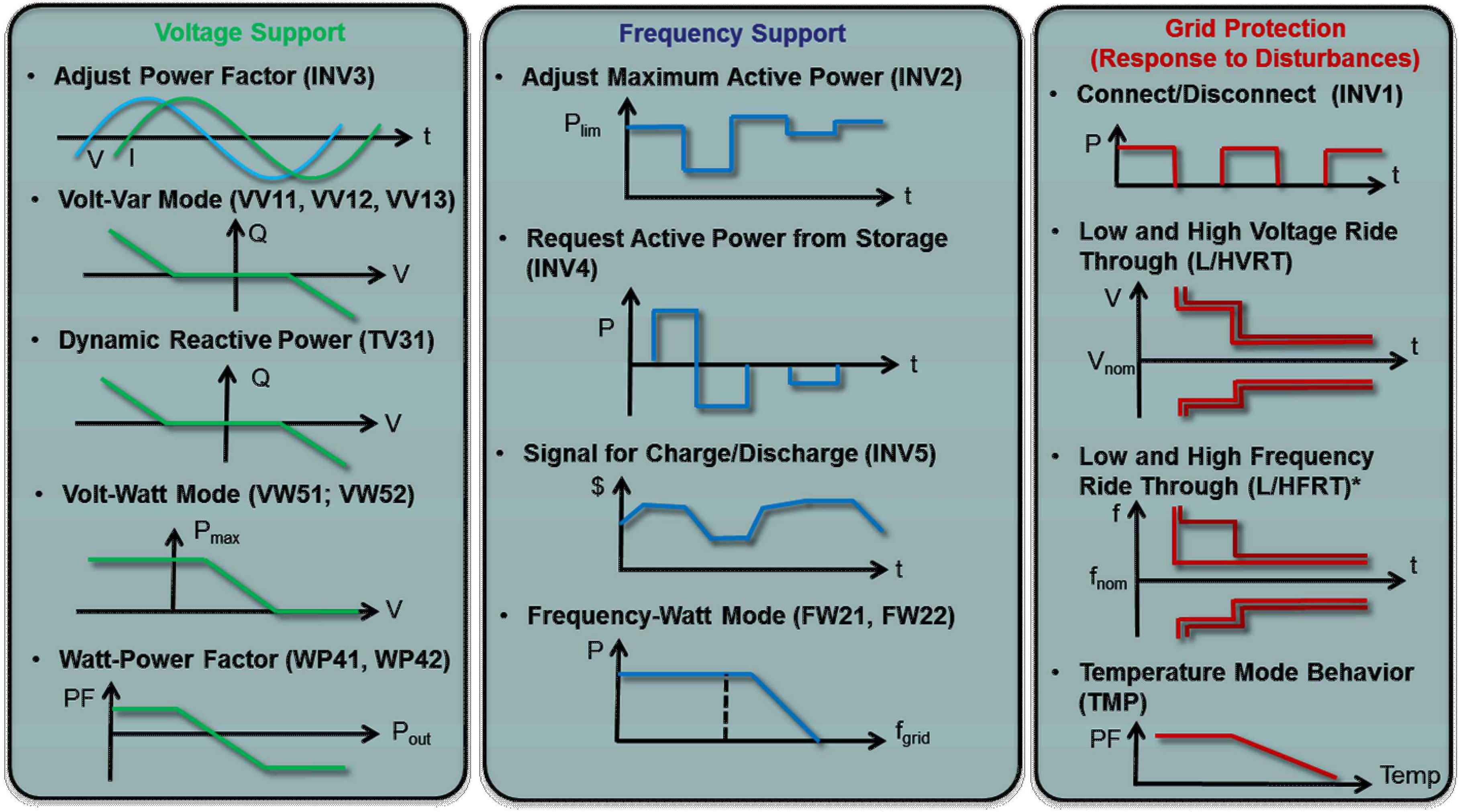
...More powerful than a rotating machine

...Able to leap deep voltage sags in a single bound

Courtessy of B. Lydic, Fronius

Grid-Support Functions

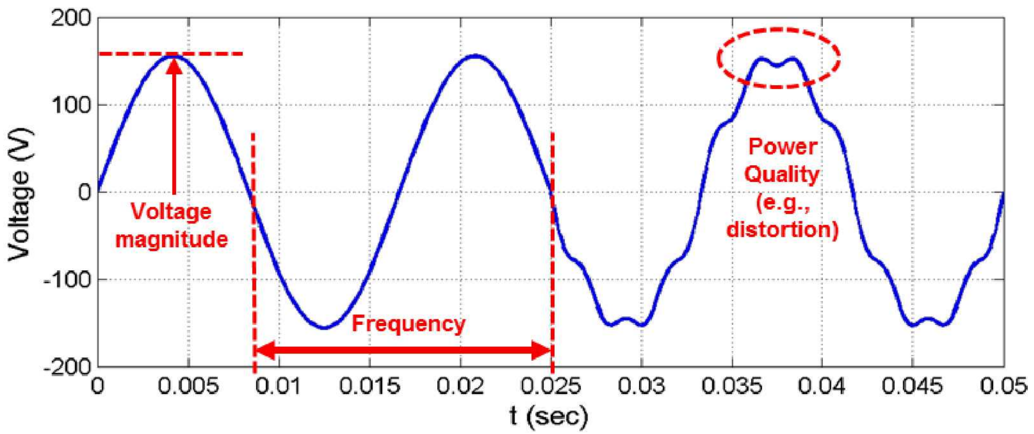
- Functional definitions describe how functions are implemented
- Autonomous: Inverter response to local voltage and frequency conditions
- Commanded: Remote control (e.g., on/off) and configure autonomous behavior

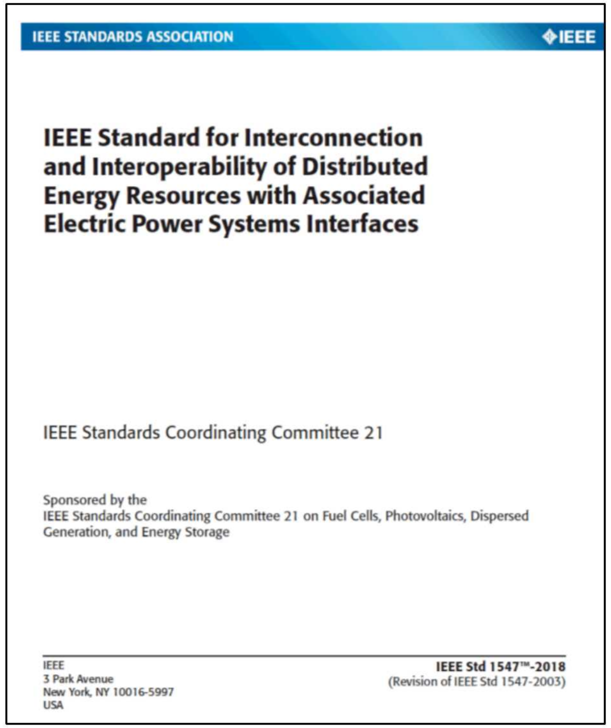


DER grid-support functions in IEC 61850-90-7 and FRT.

Importance of DER Certification

- **Standardized certification to verify DER functionality and interoperability are critical**
- This process **ensures DER equipment will operate and communicate as anticipated** in the field by inspecting “corner cases” that could lead to unexpected device behavior
  - Vendors can be certain their equipment will function as designed
  - Provides grid operators confidence the equipment is reliable
- The American interconnection standard, IEEE Std. 1547, was updated in 2018 with new grid-support functionality and interoperability requirements
  - IEEE Std. 1547.1 is nearly updated to include the conformance testing requirements for 1547. This includes hundreds of test cases for each DER





IEEE STANDARDS ASSOCIATION ◆IEEE

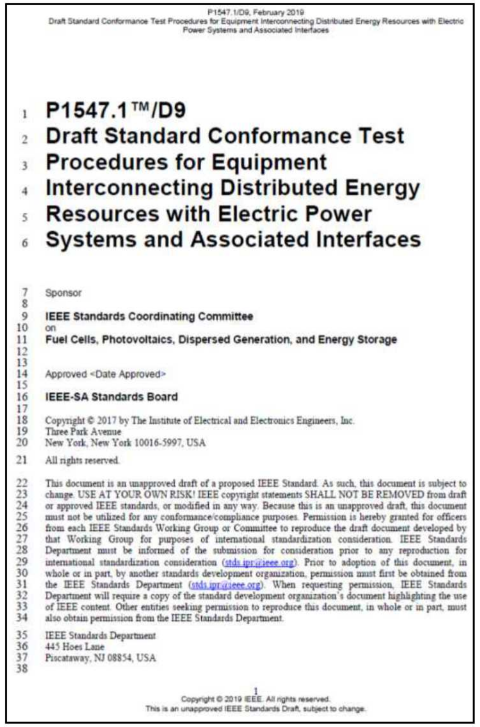
IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE Standards Coordinating Committee 21

Sponsored by the
IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1547™-2018
(Revision of IEEE Std 1547-2003)



P1547.1/D9, February 2019
Draft Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces

P1547.1™/D9
Draft Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces

Sponsor

IEEE Standards Coordinating Committee
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Approved <Date Approved>

IEEE-SA Standards Board

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SIRFN Certification Testing of DER

The **Smart Grid International Research Facility Network (SIRFN)** is conducting interoperability certification experiments with DER

The multi-lab team is assessing multiple residential-scale PV inverters using the IEEE 1547.1 standard to **provide feedback to the standards development organization** where there is ambiguity or errors

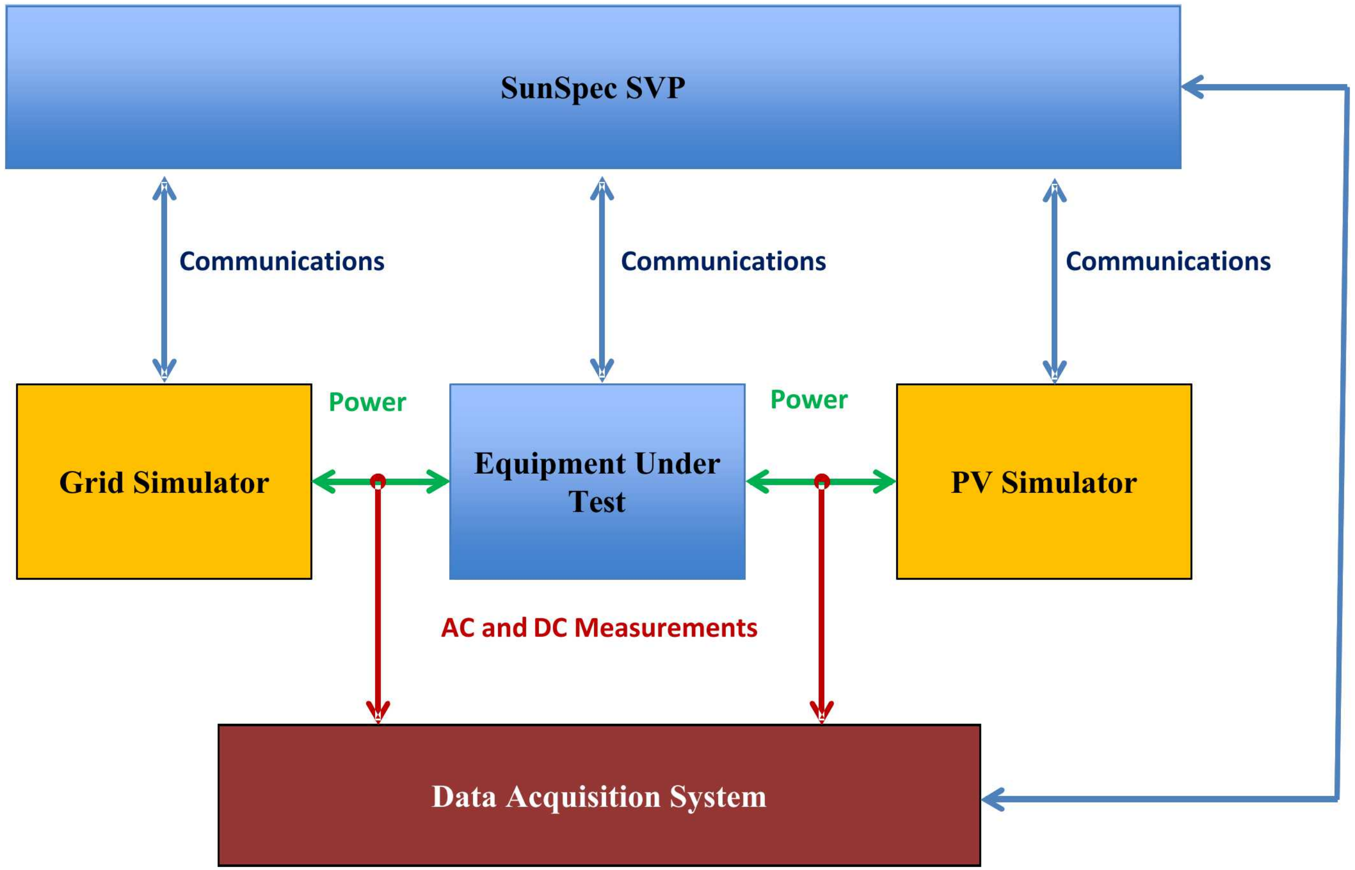
SIRFN ISGAN INTERNATIONAL SMART GRID ACTION NETWORK CLEAN ENERGY MINISTERIAL iea Energy Technology Network

System Validation Platform

DER vendors, NRTLs, and research labs need **a software solution to autonomously conduct test procedures**

The **System Validation Platform (SVP)** is co-developed by Sandia, SunSpec Alliance, and SIRFN for automated DER interconnection and interoperability testing.

The SVP communicates to grid simulators, equipment under test, battery/PV simulators, data acquisition systems, and additional test equipment (loads, switches, HIL environments, etc.) to run the interoperable grid-support function experiments, generate data sets, and plot results.

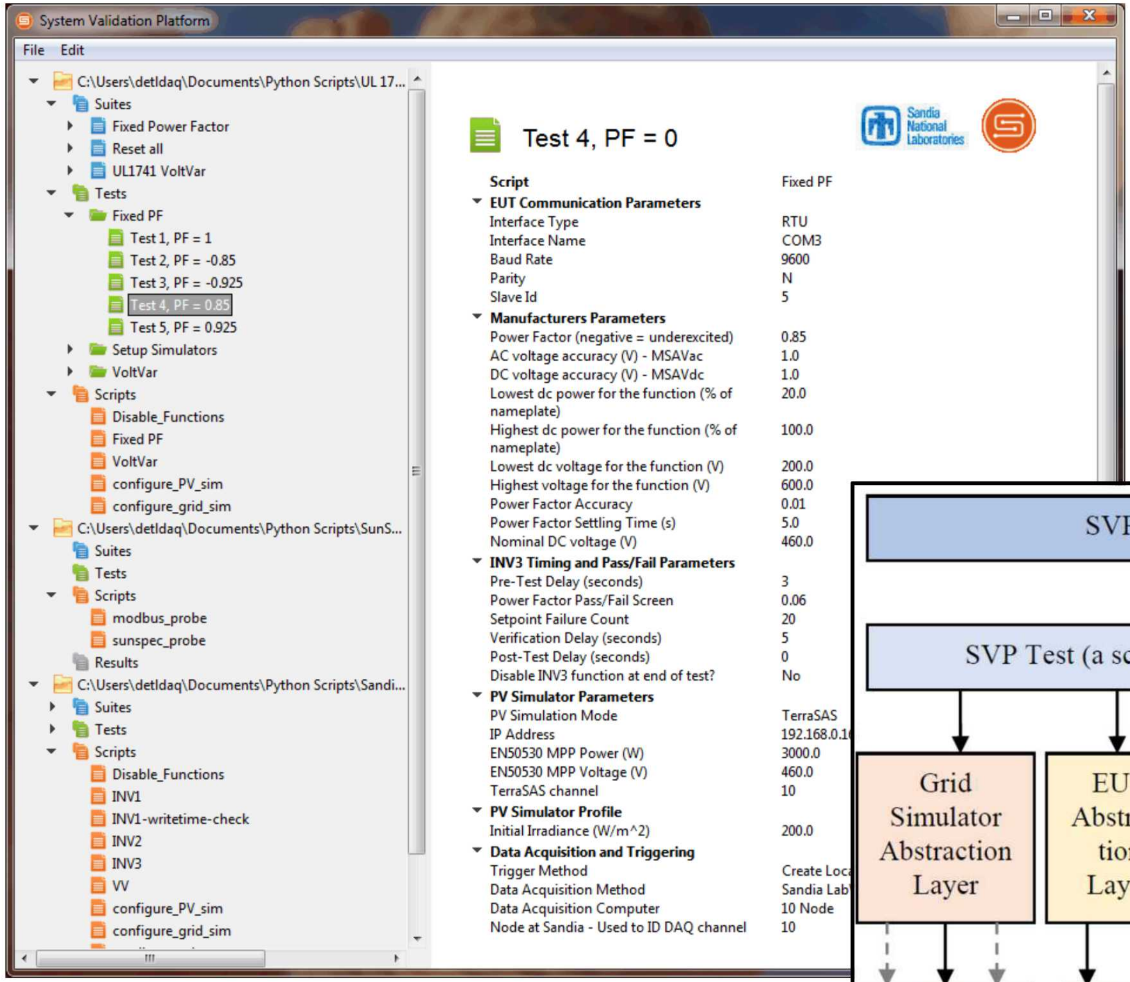


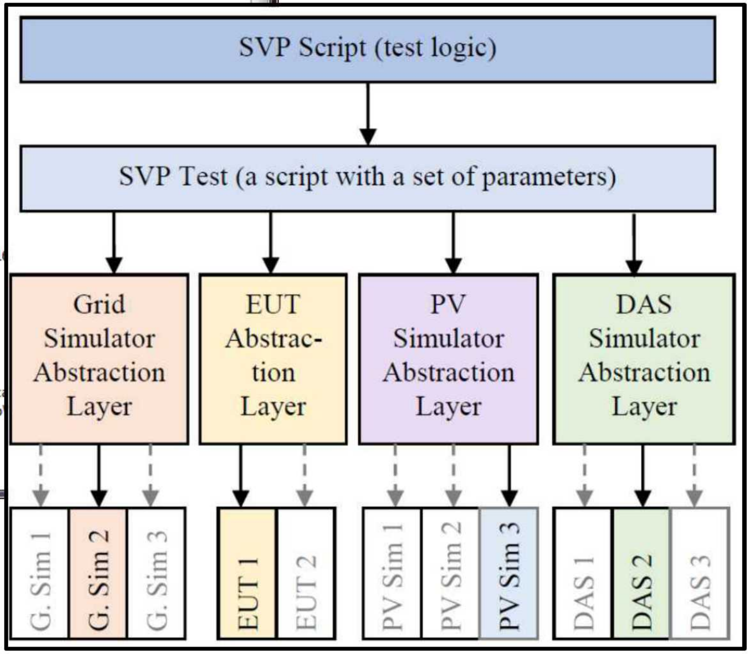
System Validation Platform

SVP is a fully scriptable automated certification interoperability platform

Abstraction layers for each equipment type connects the testing logic to communication drivers.

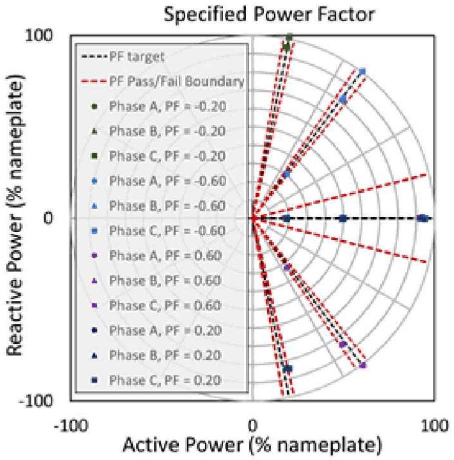
- This means the same test logic can be executed at the laboratories, even through the physical equipment is different at the labs.



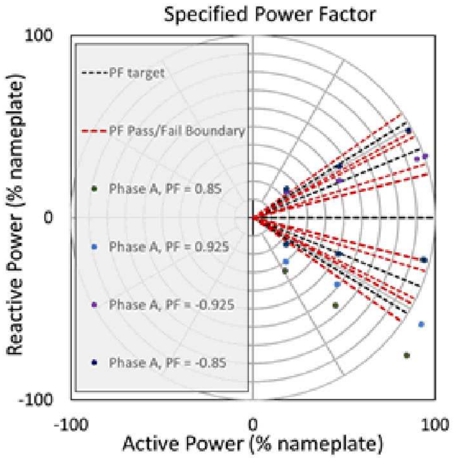


See: http://sunspec.org/sunspec-svp/
http://sunspec.org/download-svp/
https://github.com/sunspec/svp_directories

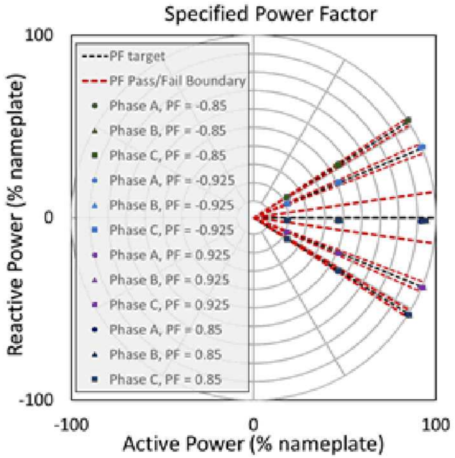
Example Results with Physical DER Equipment



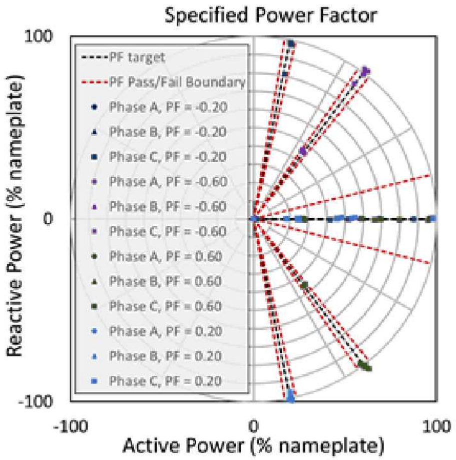
(A) 34.5 kW ASGC Solar Inverter, Reactive Power Priority, Sandia



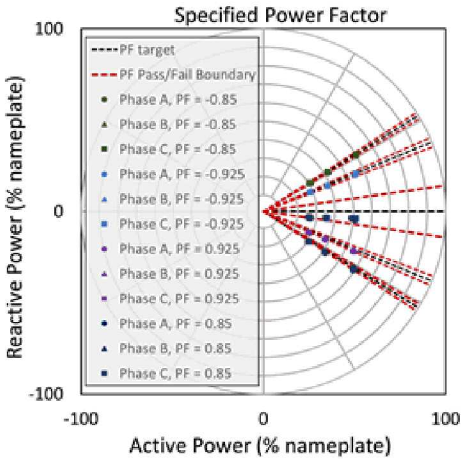
(B) 3.0 kW Solar Inverter, Reactive Power Priority, Sandia



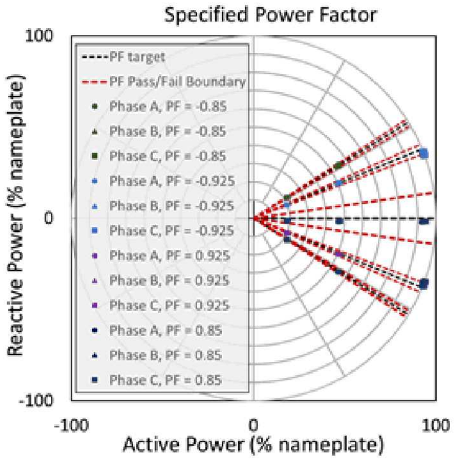
(C) 10.0 kW Solar Inverter, Reactive Power Priority, CanmetENERGY



(D) 34.5 kW ASGC Solar Inverter, Reactive Power Priority, AIT



(E) 15.0 kW Solar Inverter, Reactive Power Priority, CSIRO



(F) 10.0 kW Solar Inverter, Active Power Priority, CanmetENERGY

References:

1. J. Johnson, et al., "**International Development of a Distributed Energy Resource Test Platform for Electrical and Interoperability Certification**," 7th World Conference on Photovoltaic Energy Conversion (WCPEC-7), Waikoloa, HI, 10-15 Jun 2018.
2. D. Rosewater, J. Johnson, M. Verga, R. Lazzari, C. Messner, R. Bründlinger, K. Johannes, J. Hashimoto, K. Otani, "**International Development of Energy Storage Interoperability Test Protocols for Renewable Energy Integration**," EU PVSEC, Hamburg, Germany, 14-18 Sept 2015.
3. J. Johnson, R. Bründlinger, C. Urrego, R. Alonso, "**Collaborative Development of Automated Advanced Interoperability Certification Test Protocols for PV Smart Grid Integration**," EU PVSEC, Amsterdam, Netherlands, 22-26 Sept, 2014.

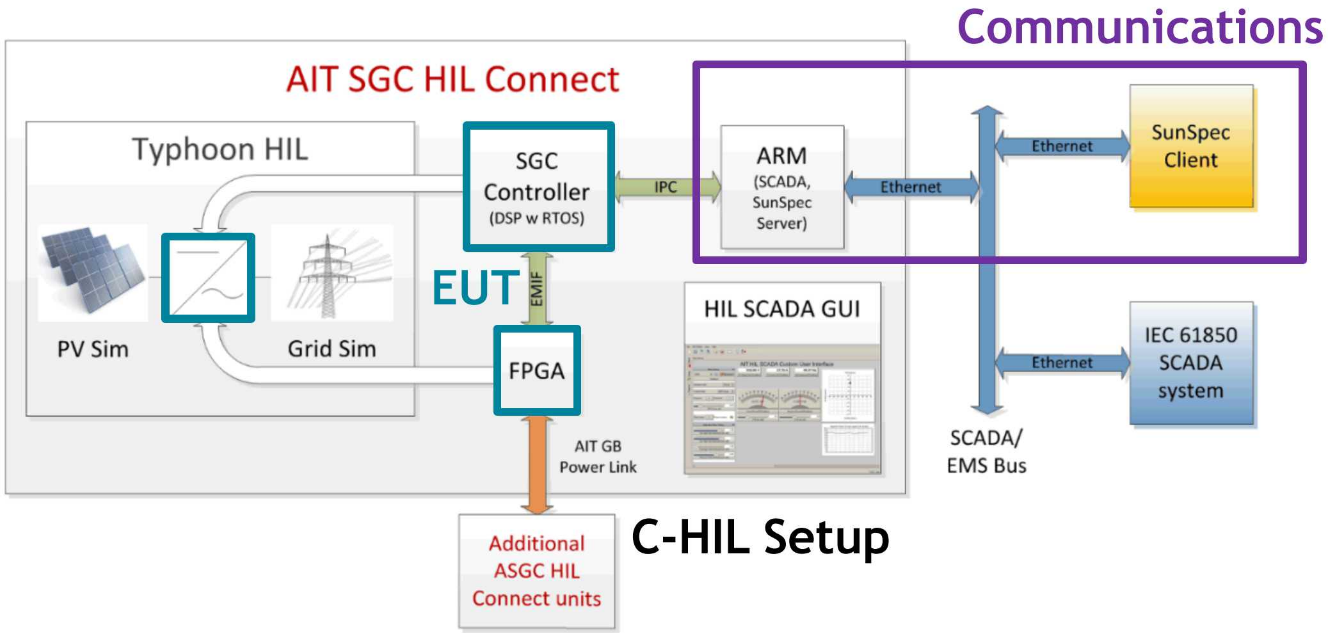
Alternative Option: C-HIL

A controller hardware-in-the-loop (C-HIL) alternative has been developed

- Converts components of large-scale, high-voltage DER testing to a less expensive, safer benchtop testing system.

Adds value for DER vendors, certification labs, universities, and standards development organizations (SDOs)

- Allows quick design iterations of the communication system to provide interoperability to a range of equipment and standards
- Executes certification tests to verify controller operation prior to hardware integration
- Can be used by SDOs to rapidly draft interconnection and interoperability codes and standards



Austrian Institute of Technology has commercialized the converter for C-HIL

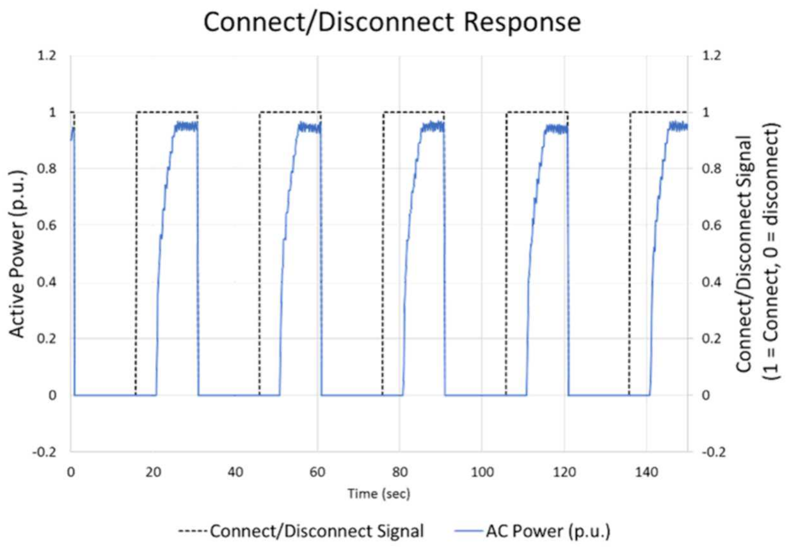
Details: J. Johnson, R. Ablinger, R. Bruendlinger, B. Fox, J. Flicker, "**Interconnection Standard Grid-Support Function Evaluations using an Automated Hardware-in-the-Loop Testbed**," IEEE Journal of Photovoltaics, vol. 8, no. 2, pp. 565-571, Mar 2018. DOI: 10.1109/JPHOTOV.2018.2794884

J. Johnson, R. Ablinger, R. Bruendlinger, B. Fox, J. Flicker, "**Design and Evaluation of SunSpec-Compliant Smart Grid Controller with an Automated Hardware-in-the-Loop Testbed**," Technology and Economics of Smart Grids and Sustainable Energy, vol. 2, no. 16, Dec. 2017. DOI: 10.1007/s40866-017-0032-7

Details of the ASGC

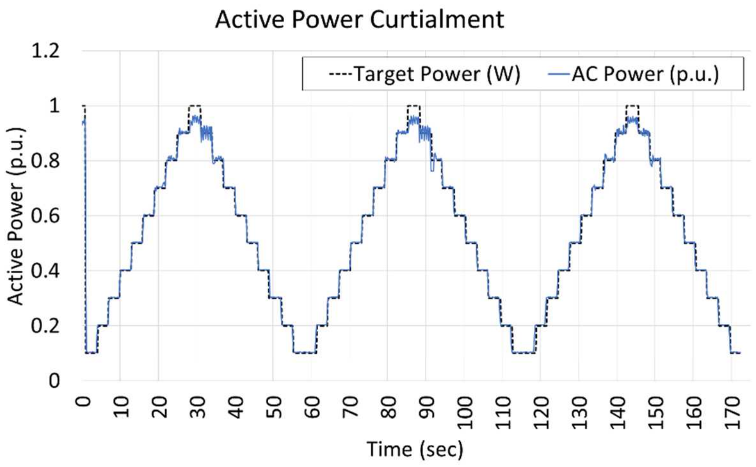
Zoran please add 2-3 slides here.

Example C-HIL Test Results



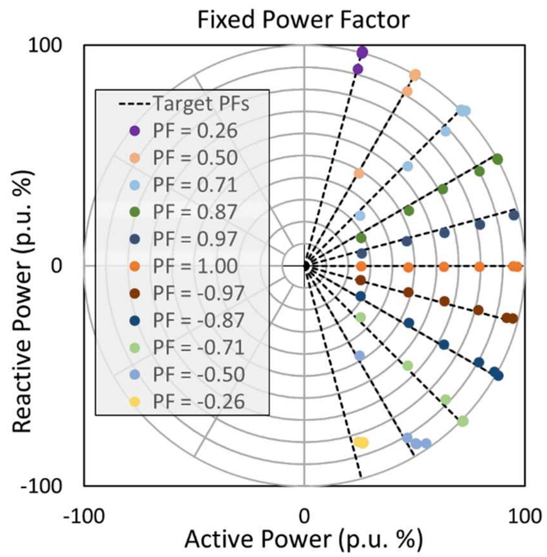
Connect/Disconnect

- For emergency protection situations
- Issued 5 disconnect and 5 connect commands
- Disconnect is quick (< 1 sec), connect requires ~5 sec for synchronization and ~5 sec for MPPT.



Active Power Curtailment

- Stepped target power level up and down in 10% increments, 3 times
- EUT tracks target power level well, except at MPP where the efficiency of the device is seen.



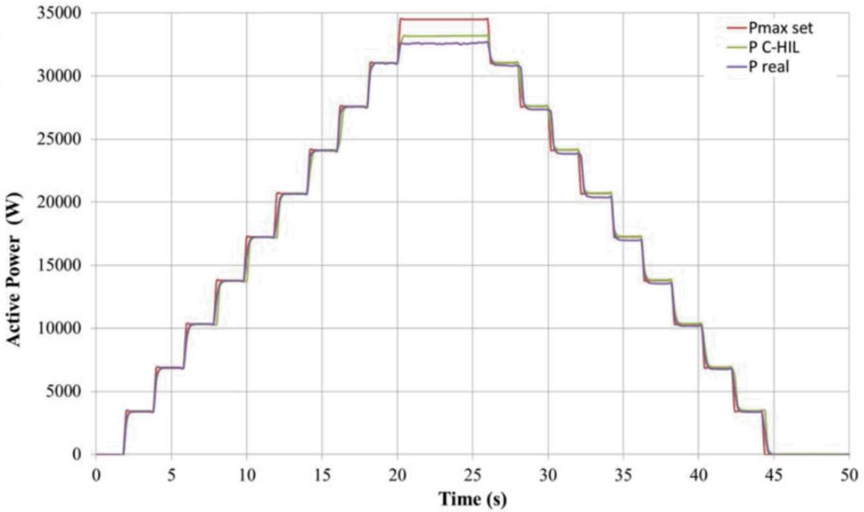
Fixed Power Factor

- Voltage regulation function
- Programmed 11 target PFs and set PV irradiance to 100, 250, 450, 600, 750, 900, and 1000 W/m^2
- EUT maximized P, while maintaining PF.
- Generally quite accurate behavior.

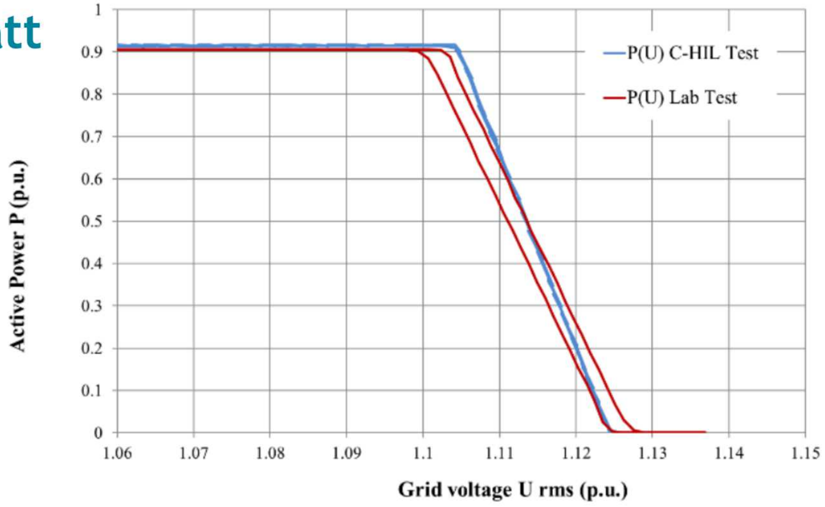
J. Johnson, R. Ablinger, R. Bruendlinger, B. Fox, J. Flicker, "Design and Evaluation of SunSpec-Compliant Smart Grid Controller with an Automated Hardware-in-the-Loop Testbed," Technology and Economics of Smart Grids and Sustainable Energy, vol. 2, no. 16, Dec. 2017. DOI: 10.1007/s40866-017-0032-7

Comparison of C-HIL and Physical DER Implementation

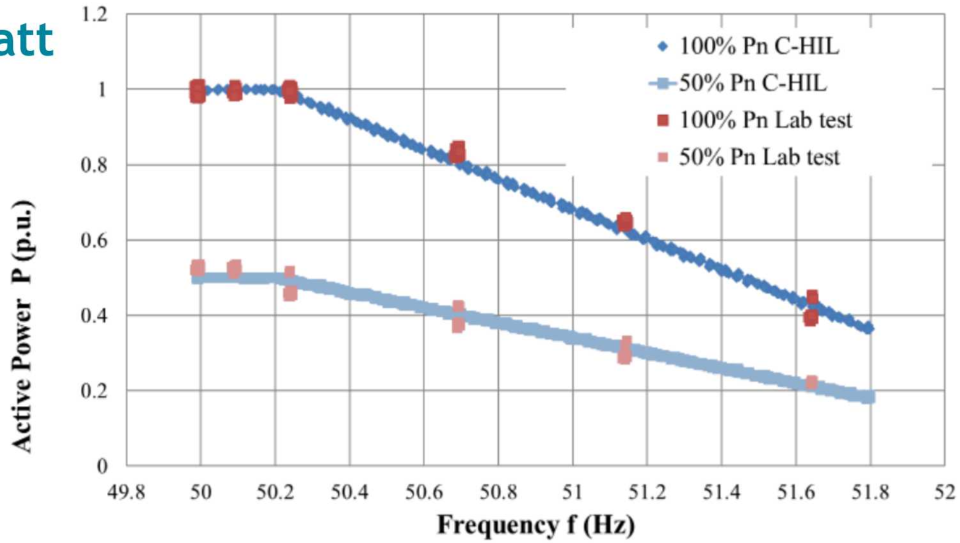
Active Power Curtailment



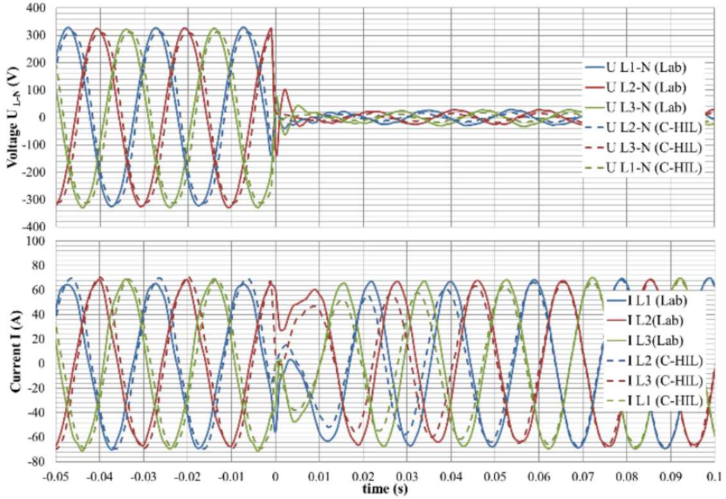
Volt-Watt



Freq-Watt



Low Voltage Ride Through (LVRT)



- R. Bründlinger, J. Stöckl, Z. Miletic, R. Ablinger, F. Leimgruber, J. Johnson, J. Shi, “Pre-certification of Grid-Code Compliance for Solar Inverters with an Automated Controller-Hardware-In-The-Loop Test Environment,” 8th Solar Integration Workshop, Stockholm, Sweden, 16-17 Oct. 2018.
- J. Stöckl, Z. Miletic, R. Bründlinger, J. Schulz, R. Ablinger, W. Tremmel, J. Johnson, “Pre-Evaluation of Grid Code Compliance for Power Electronics Inverter Systems in Low-Voltage Smart Grids,” 20th European Conference on Power Electronics and Applications (EPE'18 ECCE Europe), Riga, Latvia, 17-21 Sept 2018.

Conclusion

Nations across the globe are **facing similar challenges** when integrating high penetrations of renewable energy.

- Interoperable, **grid-support inverters**/converters are a large **portion of the solution**.
- To deploy these technologies at scale, a **common testing methodology (certification standard) is required** so the communication and power behavior is as-expected in fielded equipment.

A collection of laboratories around the world are **developing a software platform** that enables **autonomous certification testing** of DER to:

- Accelerate the DER vendor development process
- Generate certification protocols that fully evaluate the products, while minimizing the number of experiments
- Evaluate interoperability test procedures and communication products
- Educate the power industry of the capabilities of advanced DER

Demonstration