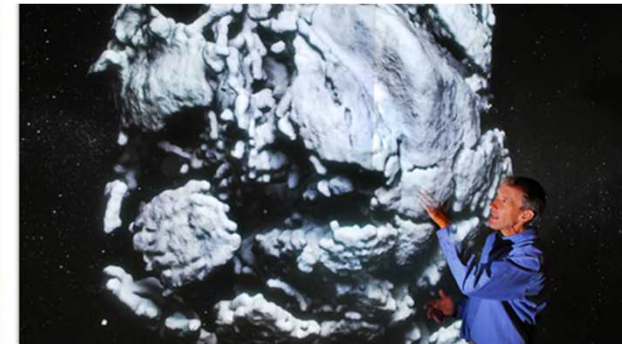


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U.S.-Korea Bilateral Smart Grid Research on Advanced Inverter Interoperability and Functionality

9 June, 2014

Michael Hightower, Jay Johnson

Photovoltaic and Distributed Systems Integration, Sandia National Laboratories



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Sandia-KERI Smarter Grid Collaboration

- 3 year project started in 2013 to:
 - Design and construct advanced interoperability test-beds at SNL and KERI.
 - Develop advanced inverter certification procedures.
 - Compare test results, communications methods, and automation procedures.
 - Standardize advanced function testing of PV inverters and energy storage systems.
- Biannual face-to-face meetings
 - March 2013 - KERI visited Sandia National Labs for project kickoff meeting.
 - Aug 2013 - Sandia attended the Energy Tech Insight Meeting and visited KERI laboratories to provide project updates.
 - April 2014 - KERI visited Sandia National Labs. SNL provided laboratory demonstration of the advanced inverter test-bed and automation platform.
 - Sept/Oct 2014 - Sandia is planning to visit KERI.



Sandia National Laboratories

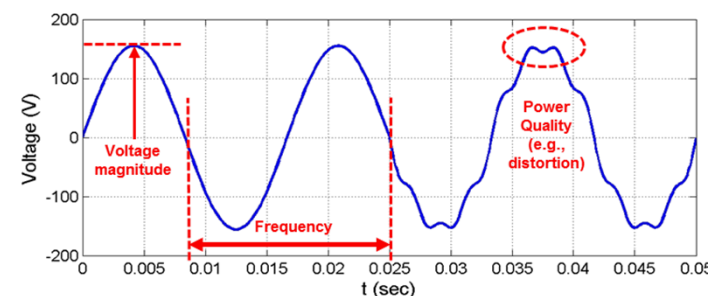
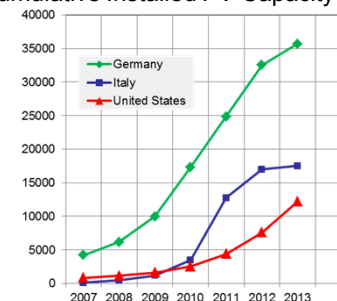


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Importance of SNL-KERI Collaboration

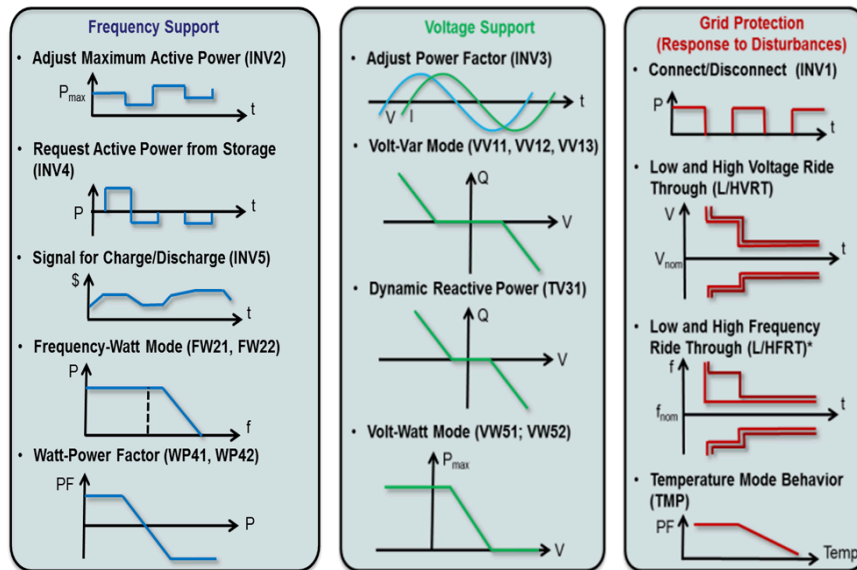
- **SNL-KERI collaboration is important to the deployment of renewable energy in the US, Korea, and rest of the world!**
 - Higher intermittent renewable energy penetrations are leading to grid voltage and frequency stability concerns.
 - Inverters and power conditioning systems (batteries) have the ability to help stabilize the grid. (Standardized in IEC TC 61850-90-7.)
 - Advanced DER functionality and interoperability are required in Europe (Germany, Austria, Italy, etc.) and could be mandated for California soon.
 - Certification laboratories need a new procedure to ensure grid interconnected devices will preform appropriately.
 - Sandia National Labs has created the Advanced Interoperability Test Protocols to provided the basis for the UL and other international certification standards.
 - SNL and KERI are excising the test protocols to verify and improve testing procedures for advance grid functions.
 - **Goal:** develop a robust consensus certification procedure for advanced inverter functions for adoption by an international standards organization.

Cumulative Installed PV Capacity (MW)

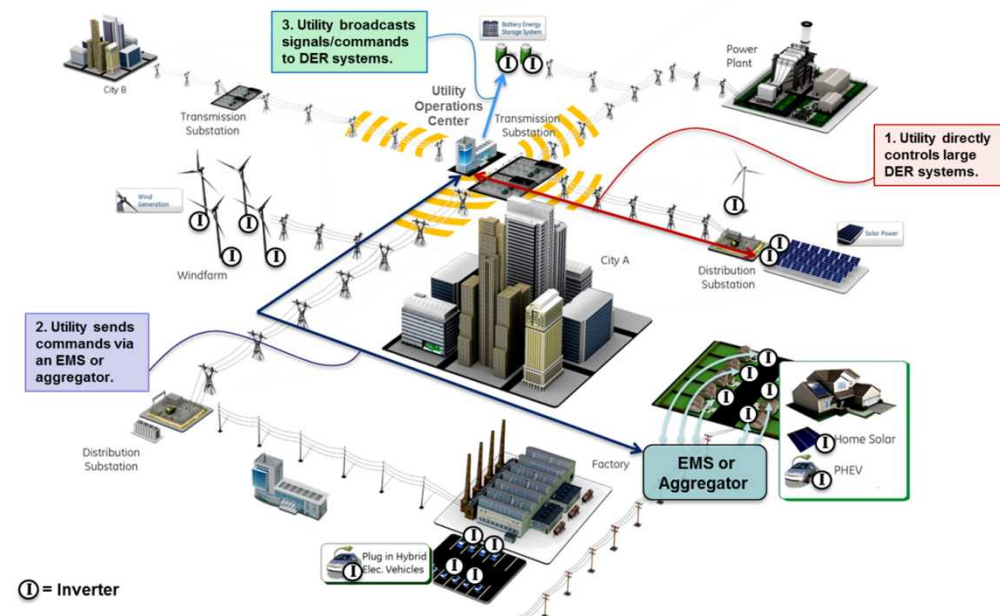


Advanced Interoperability Function Background

- New 'smart' inverters will include multiple advanced functions
 - Autonomous: Inverter response to local voltage and frequency conditions
 - Commanded: Remote control (e.g., on/off)
- Utilities will modify distributed energy resource (DER) behavior using interoperability communications



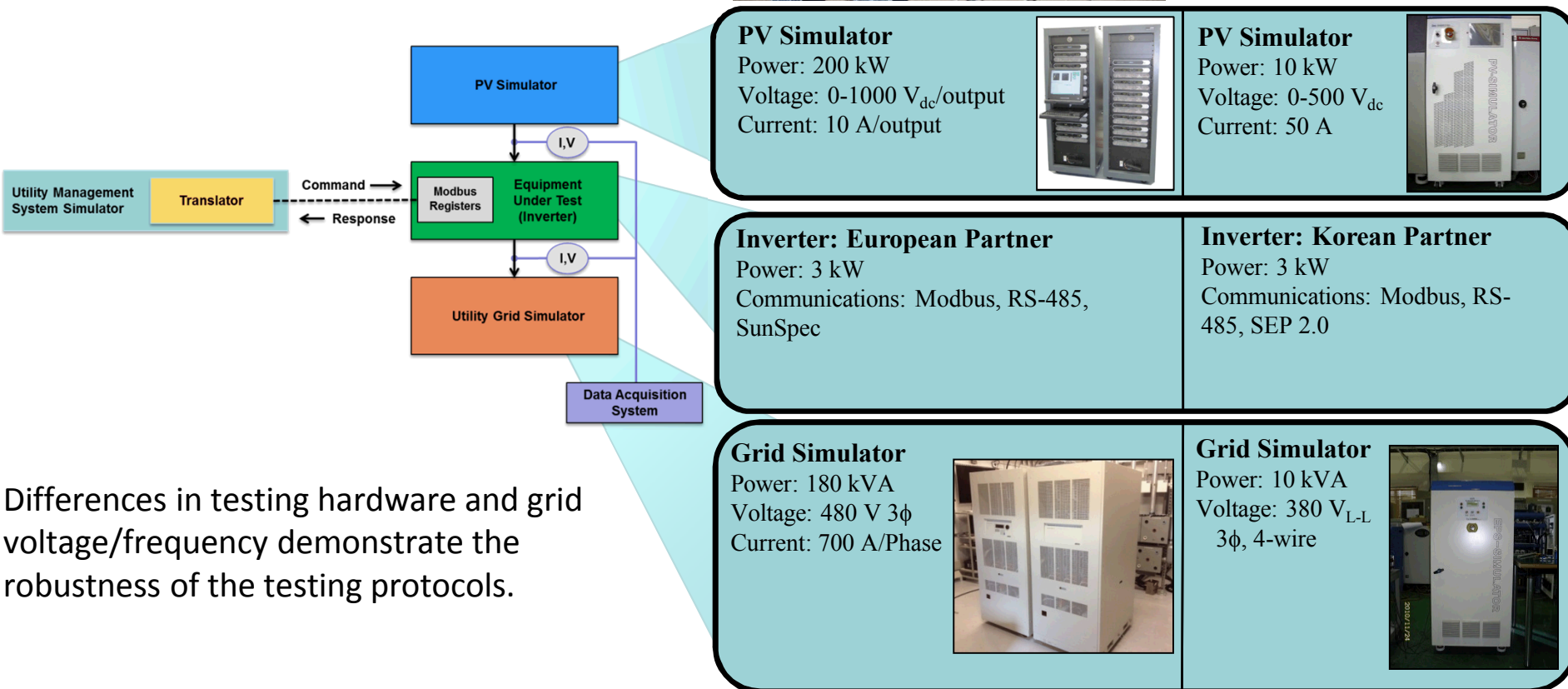
Advanced functions as defined in IEC TC 61850-90-7.



Utility communications options for advanced inverters.

Sandia and KERI Test-Bed Hardware Comparison

Both Sandia and KERI have built interoperability test-beds. These facilities are running inverter tests in parallel. As difficulties are identified, labs collaborate to address the issue.



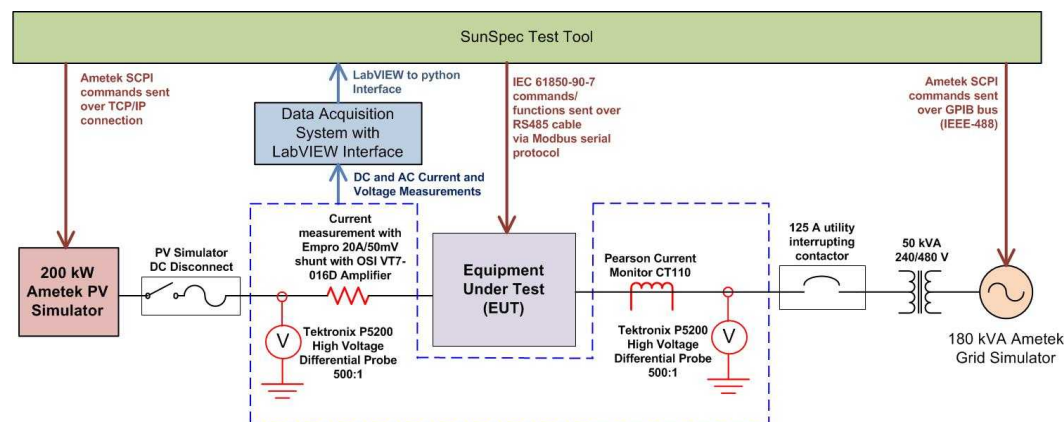
Differences in testing hardware and grid voltage/frequency demonstrate the robustness of the testing protocols.

Communications at SNL and KERI

- Collaboration seeks to also compare different laboratory test-bed communication methods and software (not only hardware)

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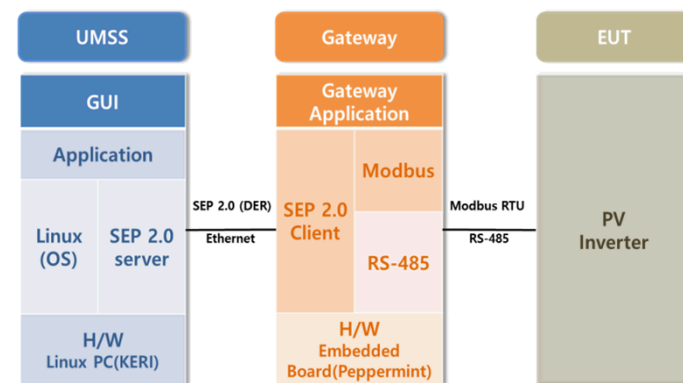
- Equipment Under Test (EUT) communications
 - IEC 61850-90-7 functions/commands via Modbus RTU over RS-485
- Utility to DER gateway
 - SunSpec translator module for DNP3, SEP, and OpenADR
- Data Acquisition
 - National Instruments LabVIEW program connected to instrumentation
- Automation
 - SunSpec test tool graphical user interface (GUI) programmed in python



SNL automated advanced inverter test-bed design

Korea Electrotechnology Research Institute

- EUT communications
 - IEC 61850-90-7 functions/commands via Modbus RTU over RS-485
- Utility to DER gateway
 - SEP 2.0 gateway created by KERI
- Data Acquisition
 - Stand-alone data acquisition system
- Automation
 - Man-machine interface (MMI) GUI designed by KERI



KERI communications system design

Sandia and KERI advanced function test results

- Sandia and KERI are comparing experiences exercising the Sandia Test Protocols and modify the test procedures and test matrices (parameters) based on the experiments.
- Comparison of results of 7 advanced functions planned for the end of the fiscal year.
 - Testing is limited by inverter manufacturers- new capabilities being added slowly.

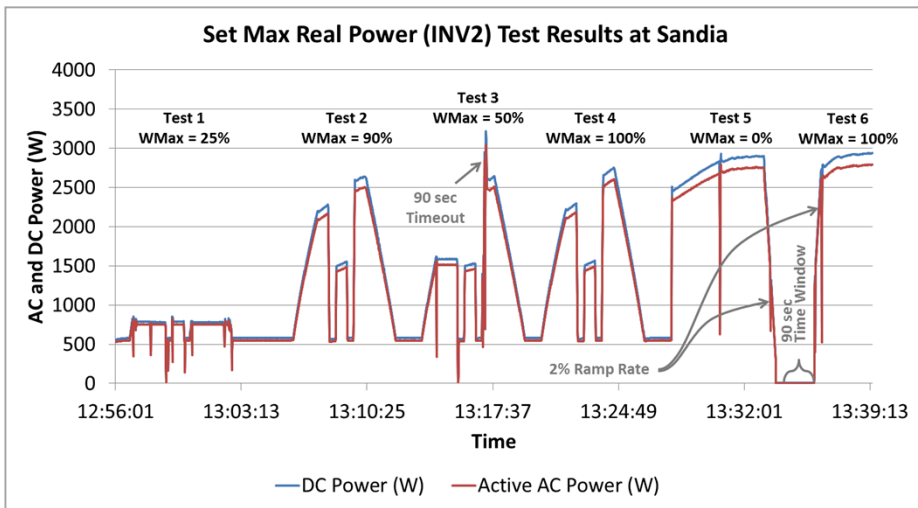
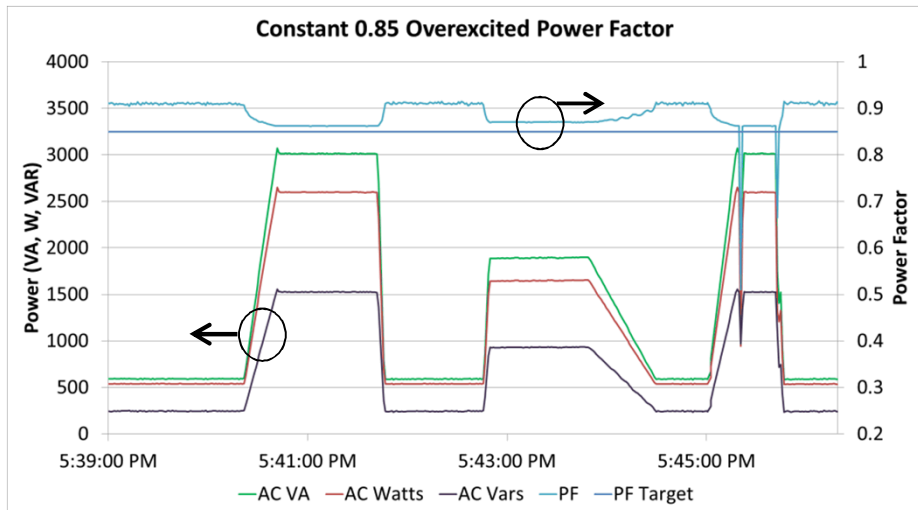
Command	Function
INV1	Connect/Disconnect
INV2	Adjust Max Generation Level
INV3	Adjust Power Factor
INV4	Request Active Power
INV5	PV/Storage Functions
VV11	Volt-Var mode
VV12	Volt-Var mode
VV13	Volt-Var mode
VV14	Volt-Var mode
FW21	Set maximum power output
FW22	Set maximum power output
TV31	Dynamic reactive power support
L/H VRT	Stay connected/disconnect settings
WP41	Power factor settings
WP42	Power factor settings
VW51	Set output to smooth voltage
VW52	Set output to smooth voltage
TMP	Temperature mode behavior
PS	Signal mode behavior
DS91	Modify DER Inverter Settings
DS92	Event/History Logging
DS93	Status Reporting
DS94	Time Synchronization

**Implementation
Successful**

**Implementation Partly
Successful**

**Implementation
Unsuccessful**

**Implementation
planned for FY14**



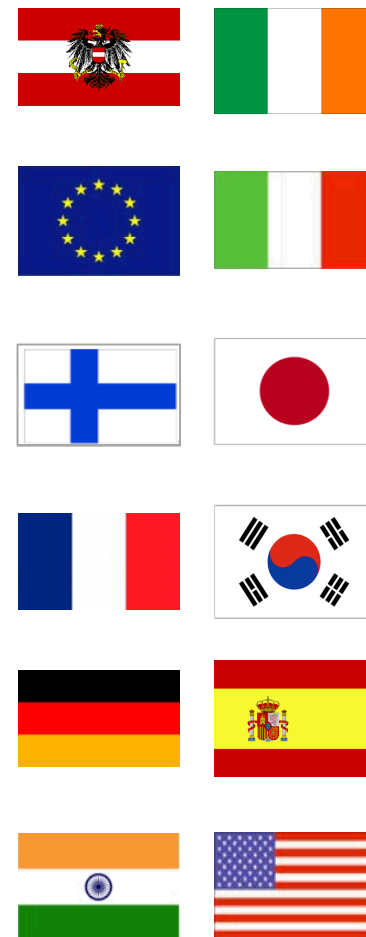
Conclusions

- Advanced functions in PV inverters and energy storage systems can stabilize the grid with greater penetrations of renewable energy
- There must be a standardized method for verifying the functionality of these devices
- Sandia and the Korea Electrotechnology Research Institute are:
 - Designing and building test-beds for advanced inverter testing
 - Comparing results from inverters using different hardware and software systems to improve certification test protocols
 - The collaboration demonstrates these test protocols are effective for testing devices anywhere in the world
 - SNL and KERI are making changes to the testing procedure
 - Improved protocols will become the basis for an international standard in the future

Opportunities for KERI in SIRFN

- Sandia National Laboratories and the US Department of Energy encourage KERI to join SIRFN (Smart Grid International Research Facilities Network)
 - SIRFN is a coordinated network of Smart Grid research and test-bed facilities and selected projects in countries participating in ISGAN (International Smart Grid Action Network).
- SIRFN has many activities for test laboratories, but one is closely aligned with the SNL-KERI collaboration. The “PV inverter test protocol activity”:
 - Provides knowledge exchange among participating facilities (same)
 - Improves test procedures for advanced PV inverters with the goal of becoming an internationally-accepted basis (same)
 - Performs round-robin testing of the Sandia Test Protocols with 3 kW PV inverters (similar)
- SNL, NREL, AIT, RSE, Tecalia and AIST are active in this project—would like to have KERI participate!
 - Currently KATS (Korean Agency for Technology and Standards) is the only Korea representative to SIRFN, but they do not have a research test laboratory for advanced inverter testing.
 - We recommend KERI join SIRFN to participate in this international research effort.

SIRFN Participants



Thank you. 감사합니다.

Additional Questions or Comments to:

Jay Johnson

Photovoltaic and Distributed Systems Integration

Sandia National Laboratories

P.O. Box 5800 MS1033

Albuquerque, NM 87185-1033

Phone: 505-284-9586

jjohns2@sandia.gov