



U.S. Department of Energy
**Energy Efficiency
and Renewable Energy**

Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable

DOE Solar Energy Technologies

Sandia National Laboratories PV Grid Integration Program 2009 Program Peer Review

Abraham Ellis

Denver, Colorado

March 10, 2009



Grid modernization is already underway... Will PV be a big part of it?



Potential barriers must be addressed NOW



PV Grid Integration (a.k.a. Systems Integration)

- Goal: “Address regulatory, technical and economic barriers to integrate solar electricity into the grid”
- Focus: high-penetration PV scenarios
 - high-density distributed, central station systems
- Scope
 - Distributed Technology R&D
 - Distribution System Integration
 - Test and Demonstration
 - System Analysis
 - Resource Assessment
 - Codes and Standards
- Relates to other DOE initiatives





Program Support and Technical Leadership

- Sandia/NREL coordinated effort

Organization	FY07 Budget	FY08 Budget	FY09 Budget (CR) *
Sandia **	\$700K	\$400K	\$400K
NREL	\$1,950K	\$400K	\$400K

* Includes \$200K for SNL and NREL under T&E program area

** Sandia funding levels exclude SEGIS solicitation (\$2,835k in FY09)

Emphasis	Organization
SEGIS – integration, controls, comm.	Sandia
Energy storage and energy management	Sandia
Advanced Inverter Functionality	Sandia/NREL
Electric Systems Integration and Simulation	Sandia/NREL
High Penetration Codes and Standards	Sandia/NREL
Outreach Activities	Sandia/NREL



PV Grid Integration at Sandia

- Sandia Team on PV Grid Integration
 - Abraham Ellis – Principal Investigator
 - Ward Bower – Inverter/Controller R&D
 - Dan Borneo, Stan Atcitty – Energy Storage, Power Electronics
 - Dan Riley – PV System testing and monitoring
 - Sig Gonzalez, Scott Kuszmaul – Microgrids, applications
 - Shannon Spires, Steve Goldsmith – Advanced controls
 - Jennifer Stinebaugh – Project Management
- At present, PV System Integration funding levels require us to leverage other resources to maintain expertise/readiness in this important technical area



PV Grid Integration at Sandia

- FY08 Milestones

FY08	Status
Complete RSI Reports (SNL/NREL)	Completed
Energy Storage (SEGIS-ES) program definition	Completed
Microgrid R&D *	Completed
Revised RSI Multi-year Research Plan (SNL/NREL)	Completed
Collect analyze data from fielded systems (high-penetration PV)	Progress
Tech. assistance to Hawaii, other partners (e.g., Forest City, PNM)	Continuing
Conducted REGIS workshop (1/09; FY08 effort)	Completed
Development of power/communications co-simulation software	Completed
SEGIS (reported separately)	Continuing

* Leveraged Sandia LDRD



Renewable Systems Interconnection Study

– Grid Advances

Power System Planning: Emerging Practices Suitable for Evaluating the Impact of High-Penetration PV (GE)

Advanced Grid Planning and Operations (EPRI)

Distribution System Performance Analysis for High Penetration PV (GE)

Transmission System Performance Analysis for High Penetration PV (GE)

Cyber Security Analysis (Sandia)

– Technology Advances

Advanced PV System Designs and Technology Requirements (BEW)

Enhanced Reliability of PV Systems with Energy Storage and Controls (GE)

– Tests and Demonstrations

Test and Demonstration Program Definition to Support High PV Penetration (BEW)

– Analysis

Utility Models, Analysis and Simulation Tools (EPRI)

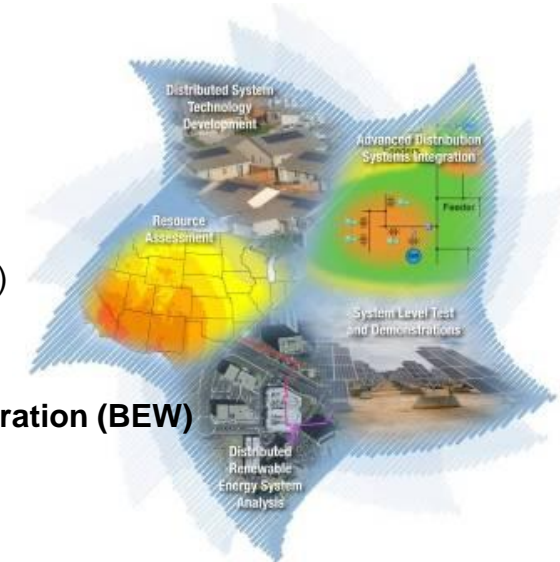
Production Cost Modeling for High Levels of PV Penetration (NREL)

Value Analysis (Navigant)

PV Business Models (Navigant)

PV Market Penetration Scenarios (Navigant)

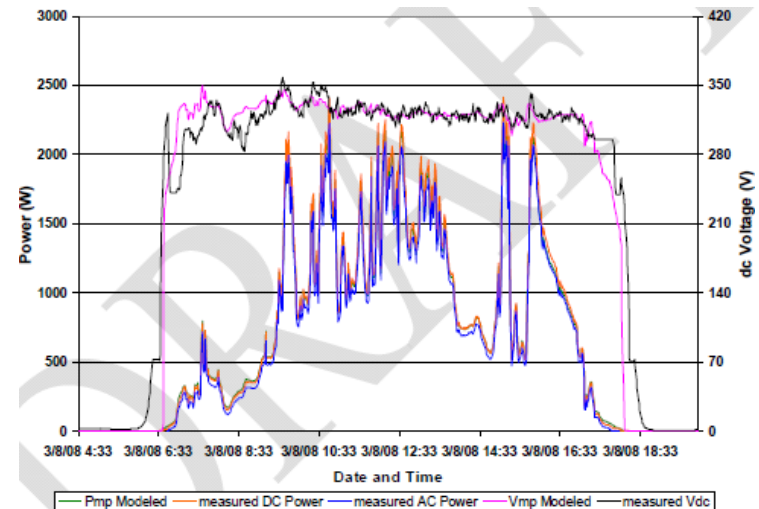
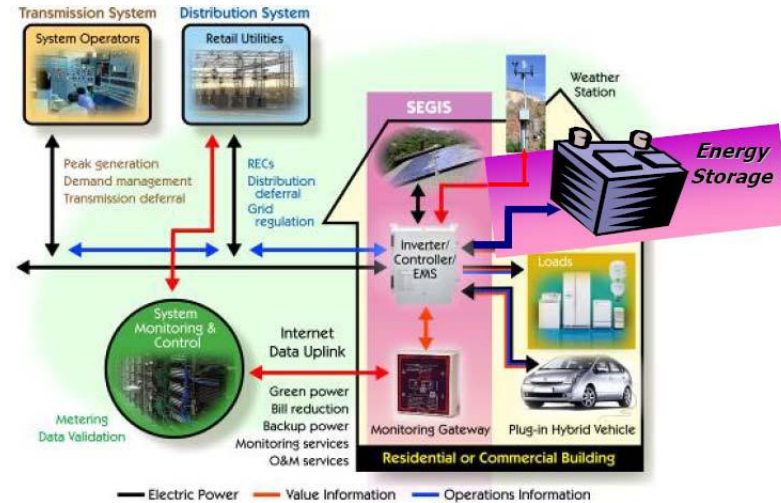
Solar Resource Assessment: Characterization and Forecasting to Support High PV Penetration (NREL)





SEGIS – ES (Energy Storage)

- FY08: Completed SEGIS-ES Concept Paper (05/08)
 - Defines scope of new SEGIS-ES program to deploy storage on PV systems by conducting R&D and develop technology
 - Builds on SEGIS program
 - Targets residential to commercial applications
 - Increasing value to consumer and utility
- FY09 (EN): Preparing for SEGIS-ES solicitation in FY10
 - Significant funding (several Million) for industry contracts will be required
 - Priority should be raised





Data Collection and Analysis



- Nellis AFB 14.2 MW DC System
- Commissioned in December, 2007
- Key stakeholders: MMA, SunPower, NV Energy, Nellis AFB

Nellis 14 MW (FY08/09 activity)

- High-penetration on radial feeder
 - ✓ Close to 100% penetration at low load
- Data collection at sub-minute intervals
- Scope of work
 - ✓ Characterize PV variability due to cloudiness
 - ✓ Statistically characterize output over time
 - ✓ Analyze benefits and impacts on local grid
 - ✓ Analyze voltage profile, equipment loading
 - ✓ Analyze system operations issues

Lanai 1.2 MW (FY09 activity)

- High penetration on island system
- Data collection already underway

Other opportunities developing

- Springerville PV Plant (TEP)
- Other large systems (SunPower)



Hawaii Support and Other Industry Collaboration



- Lanai 1.2 MW PV system
- Dedicated January 6, 2009
- Key Stakeholders: Castle & Cooke, MECO/HECO, SunPower, Satcon
- Advanced inverter features
 - ✓ Frequency and voltage ride-through
 - ✓ Utility-dispatchable reactive support
 - ✓ Ramp-rate control (using batteries)

• Hawaii

- ✓ Renewable energy deployment roadmap for Lanai (SNL/NREL)
- ✓ Specification of battery system for Lanai PV System
- ✓ Modeling support for power flow and dynamic performance studies (FY09 activity)
- ✓ Siting of 3 MW PV array, smart controls for homes with integrated PV (Forest City, Oahu)

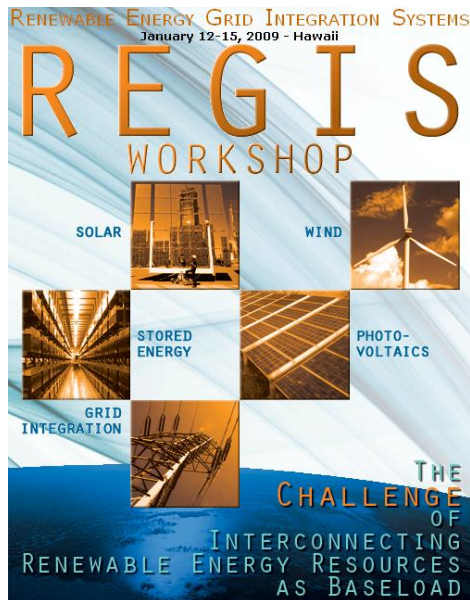
• Other

- ✓ Residential PV systems with energy storage (Forest City, PNM, EPRI – Mesa Del Sol, NM)
- ✓ SunPower – Collection and analysis of high-resolution data



Renewable Energy Grid Integration (REGIS) Workshop

- Held January 12-15, 2009 in Lanai, HI
- Collaborative activity between DOE and Asia – Pacific Economic Cooperation (APEC)
- International information sharing on high-penetration renewable integration issues and solutions

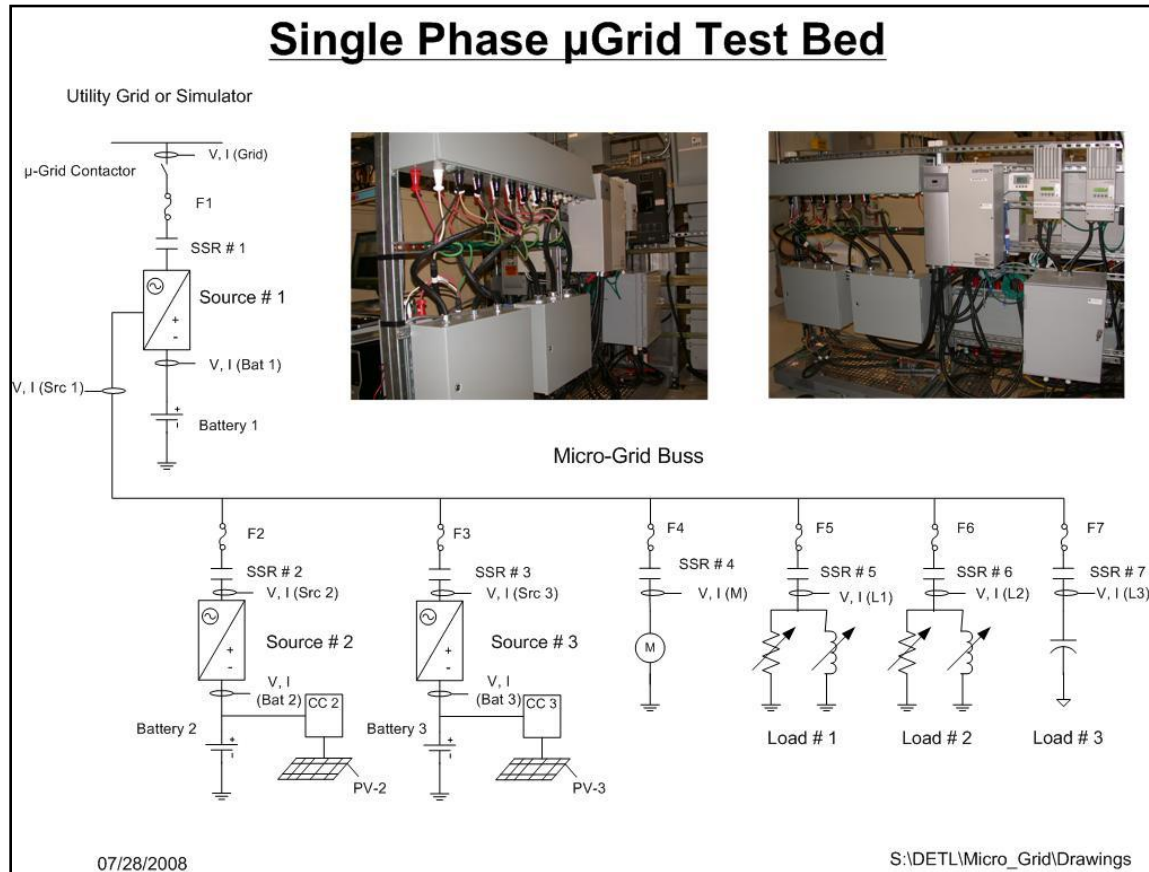


Industry Sector	Participants
Electric Power Generation	5
Wind Energy Technology	3
Energy Storage	3
Policy & Regulations	6
Transmission and Distribution	3
Solar Energy Technology	5
Electric Utility Management & Ops	3
Standards	1
Other:	4



Distributed Energy Technology Laboratory (DETL)

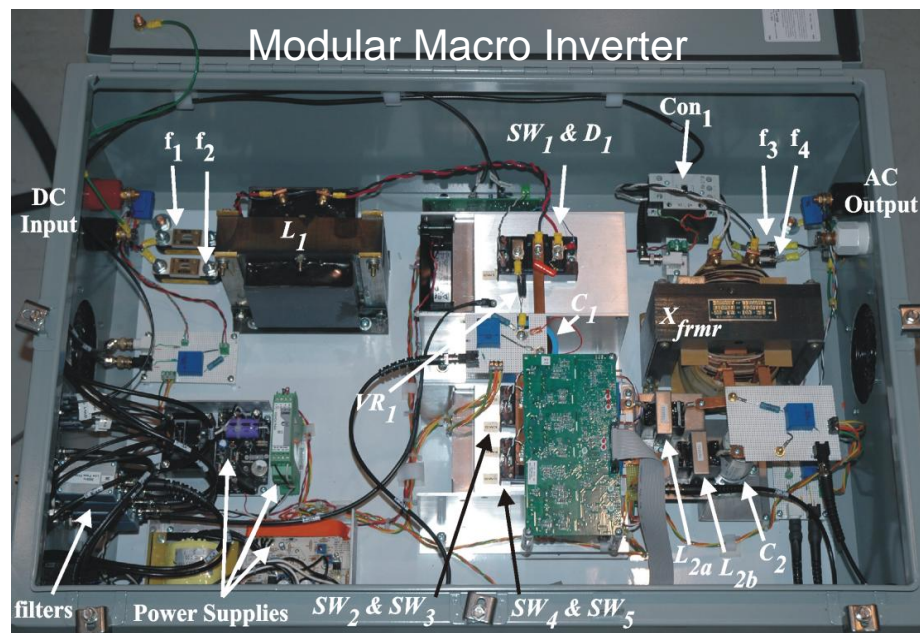
- Expansion partially funded DOE; significant internal resources leveraged
- Integrates multiple sources (PV, diesel, microturbine), energy storage, and loads in multiple configurations
- Algorithm development platform and expanded testing capability
- Supports several PV program areas
 - DOE: SAI, SEGIS, HCEI, SCADA, Storage, Power Electronics
 - Industry: PNM/EPRI, Mesa Del Sol, Sharp, GE
 - Internal R&D on advanced microgrid applications (next page)





Lab-Directed Research & Development (LDRD)

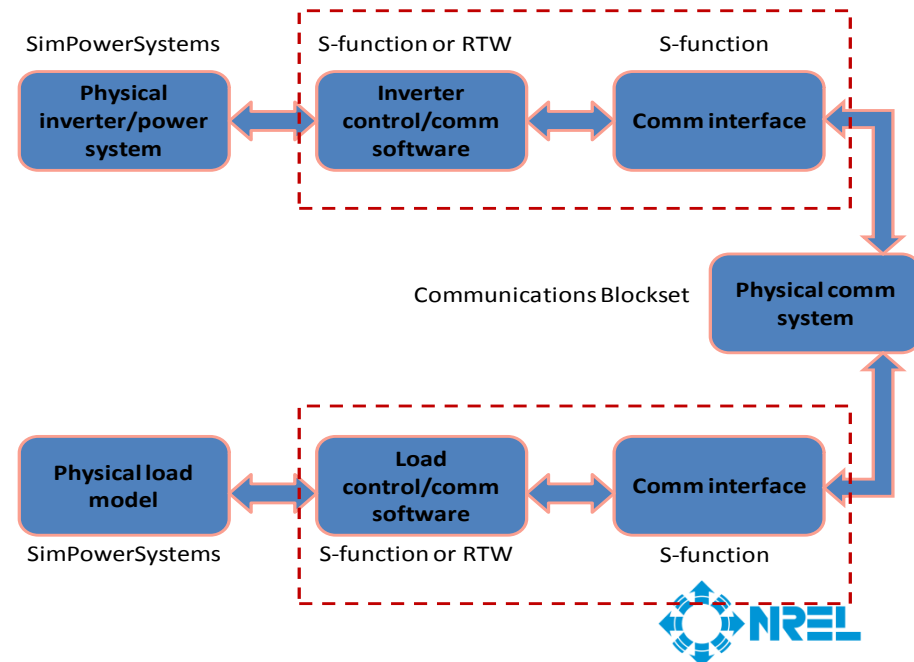
- Intelligent Power Controllers for Self-Organizing MicroGrids
 - ✓ Develop open, fully controllable converter platform capable of hosting advanced controls
 - ✓ Status: Modular Macro Inverter hardware completed, working on controller
- Innovative Control of a Flexible, Adaptive Energy Grid
 - ✓ Develop scalable closed-loop nonlinear control concepts and analyses based on exergy/entropy, as applied to systems that contain variable sources and storage
 - ✓ Using Lanai PV system as a test case
 - ✓ Presented theory as a day-long IEEE Conference on Decision and Controls (Dec. 2008 – Cancun, MX)
- Scalable Micro-grids
 - ✓ Develop revolutionary control architecture for future micro-grids; develop low cost sensors using micro-systems technologies





Power systems/communications co-simulation capability

- Needed to rapidly develop and prototype advanced controls and intelligence in microgrids
- Involves overcoming several fundamental system simulation issues (vastly different time scales, digital vs. continuous phenomena, others)
- Approach leverages existing Sandia Matlab/Simulink expertise
- Status:
 - ✓ Communications interface block developed and tested
 - ✓ Novel approach to modeling of communications under development; full physical simulation may be rendered unnecessary





Industry Partnerships

- Strong industry partnerships keep our work relevant!
- A key role for the Grid Integration program is to catalize industry connections (utilities, integrators, developers, users, OEMs, standards, etc.) to address technical challenges and prioritize activities

- ✓ Technology development
- ✓ Impacts and benefits
- ✓ Modeling and analysis
- ✓ Standards development
- ✓ Regulatory implementation





Future Plans (FY09)

- Investigate energy storage applications for high-penetration PV
 - Preparing SEGIS-ES solicitation
- Define comprehensive effort on high-resolution PV data collection and analysis (Sandia/NREL)
 - Industry consultation through Ad-Hoc Group
 - Directly address main concerns: high variability, high ramp rates
 - Allows for exploration of system-level and local mitigation options: energy storage, advanced controls, forecasting, generation flexibility, markets
- Codes and Standards for high-penetration PV (NREL/Sandia)
 - Review existing standards and on-going efforts
 - Prioritize critical needs to enable high-penetration PV
- Develop methods and tools to integrate large-scale variable generation in utility planning and operations
- Develop grid simulation models and guidelines



Sandia FY09 Planned and Proposed Activities

Milestones	Funding
Continue Industry and program support	CR
High-Penetration PV Workshop	CR
Data Collection and Analysis (Nellis, Lanai)	CR
White paper on high-resolution data collection requirements	CR
SEGIS-ES draft RFI, technical foundation white paper	CR*
SEGIS-ES industry consultation, industry workshop	CR*
Codes and Standards for high-penetration PV	EN
Guidelines for modeling PV systems in utility studies	EN
Prototype grid simulation models for PV system	EN
Integration and validation for new communications and	EN



- PV Grid Integration program focuses on technical issues related to high-penetration PV
- Critical efforts that need more attention
 - High-resolution data collection and analysis
 - Utility planning/operations models, methods and tools
 - Codes and Standards for high-penetration PV
 - Energy storage
- Main challenges going forward
 - Industry coordination
 - Prioritization of activities with constrained budget