2014 Smart Grid R&D Program
Peer Review Meeting

Smart Grid Pre-Standard Testing Support

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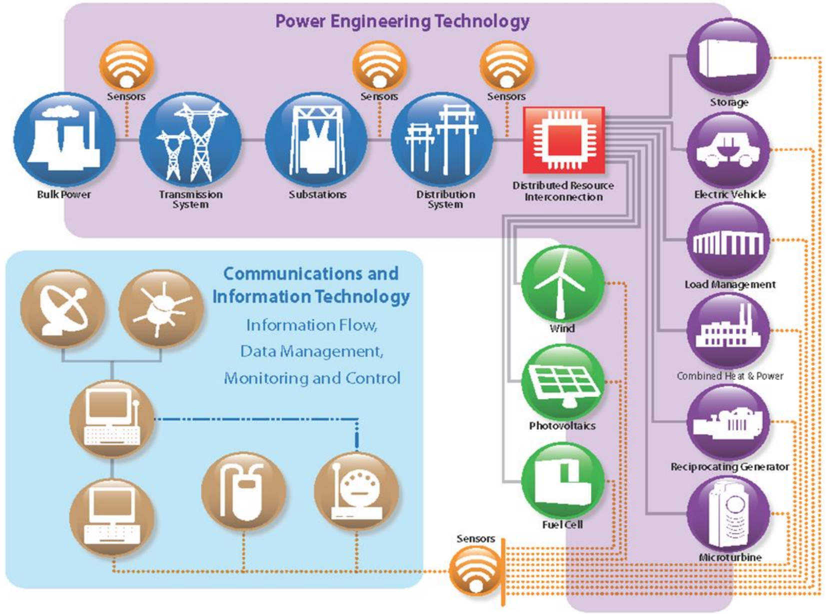
Smart Grid Pre-Standard Testing Support

Objective

Support evolution of the electric power system (EPS) that modernizes the EPS, enhances its security and reliability, facilitates recovery from disruptions, and, provides for incorporation of clean technologies, customer participation in electricity use, and choice in load management. Standards conformance testing play a major role in reducing technical, business and regulatory barriers and impacts, and toward increasing efficiency and resiliency of our electric infrastructure.



Life-cycle Funding Summary ($K)

FY 13, authorized	FY14, authorized	FY15, requested	Out-year(s) (FY16-17)
200	200	200	1000

Technical Scope

Work with, and facilitate, subject matter experts to identify and address gaps in, and recommendations for, standards testing requirements and procedures, and, establish, validate, and conduct advanced testing for: DER-EPS infrastructure including multi-path power and energy flows; improved operating practices; integration, and interoperability of power, communications and information technologies, and, for end-use applications and loads.

Problems, Needs, Benefits, and Impact of Conformance Testing (1 of 3)

- Lack of common understanding and knowledge base for SG interconnection and interoperability systems integration and product testing among power, information and communications technologies, stakeholders, and their roles
- Incomplete set of testing standards and best practices
- Lack of standards testing coordination and harmonization
- Untested or non-validated technology, operations, and tests
- Technology and testing: non-uniformity, non-interoperability, quality assurance, and acceptance practices
- Improved/validated DER integration practices, and agreed upon advanced operating strategies
- Lack of standardized interfaces – hardware and software, operational, and informational
- Lack of uniform, agreed upon implementation protocols

Problems, Needs, Benefits, and Impact of Conformance Testing (2 of 3)

- Standardized testing conformance to local, national and international SG interoperability standards is a patchwork (gaps in validity or acceptance) or is customized (testing schemes established on a case-by-case basis).
- Conformance via standardized test protocols (using accepted test beds and methods) provides confidence in claims of performance, and transparency for, manufacturers, vendors, integrators, utilities, authorities having jurisdiction over the grid, and to electricity customers.
- Conformance costs range up to 40% of a project's total cost for product/system design (type) testing, production testing, impact studies, installation evaluation, and commissioning; undue testing may cause projects failure (e.g., custom testing, or non-acceptance across different jurisdictions).

Problems, Needs, Benefits, and Impact of Conformance Testing (3 of 3)

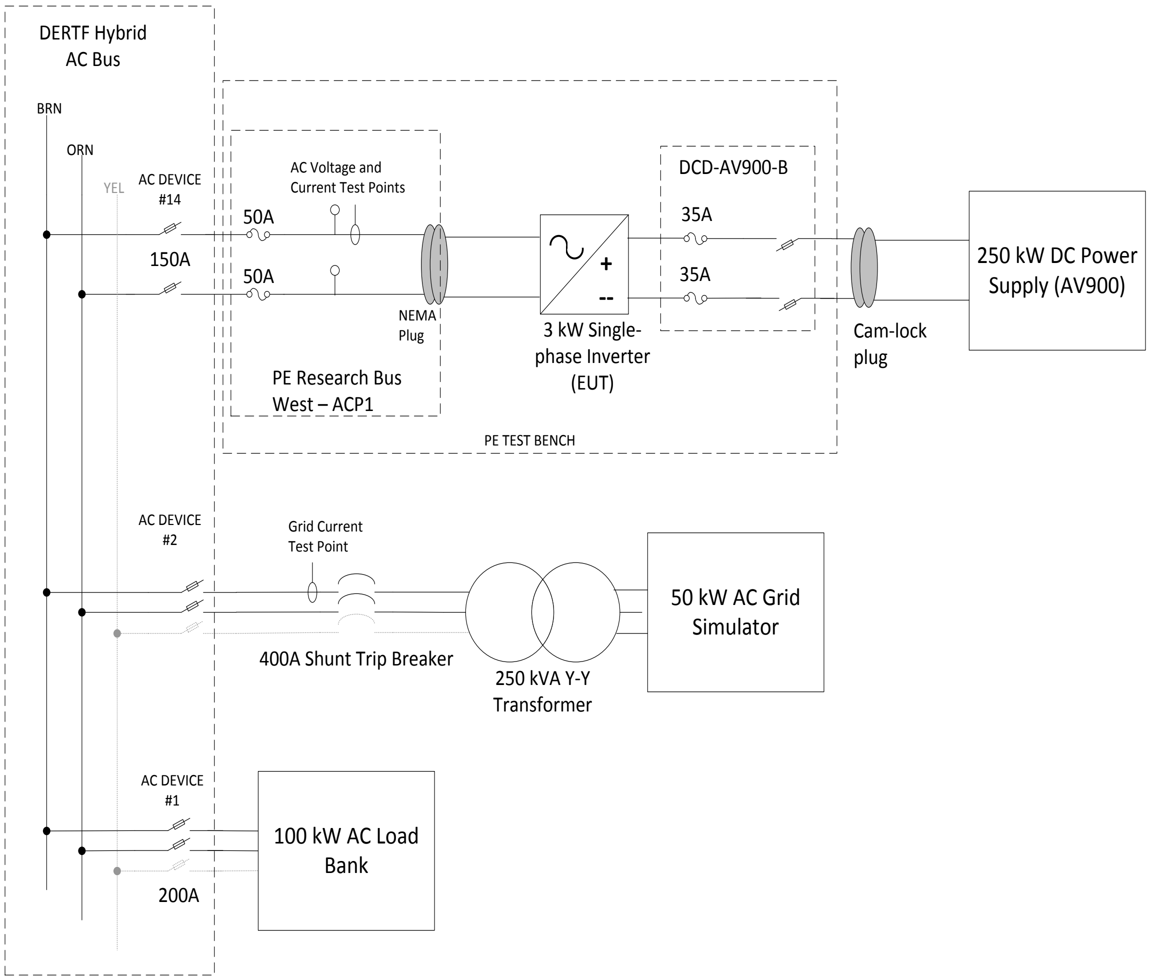
- New requirements and new product/system features mandates an ever-changing landscape for testing – having proven approaches and methodologies streamlines establishment of new testing protocols.
- Impacts/benefits of this project includes: establishing revised and new accepted conformance testing, lowering the cost of compliance, increasing confidence in advanced technology functions and grid-interactive operations, accelerating technology development through validation, and, maintaining or improving the efficiency, reliability, safety, and resiliency of the grid with integrated DER.

Technical Approach: Work with Partners and Stakeholders

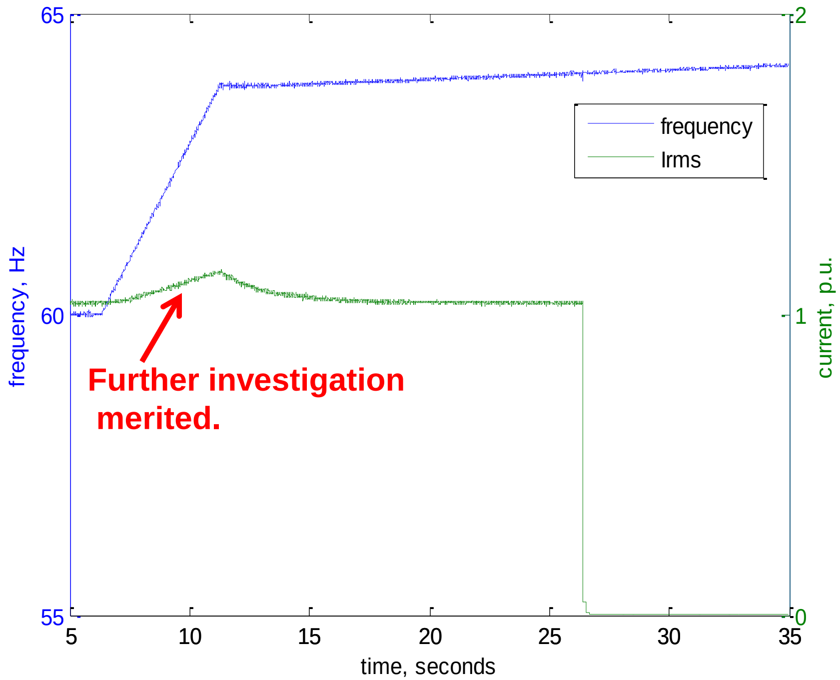
- New and revised test procedures are needed to verify the conformance of advanced DER interconnection systems to the requirements of the revised 1547 requirements, including advanced grid support features.
- Advanced grid support features may be interdependent, so these new test procedures should verify that interactions between features do not negatively affect grid safety, stability, or power quality.
- Advanced grid support features operate on a range of time scales, from milliseconds to many minutes, so the new test protocols should also test DER dynamic responses.
- New test protocols should build upon the success of IEEE Std 1547 by preserving the characteristics of IEEE Std 1547.1 to the extent possible.

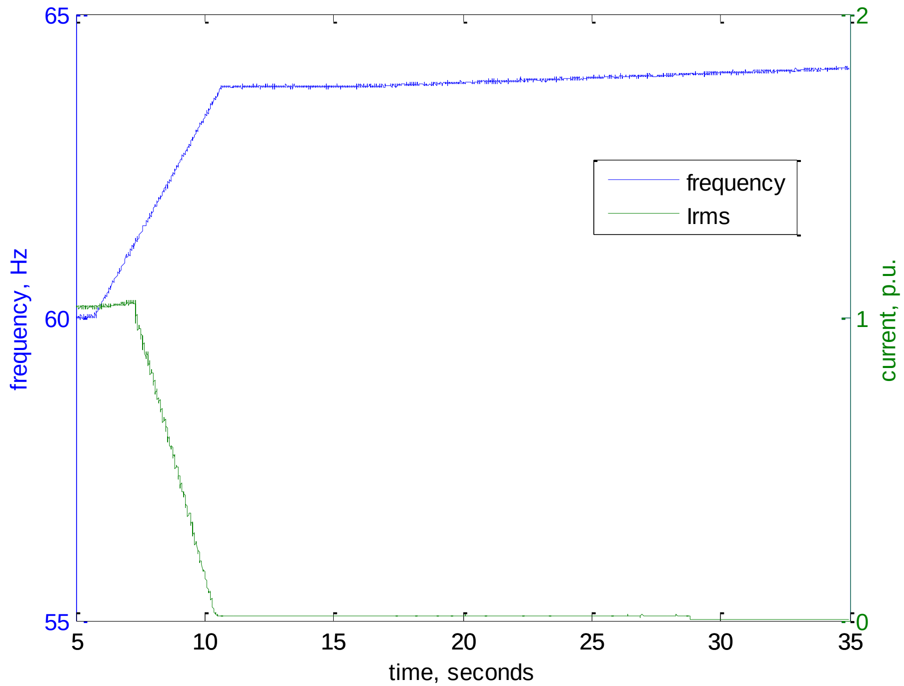
Prior Year Results, e.g., Grid-Support Advanced Inverter Frequency Testing

Commercially available string inverter that provides advanced grid support capabilities: tests were performed before complete manufacturer documentation of the advanced features was available.
Features tested were multi-level voltage trip settings, multi-level frequency trip settings, anti-islanding, volt-VAR control (voltage regulation), and high frequency power curtailment.



Prior Year Results, e.g., Grid Support Inverter Over-Frequency





Advanced-Inverter Power-Reduction Disabled. The rise in current during the frequency ramp in the test on the left is unexpected. That artifact is due to the inverter absorbing reactive power.

Advanced Inverter Power-Reduction Enabled (and tuned so the inverter output current is nearly zero when the trip frequency is reached). Note that the effect on the trip frequency was negligible.

FY2014 Milestones and Status

- Establish test procedures using PHIL; extend to control hardware in the loop (CHIL), initial data acquisition for volt/var control, and voltage ride-thru.

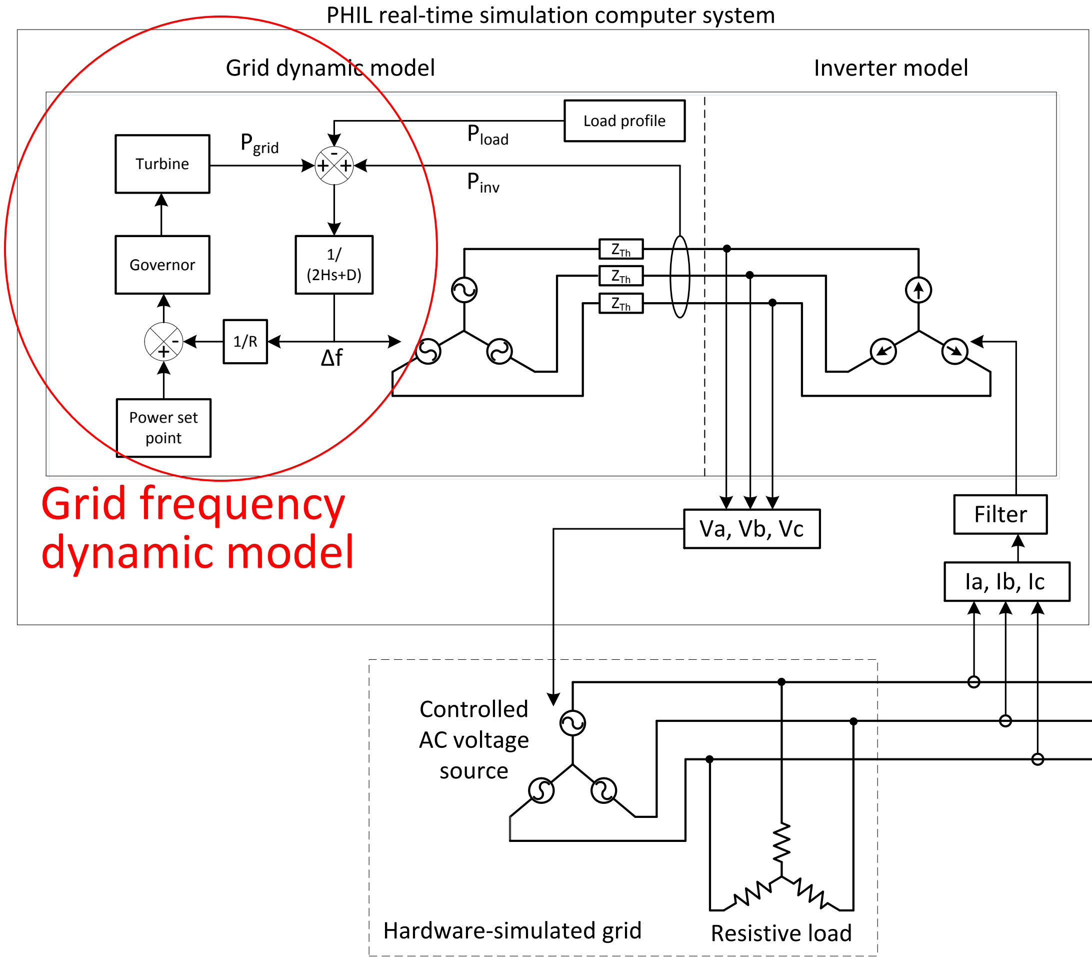
  Status:
  - Wrote letter report Jan ‘14 (A. Hoke, S. Chak., & T. Basso)
  - Article accepted in Journal of Photovoltaics (JPV)
  - Technical report on Beta Test Plan for Advanced Inverters published
  - Conducted frequency ride through test development and testing (instead of CHIL).

- Test volt/var control, and voltage ride-thru; establish test procedures and initial data acquisition for frequency ride-thru (NREL letter report; July 2014)

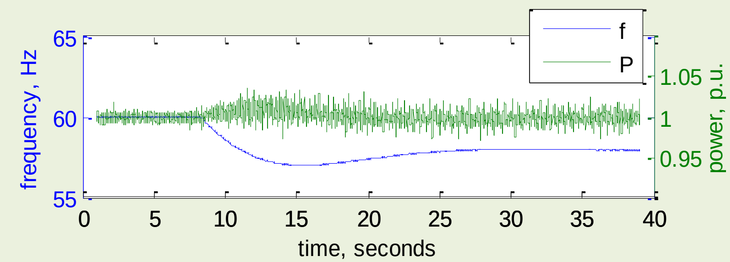
  Status:
  - Testing underway (will append to Jan 2014 report)

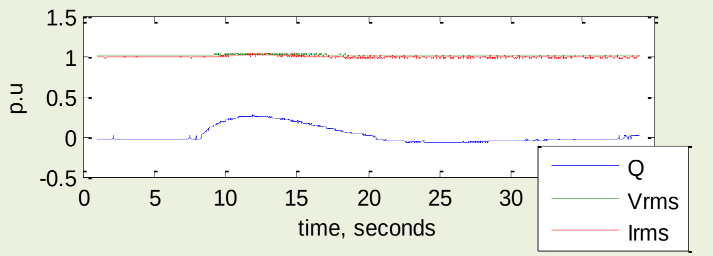
FY14 Results: Incorporated Grid Frequency Response Into PHIL System

PHIL model emulates grid frequency dynamics including governor (droop) control, inertia, damping, and other dynamics:



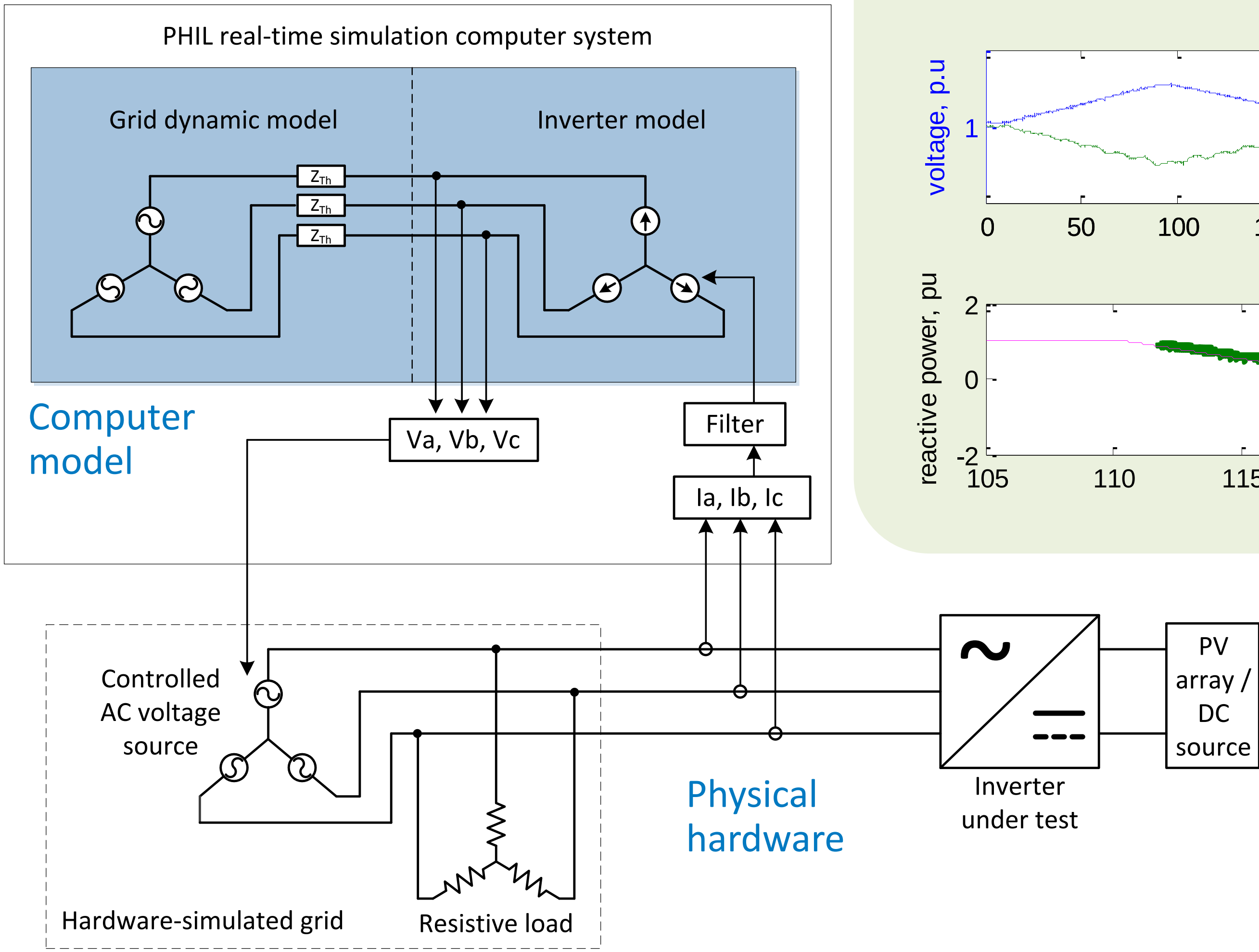
- PHIL test emulating major grid frequency event
- Commercial advanced inverter performing frequency ride-through:



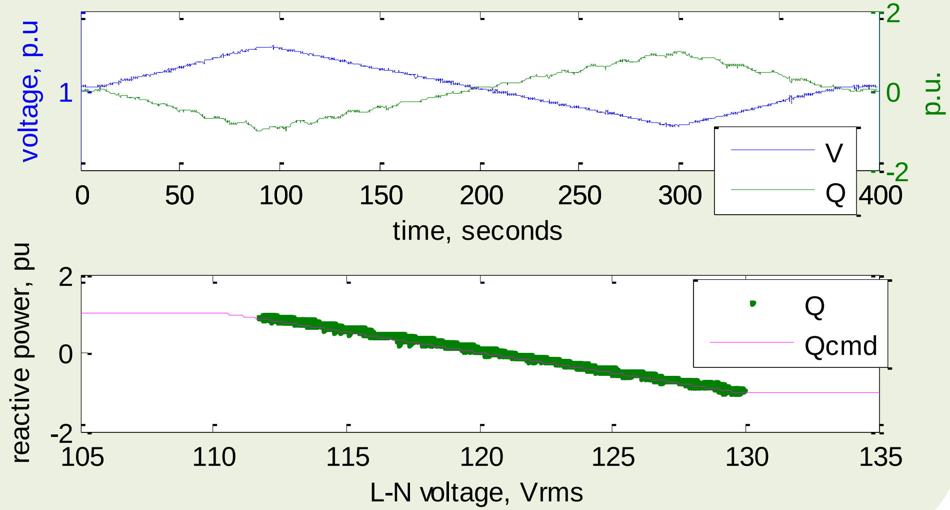


FY14 Results: Extended Advanced Inverter PHIL Test System to 3-phase

Power hardware-in-the-loop (PHIL) system for volt-VAR and voltage ride-through testing expanded for testing 3-phase inverters:



- 3-phase, 50 kVA inverter PHIL test
- Inverter performing volt-VAR and voltage ride-through:



Collaborations and Sharing

- Smart Grid Interoperability Panel (SGIP) Distributed Renewables Generation and Storage Subgroups: Distributed Energy Resources (DER) Interconnection Standards, and, Smart Grid Testing, Certification and Conformance; and support to Smart Grid partners and stakeholders (EERE, NIST, IEEE, IEC, CA Smart Inverter Working Group, CA Rule 21 revision, UL, TUV, SunSpec Alliance, etc.), FERC/NERC, SNL, States (such as CA, NJ), Utilities, Universities, system integrators.
- Working with IEEE 1547 standards development, it is estimated industry invests $5 for $1 of DOE funding.
- Working with other stakeholders, testing protocols and best practices are shared and debated within proprietary constraints.

Proposed FY15 Tasks

- PHIL testing with **multiple inverter interactions**
- PHIL testing of volt-VAr control using an EPS model that includes **nonlinear elements** (switched capacitors, tap-changing transformers, etc.)
- PHIL testing of other **advanced inverter features** (and interactions between those features), including frequency regulation, anti-islanding, and other methods of voltage regulation
- PHIL testing including more **detailed feeder models**; Thévenin equivalent circuits fully model the inverter terminal voltage and current, but they do not model the effect of inverter output on other elements of the circuit

Thank You!

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NREL: http://www.nrel.gov

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