India SMART GRID Week 2018

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India Smart Grid Forum

International Collaboration on the Evaluation and Certification of Interoperable Grid-Support Converters

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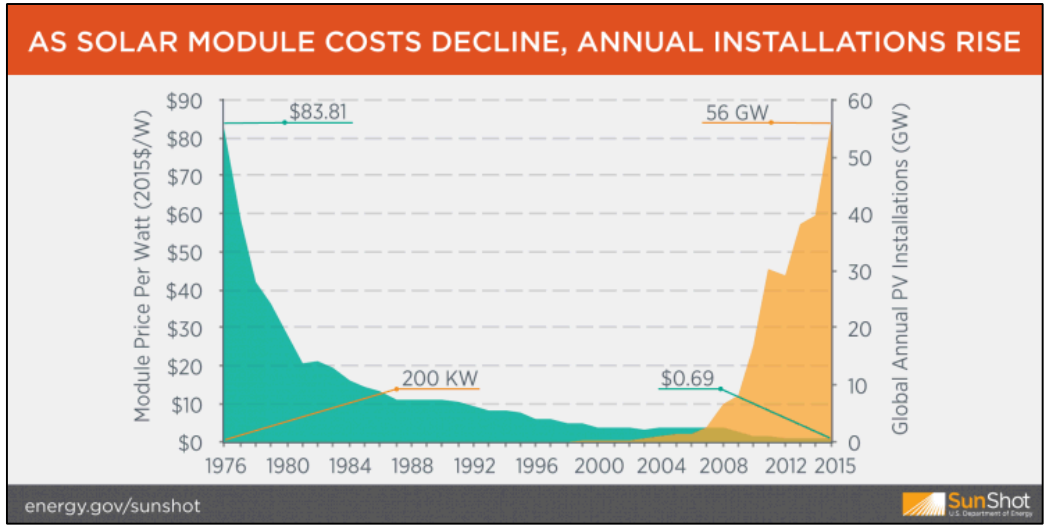
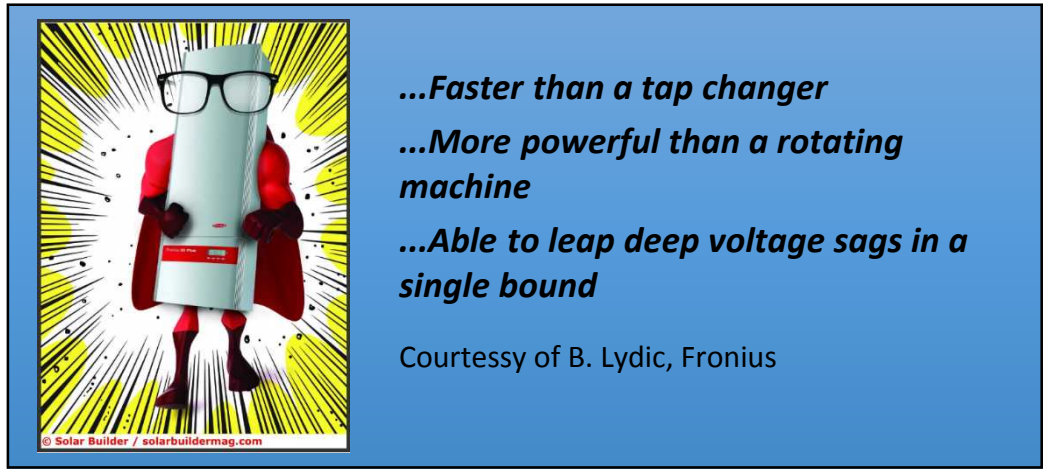
Background

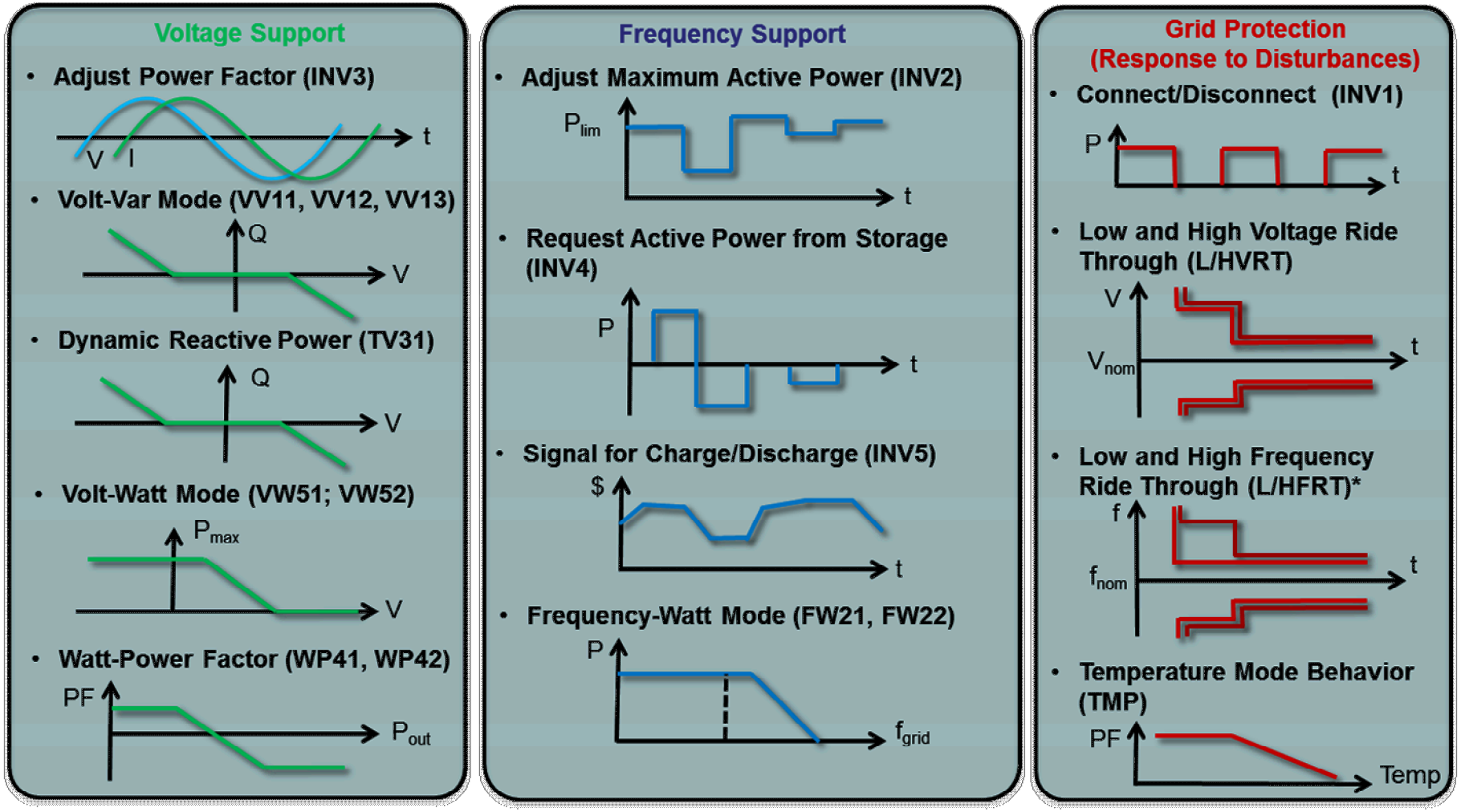
- The context
  - Total installed capacity of PV is growing fast in the world
  - Large growth expected in distribution systems
- The problem
  - Because the grid is slow to evolve, we encounter technical challenges with voltage/frequency regulation, protection, etc.
  - Unless mitigated, these challenges 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





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.

Smart Grid Research Facility Network (SIRFN)

- IEA (International Energy Agency)
  - Clean Energy Ministerial (CEM)
    - International Smart Grid Action Network (ISGAN)
      - Smart Grid International Research Facility Network (SIRFN)
        - Smart Grid Modelling
        - Advanced Laboratory Testing Methods
        - Power Systems Testing
        - Microgrids
        - Electric Vehicles
        - Test Protocols for Advanced Inverter Functions

SIRFN ISGAN Annex 5

Smart Grid International Research Facility Network

Primary goal: Develop and demonstrate consensus-based interoperability certification standards for Distributed Energy Resource (DER).

- Design, expand, and network power system test-beds at each laboratory.
- Develop test procedures and encode this in a common automated testing environment.
- Perform advanced DER certification tests using common software.
- Compare test results and gradually improve draft test procedures.

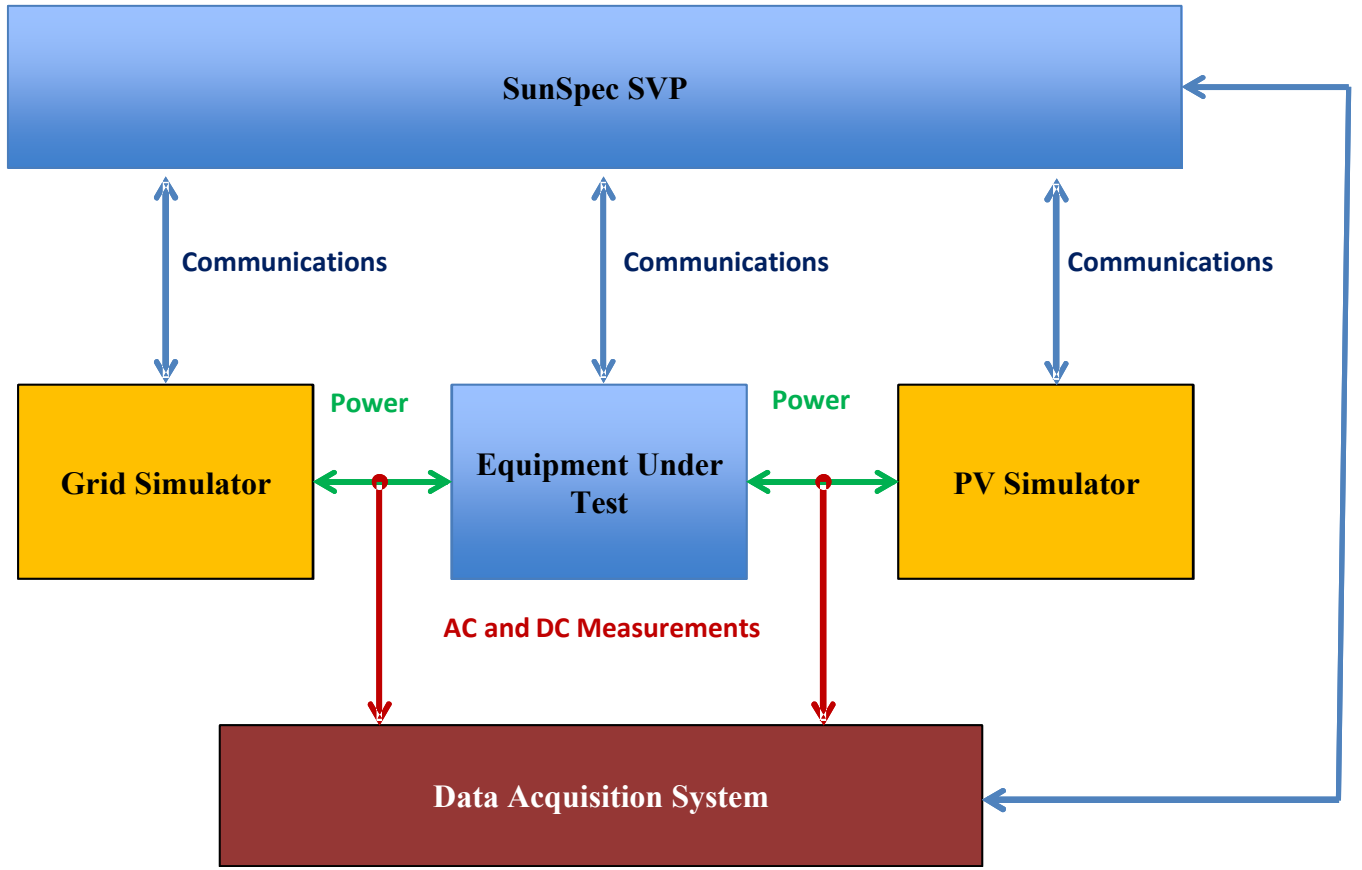
DER Certification Testing

- Interconnection standards enumerate Distributed Energy Resource (DER) requirements.
  - In some regions like the US, certification testing is conducted by an independent laboratory called a Nationally Recognized Testing Laboratory (NRTL).
- DER vendors test their products for performance, interoperability, safety, and control requirements prior to certification.
- Research labs conduct DER experiments to:
  - Work with standards development organizations to write test procedures
  - Report state-of-the-art DER functionality
  - Demonstrate grid-support capabilities
  - Research communication options
  - Develop interoperability requirements
  - Measure speed and accuracy of converters
  - Investigate corner cases and evaluate newly-discovered power system risks

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

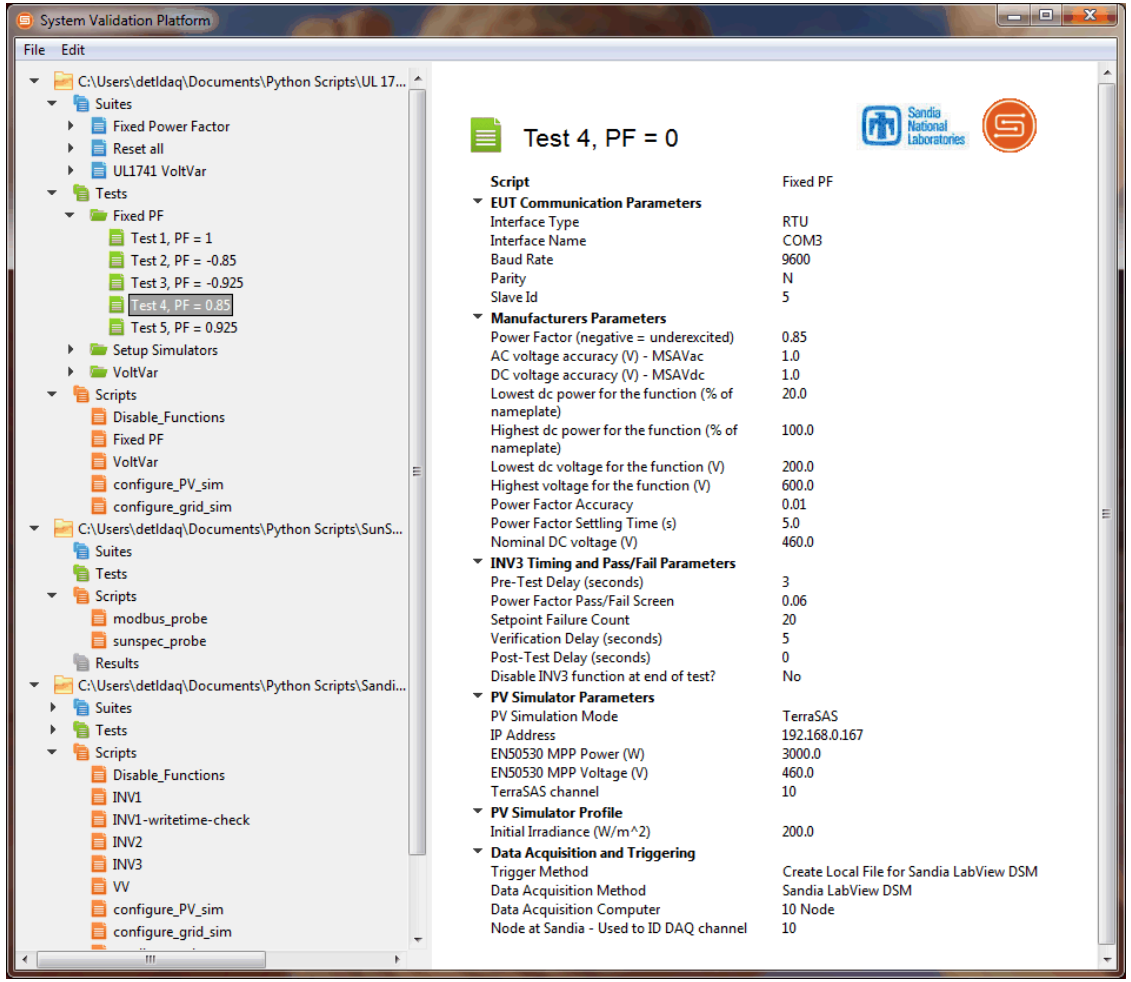
System Validation Platform

- The **System Validation Platform (SVP)** is co-developed by Sandia and SunSpec Alliance 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

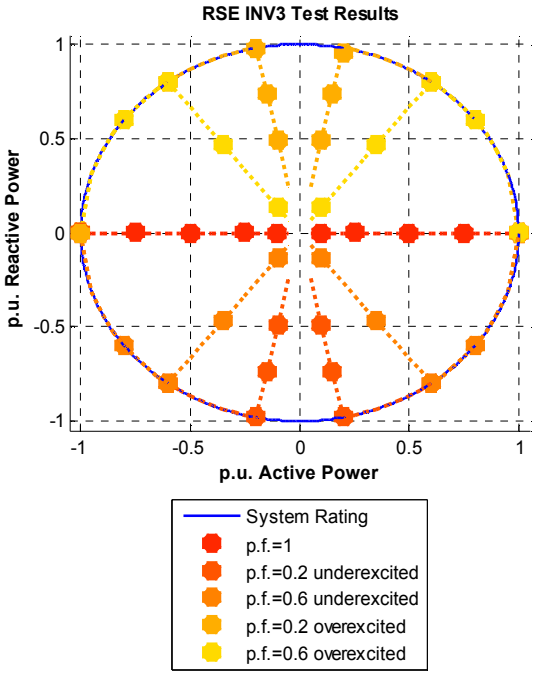
- SVP is a fully scriptable automated certification interoperability platform
- Abstraction layers for each equipment type connects the testing logic to communication drivers.
  - This means the same test logic can be executed at the laboratories, even through the physical equipment is different at the labs.

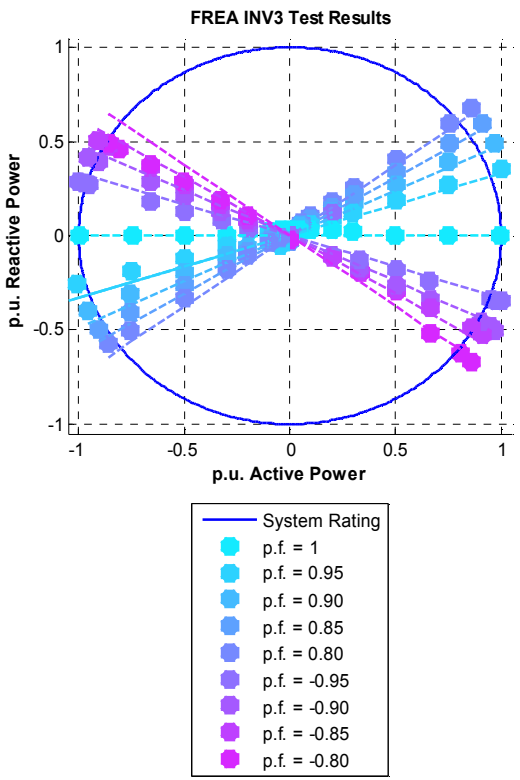


See: http://sunspec.org/sunspec-svp/
http://sunspec.org/download-svp/
https://github.com/sunspec/svp_directories

Example Test Results

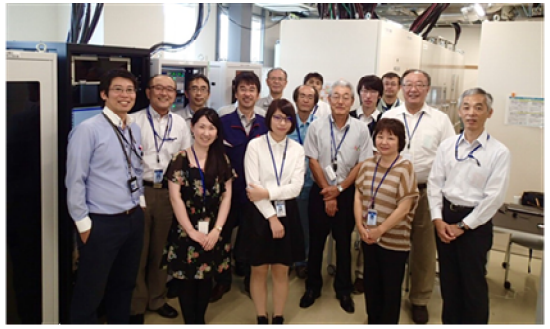
- Fixed Power factor Results





Team members at AIT Smart Electricity Systems and Technologies (SmartEST) PV inverter test laboratory

Team Members at RSE Distributed Energy Resource (DER) Test Facility



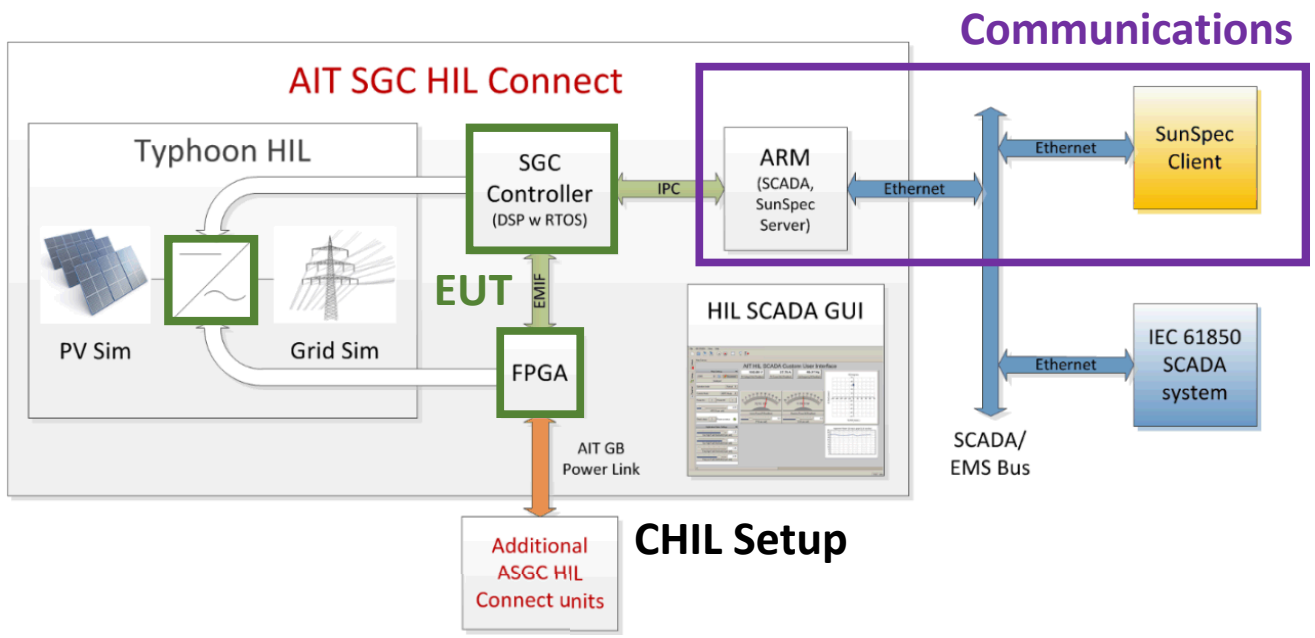
Team members at FREA Smart DER Research Facility

Team Members at Sandia's Distributed Energy Technologies Lab (DETL)

Details: 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.
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: CHIL

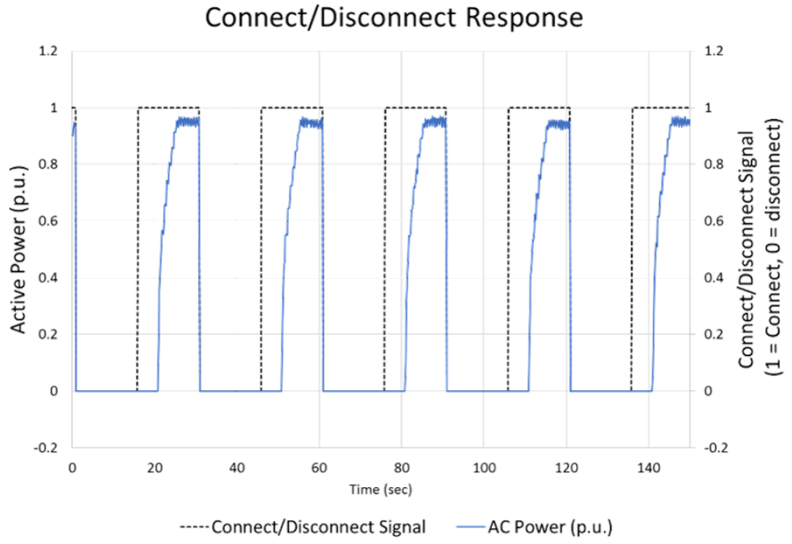
- A controller hardware-in-the-loop (CHIL) alternative has been developed
  - Converts components of large-scale, high-voltage DER testing to a less expensive, safer benchtop testing system.
- Adds value for DER vendors, certification labs, universities, and standards development organizations (SDOs)
  - 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



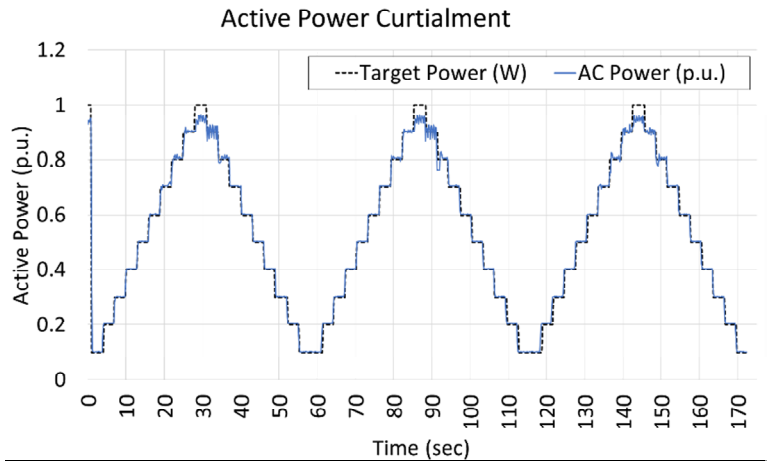
Austrian Institute of Technology has commercialized the converter for CHIL experimentation.

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

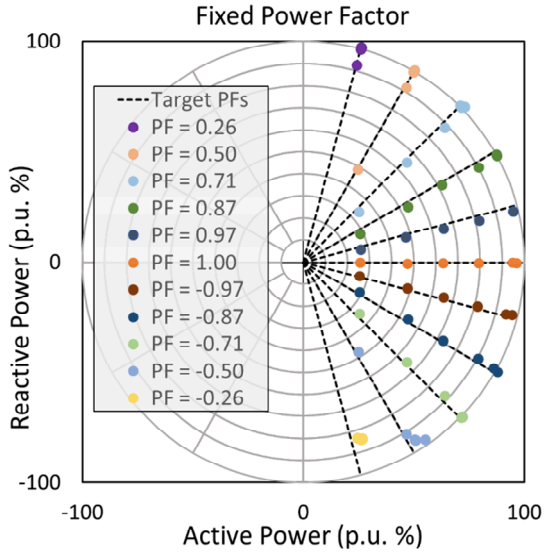
Example CHIL Test Results



- 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

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

One possibility: CHIL systems for power engineering students!

Thank You!

Are there any questions?