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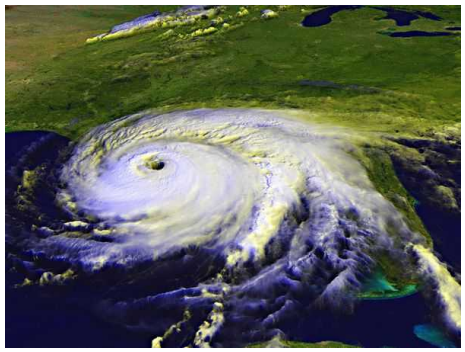


International Development of Energy Storage Interoperability Test Protocols for Photovoltaic Integration

09/17/2015 **David Rosewater**, Jay Johnson, *Christian Messner, Roland Bründlinger, Kathan Johannes, Maurizio Verga, Riccardo Lazzari, Jun Hashimoto, Kenji Otani*

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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Overview

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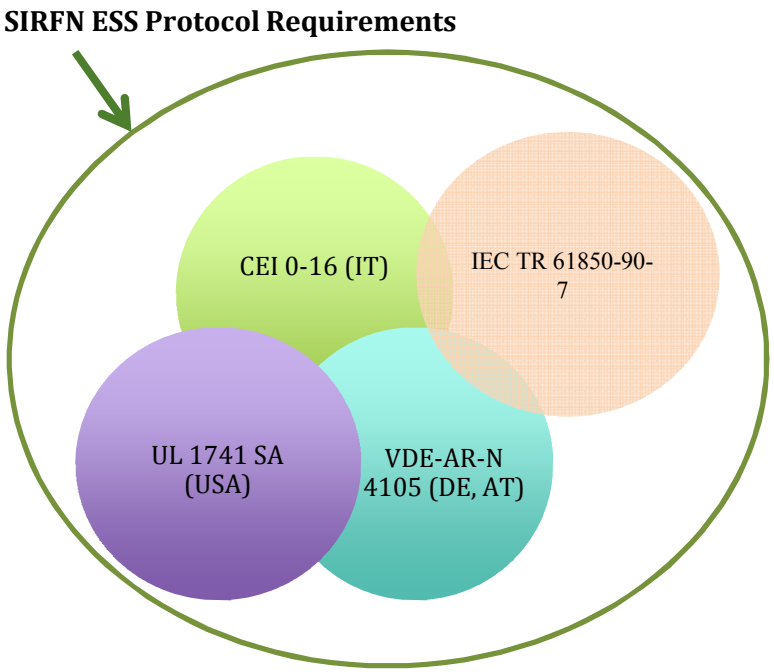
- Overview (1min)
- Introduction (5) 15 min (10 quick slides) practice
  - SIRFN (1 min)
  - Our goal (1 min)
  - Why (2 min)
  - Team (1 min)
- Protocol Development (8)
  - Review Grid Codes (2)
  - Draft Testing Protocols (2)
  - Apply Protocols to Energy Storage Systems (ESS) (2)
  - Review Data and refine protocols (2)
- Conclusions (1)

What is SIRFN

The Smart Grid International Research Facility Network (SIRFN) is a ***coordinated network of smart grid research and test-bed facilities and relevant projects in the field*** in countries participating in ISGAN.

SIRFN's collaborative testing/evaluation capabilities are meant to be leveraged by the international community to enable improved design, implementation, and testing of smart grids.

Goal: Extend Test Protocols for Advanced Inverter Functions to Energy Storage Systems (ESS)



Targets

the SIRFN ESS Protocol must :

- Create a concise set of test procedures for evaluating ESS interoperability and functionality
- Consider peculiar aspects of ESS (Bi-directional, 4 quadrants capability, etc.)
- Be harmonized and inclusive with existing international standards, International requirements and National Grid Codes
- Enable easy interpretation of test procedures by laboratory personnel
- Define test acceptance criteria
- Provide the basis of an international testing standards for ESS grid-support functions

Why is it important?

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As variable, non-dispatchable photovoltaic power continues to displace traditional generation assets, additional resources are needed to control bulk and local power systems.

> Decentralized storage and the ability for those devices to respond to commanded signals will "help support distribution grids operation - and even sometimes avoid costly grid reinforcements." - European Photovoltaic Industry Association (EPIA)

Sandia National Laboratories Albuquerque New Mexico

Team: ESS Test Protocol Working Group

The group right now composed by 4 partners:

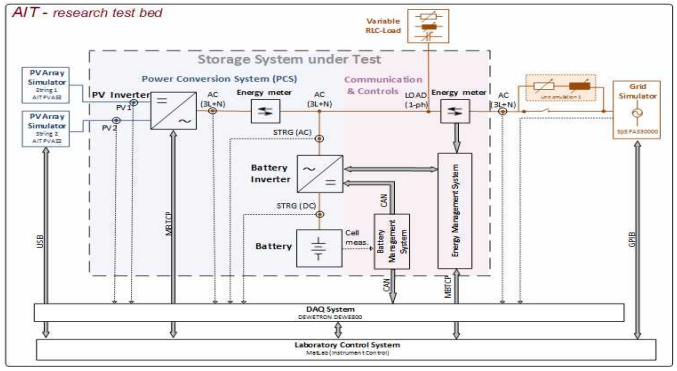
- AIT – Austrian Institute of Technology *(Christian Messner, Roland Bründlinger, Kathan Johannes)*
- FREA-AIST Fukushima Renewable Energy Institute *(Jun Hashimoto, Kenji Otani)*
- Sandia National Laboratories *(David Rosewater, Jay Johnson)*
- RSE-Ricerca sul Sistema Energetico *(Maurizio Verga, Riccardo Lazzari)*

- *Activity started regularly on Dec 2014*
- *Regular web meeting every 2 weeks (Tuesday meeting)*
- *Continuous contacts via e-mail*

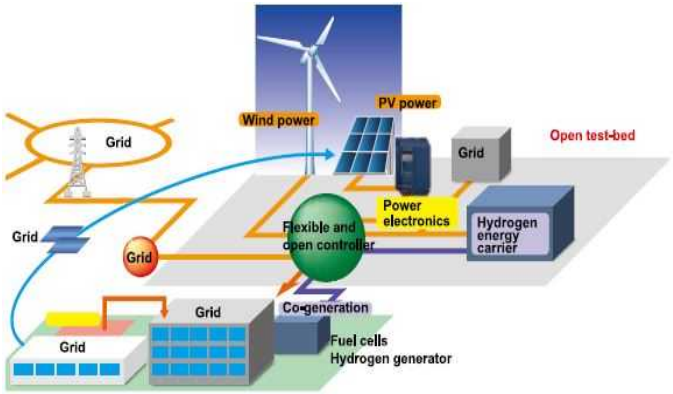
New partners are welcomed !!!!

Team: ESS Test Protocol Working Group

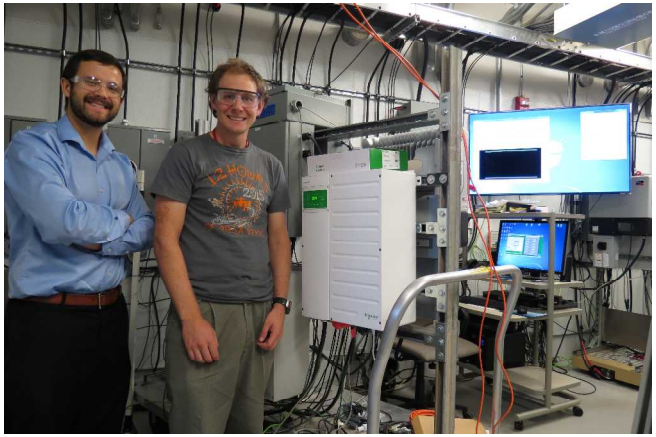
Team members at RSE's Distributed Energy Resource (DER) Test Facility



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



FREA Open test bed for testing of grid-connected inverters and energy storage systems.



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

Protocol Development

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1. Review of appropriate grid codes, technical rules, standards, and ESS functions,
2. Consolidation of function requirements into draft protocol language,
3. Execution of draft protocol to ESS with equipment units at SIRFN laboratories, and
4. Updating draft protocols to improve usability and to generate better results.

Review of appropriate grid codes

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Example review of Volt / VAR function

Country/ Grid Code	Data Requirements	Specified Curve
Italy/CEI 0-21:2014-12 (LV)	P, Q, V_{ac} measured (1 s average) , Q awaited, Q error	V_{1i}= under voltage at the left edge of the deadband V_{2i}= under voltage at max capacitive reactive power V_{1s}= over voltage at the right edge of the deadband V_{2s}= over voltage at max inductive reactive power Q_{1i}=reactive power at V_{1i} Q_{2i}=reactive power at V_{2i} Q_{1s}=reactive power at V_{1s} Q_{2s}=reactive power at V_{2s} $Q_{max,cap}$ and $Q_{max,ind}$ from capability curve
US (California)/ UL 1741 SA: 2015	AC and DC current and voltage. The minimum measurement accuracy shall be 1% or less of rated EUT nominal output voltage and 1% or less of rated EUT output current.	• Q_1 = maximum capacitive reactive power setting • Q_2 = reactive power setting at the left edge of the deadband • Q_3 = reactive power setting at the right edge of the deadband • Q_4 = maximum inductive reactive power setting • V_1 = voltage at Q_1 • V_2 = voltage at Q_2 • V_3 = voltage at Q_3 • V_4 = voltage at Q_4
Germany/ FGW - TR3 Rev23 (optional test)	Displacement factor, P, Q, and V useing a 0.2s (min) sliding average. The settling time shall be determined on the basis of ±5% rated active power.	Aditional tests are carried out for PGUs with reactive power control with Q(U) caricteristic curve. The voltage steps start at the lowest voltage to the highest voltage and vice vcersa.

4 functions have been selected so far:

- ESS1 - Request Active Power from Storage *(ESS Active power bi-directionality)*
- INV 3 – Adjust Power Factor *(ESS 4 quadrants capability)*
- VV – Volt Var mode *(ESS reactive power control)*
- FW – Frequency-Watt mode *(ESS Active power bi-directionality)*

Draft Testing Protocols

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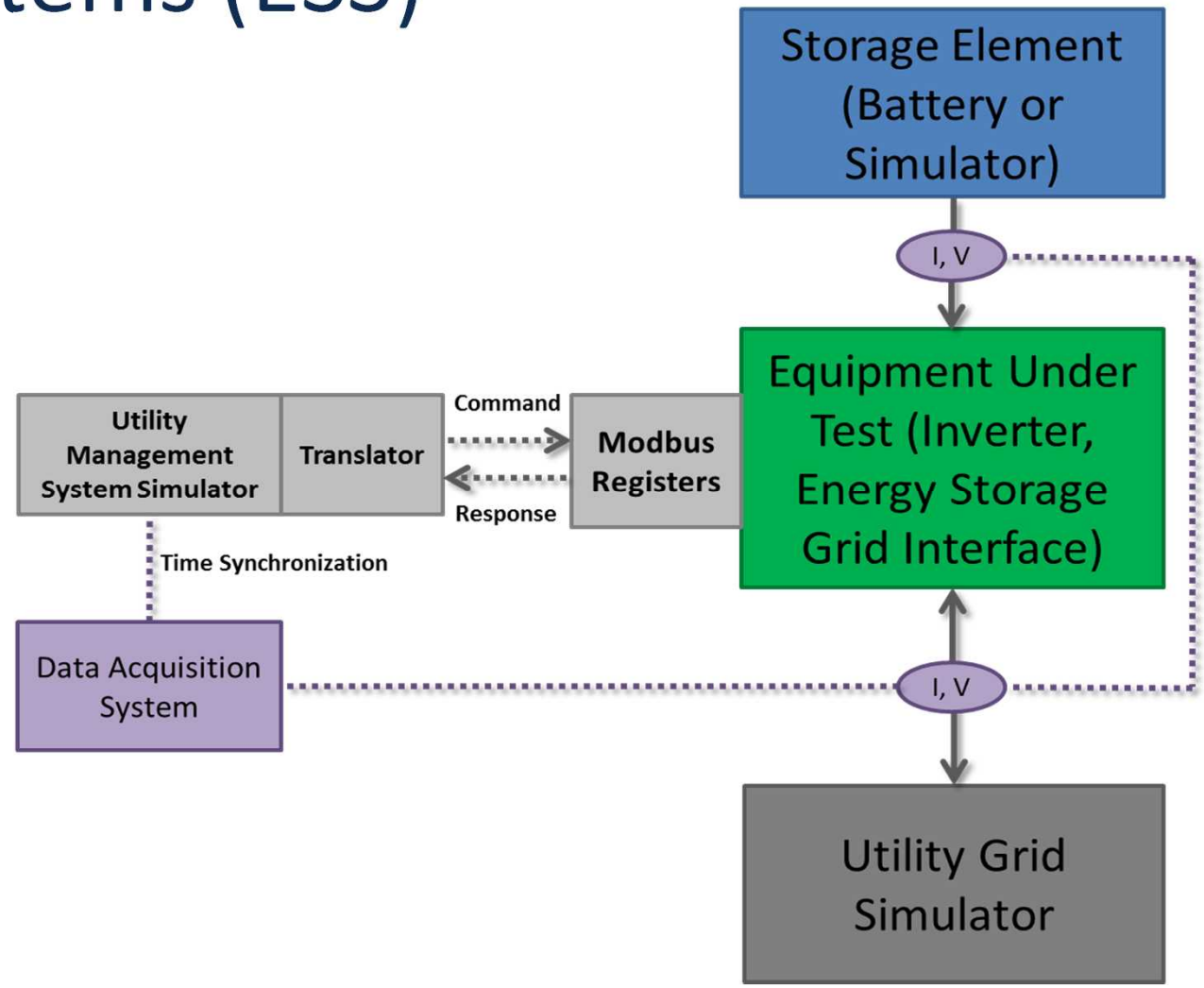
Necessary to describe the different functions with the same procedure format and adopting a unique methodology

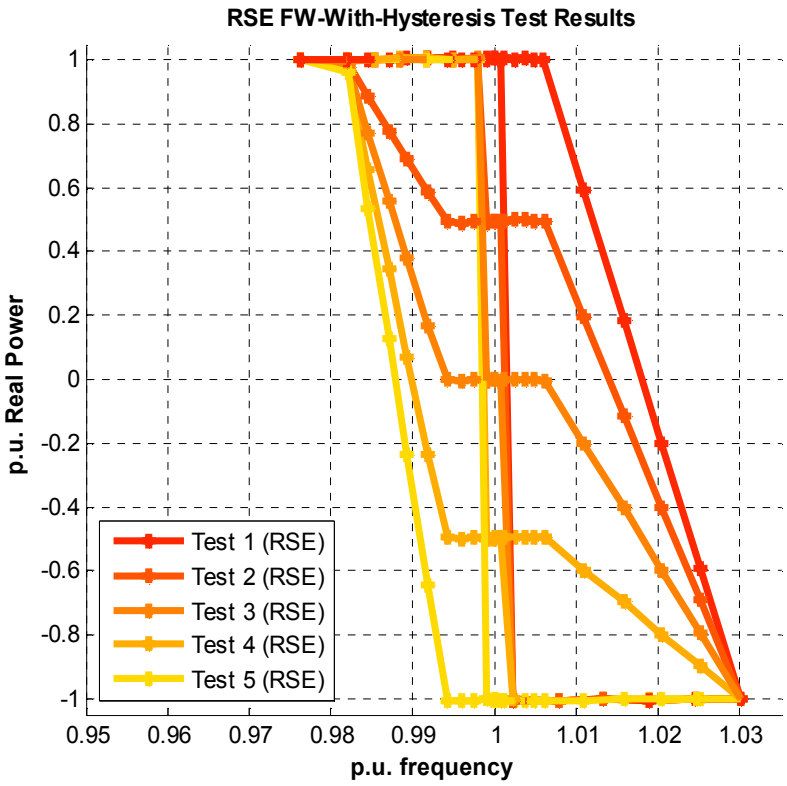
For each function to be tested the procedure is organized as follows:

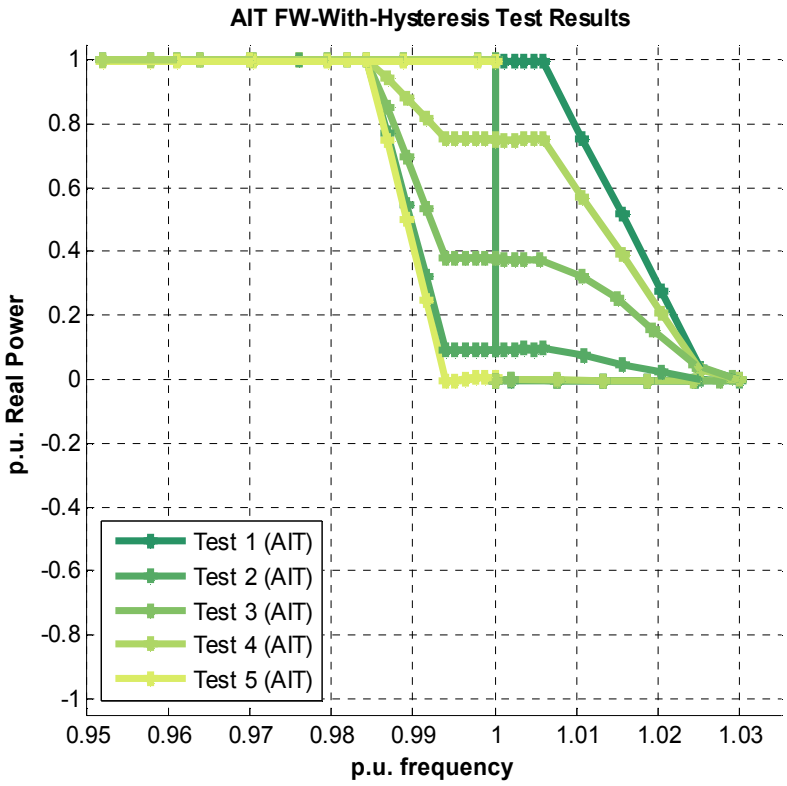
1. **Function definition**
   definition of what is requested to ESS and list of International standards/requirements ant Grid Codes
2. **Parameters**
   peculiar parameters, from manufacturer or Grid Codes, that define the function)
3. **Function Capability Table (FCT)**
   summary of test to be performed depending on EUT capabilities, timing parameters, etc.. (FCT table send to tests described in chapt.5)
4. **Function test definition**
   detailed description of test points, test matrix, timing parameters and set-up to be sent to the EUT
5. **Function test sequence**
   detailed description of each step (sequential) the must be performed during test execution
6. **Acceptance criteria**
   EUT test pass/fail criteria (general and as requested by different Grid Codes)

Apply Protocols to Energy Storage Systems (ESS)

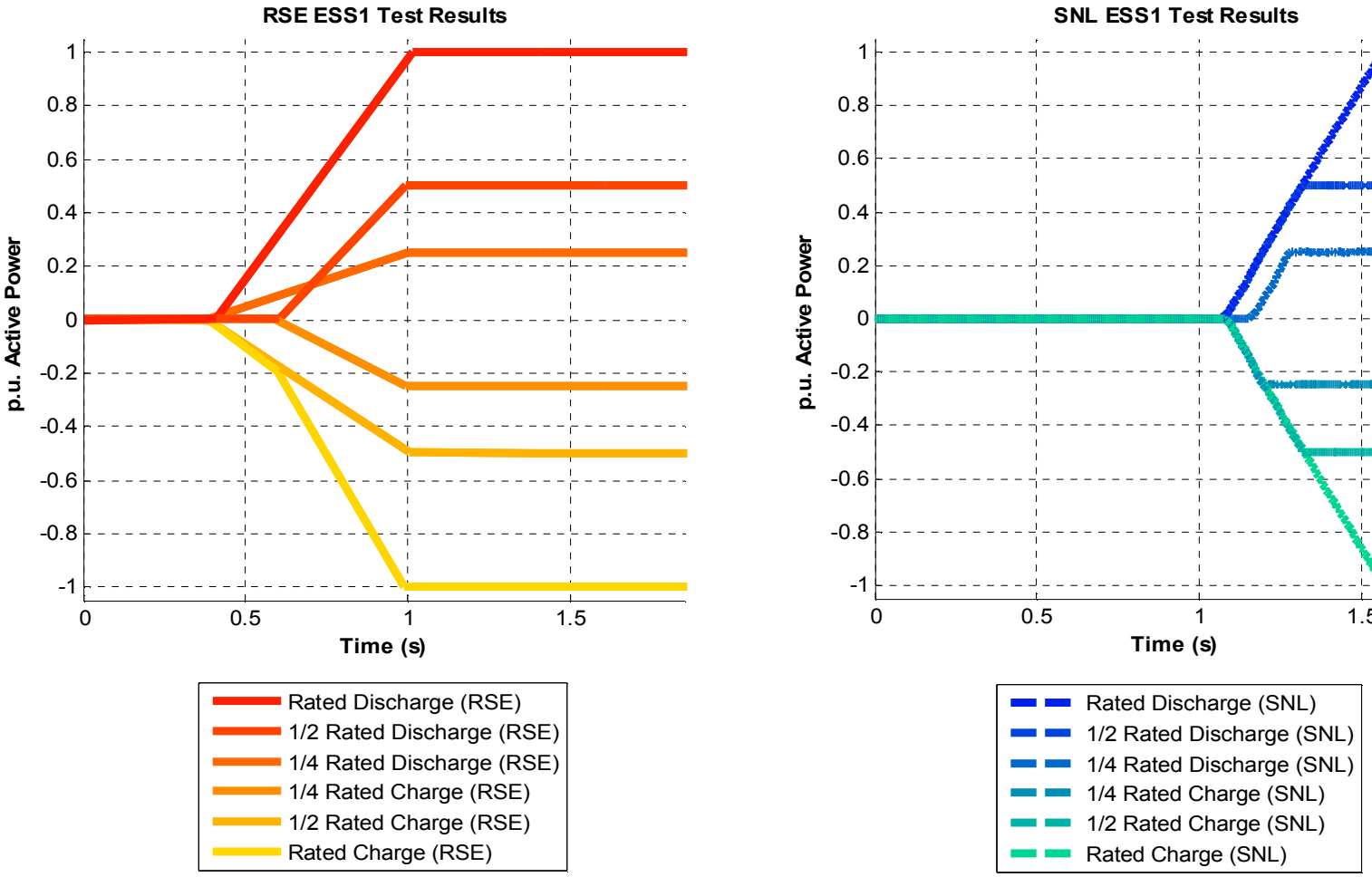


Review Data and Refine Protocols: Frequency / Watt

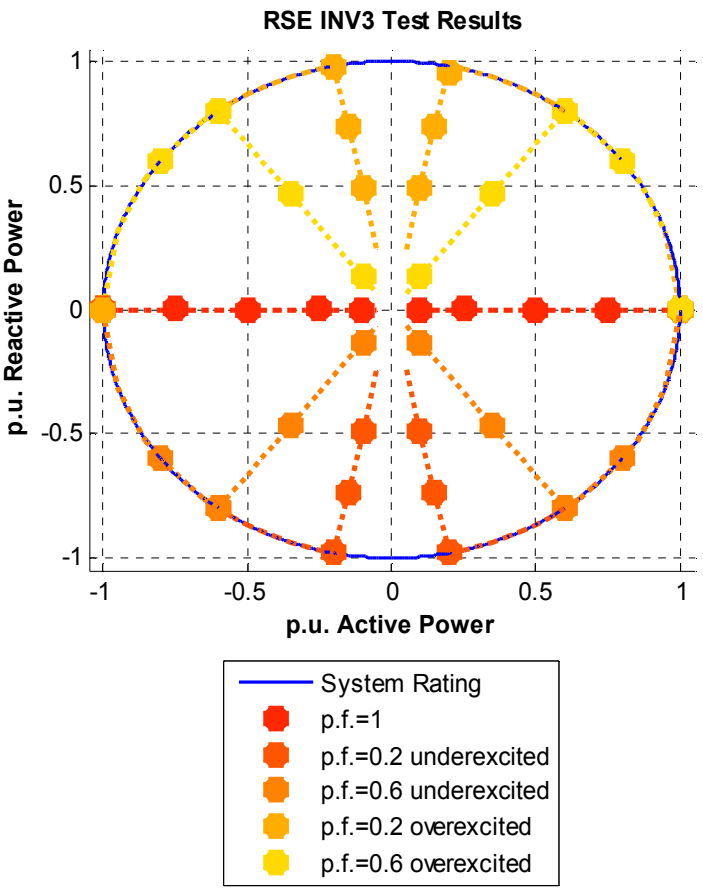


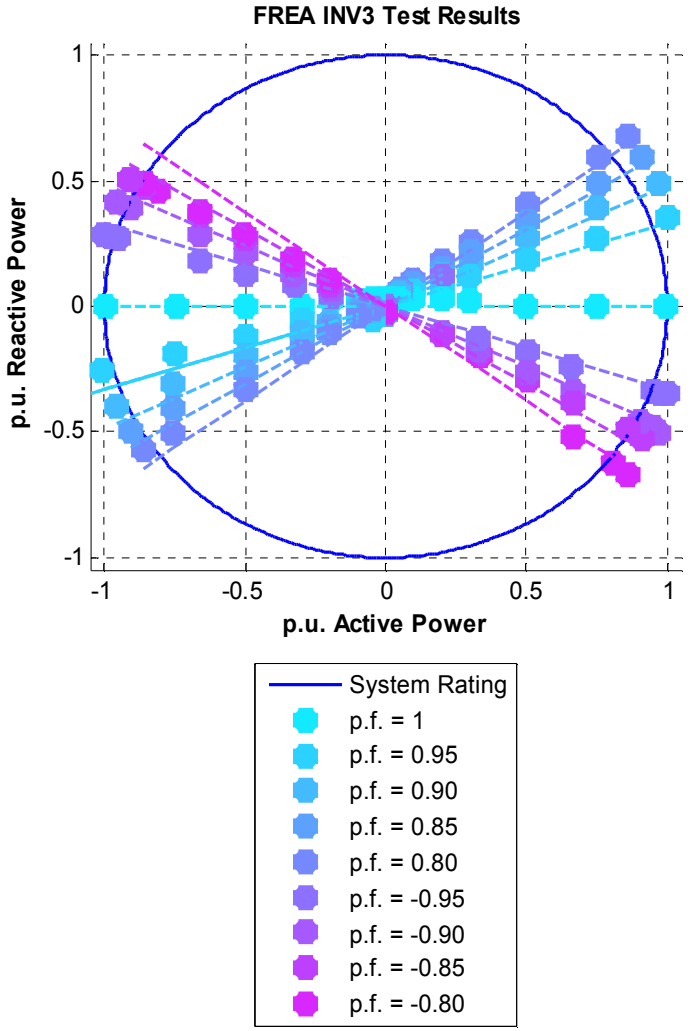


Review Data and Refine Protocols: Commanded Active Power



Review Data and Refine Protocols: Commanded Power Factor





Conclusions

- Energy storage advanced functions help support the grid
- Need a standardized method for verifying DER functionality
- SIRFN is improving certification protocols so they may be recommended as an international standard, by:
  - Building test-beds for advanced inverter testing (electrical performance and interoperability)
  - Comparing results from advanced DER functions
- This project identified differences in lab testing methodologies and is leading to improved testing protocols.

Questions?

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