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Renewables Grid Integration and Related Activities at Sandia

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Sandia National Laboratories

Exceptional service in the national interest

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NNSA

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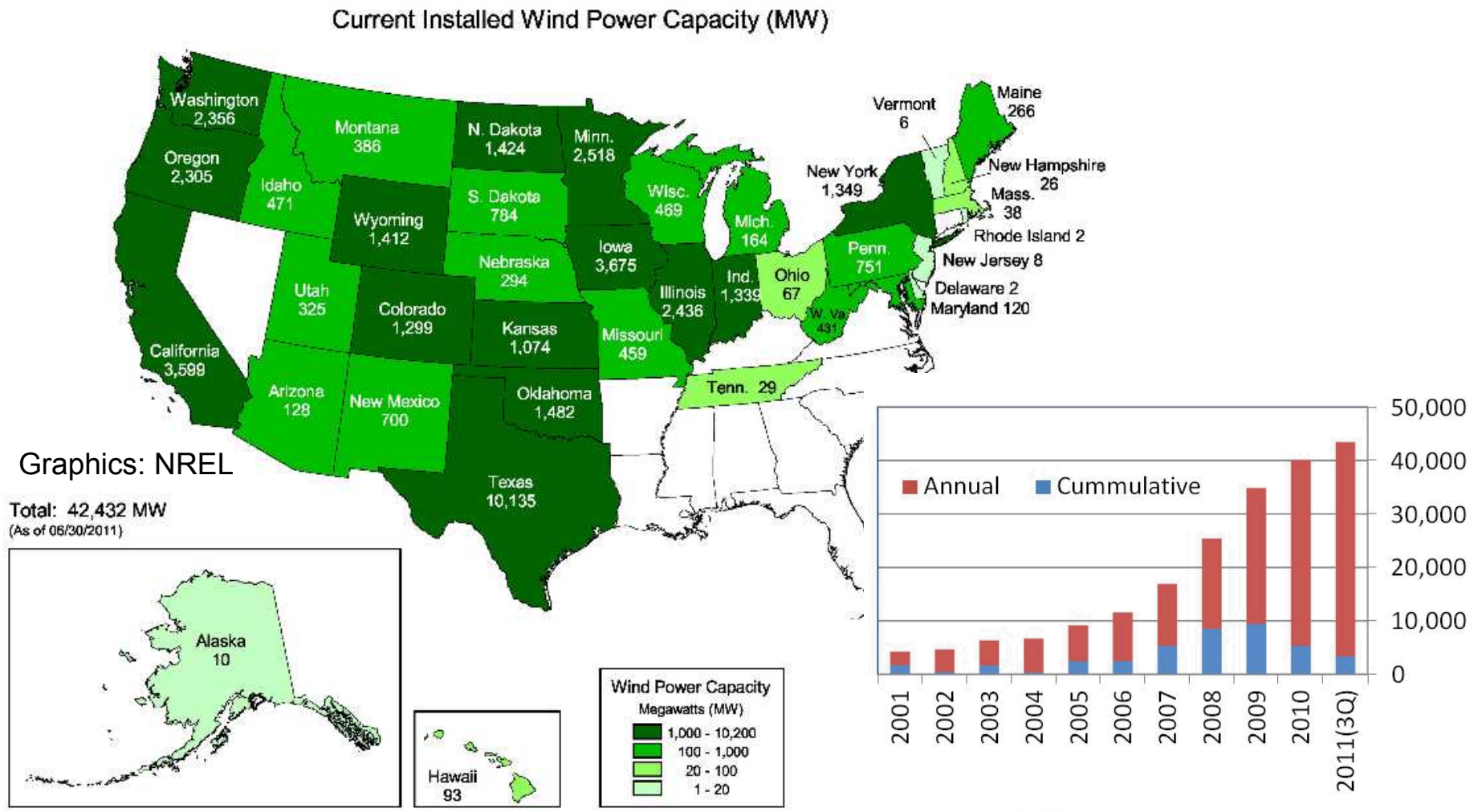
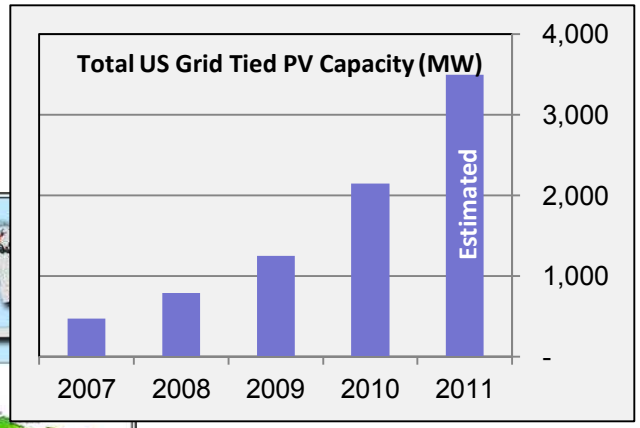
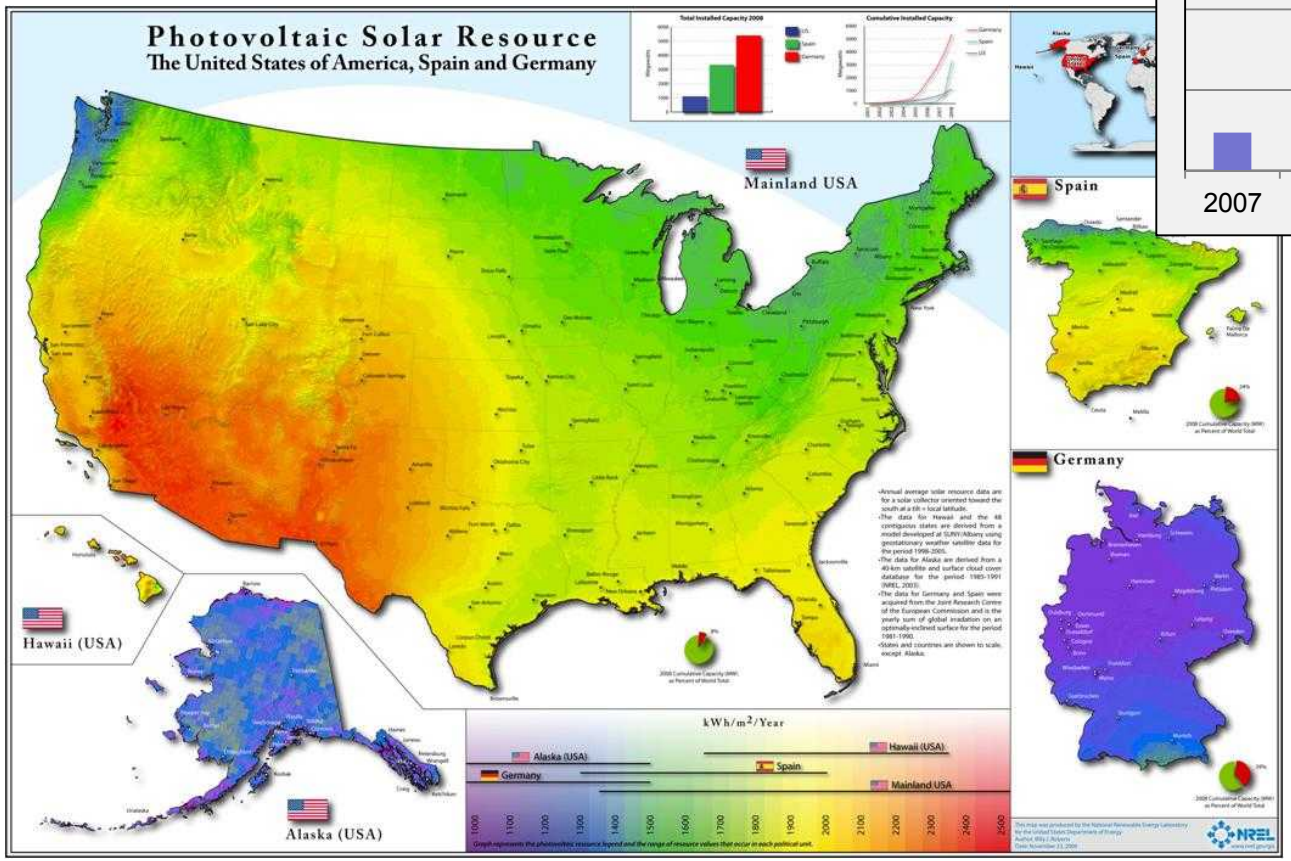
Wind Generation Deployment in the US Still Going Strong!



PV at a Lower Deployment Scale, But Future Potential is Huge!

- 2010: 2.1 GW total; 2011:~3.5 GW total
- Trend toward larger plants





Renewables Grid Integration and Related Activities at Sandia

- Wide range of technical areas
  - Solar (PV, Thermal), Wind, Hydro, Geothermal
  - Energy Storage, Power Electronics, Microgrids
  - Controls, Visualization, Cyber Security, Reliability, etc.
- Wide scope
  - Distribution and Transmission
  - Planning and Operations
  - Technology Development
  - Modeling and Analysis
  - Testing and Demonstration
  - Standards Development

- The following material describes a portion of Sandia's recent work in areas related to Distributed PV / Smart Grid

PNM Smart Grid Project

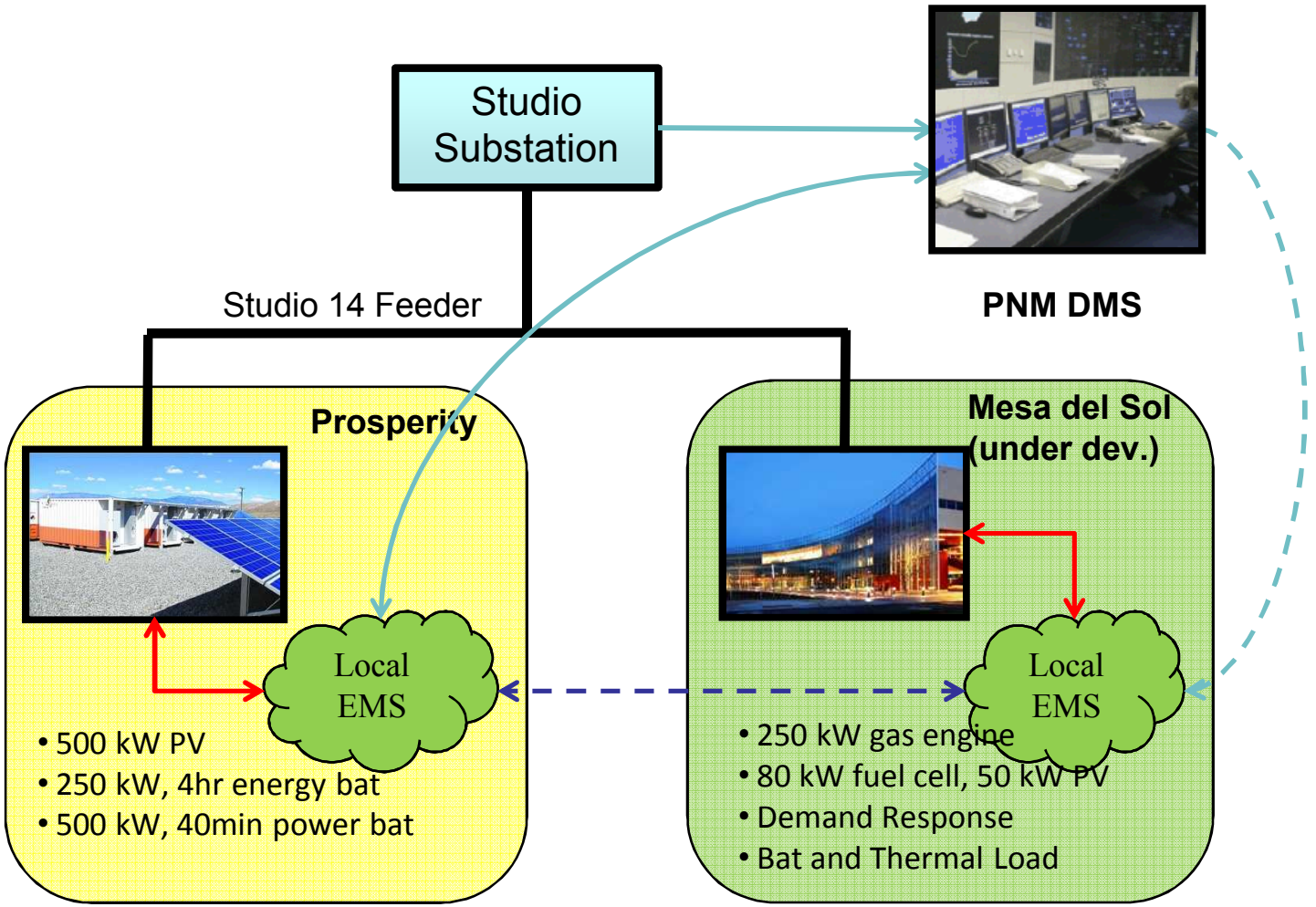
- Full integration of a Renewable Energy and Smart Grid concepts into utility operations
  - PV, Wind, Energy Storage and Demand Response, other DER
  - Residential/Building/Utility scale resources and systems
  - Layers of controls

- Large-scale testbed fully accessible to research, testing & demonstration

Graphic: EPRI / PNM

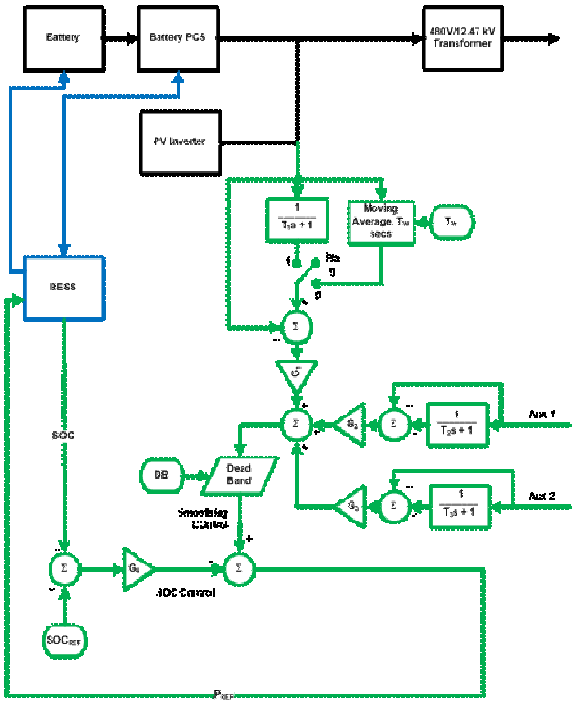
PNM Smart Grid Project

- Local and Coordinated Microgrid Controls

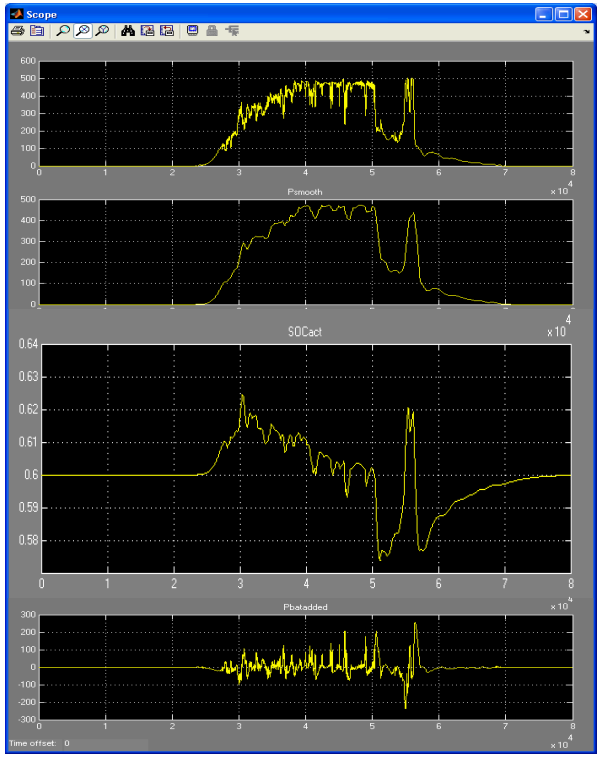


PNM Smart Grid Project

- Local Control: Active Power Management
  - PV ramp mitigation, energy shifting, optimized dispatch
  - Research focuses on performance of advanced batteries



Sandia Smoothing Simple Version A1



← PV Output

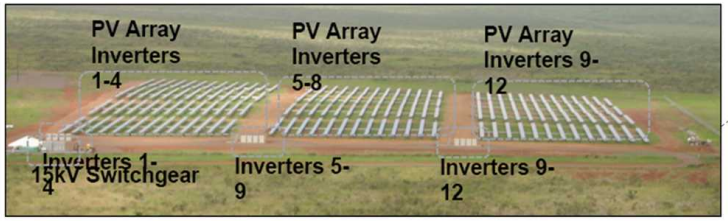
← PV+ BAT Output

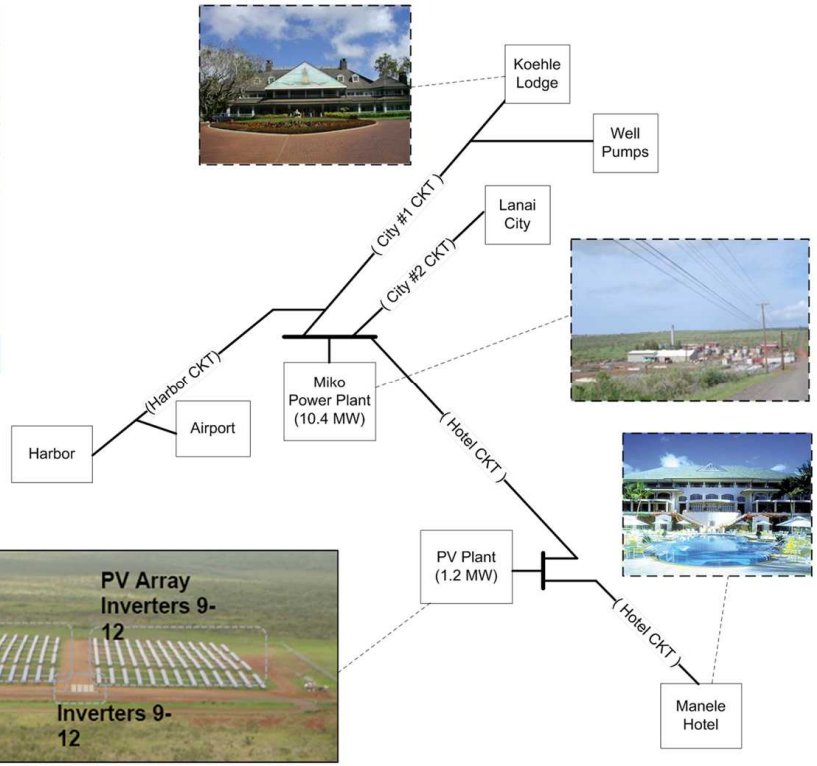
← BAT SOC

← BAT Output

Lanai Island High Penetration PV µGrid

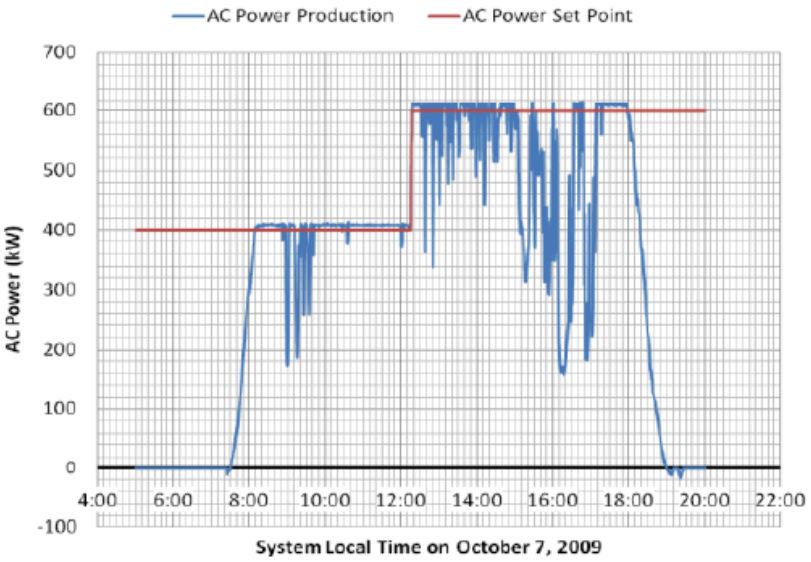
- 1.2 MW PV, 1 MW-hr battery, 4.5 MW peak load
- PV/storage system features advanced grid support functions
- Commercial system, heavily instrumented

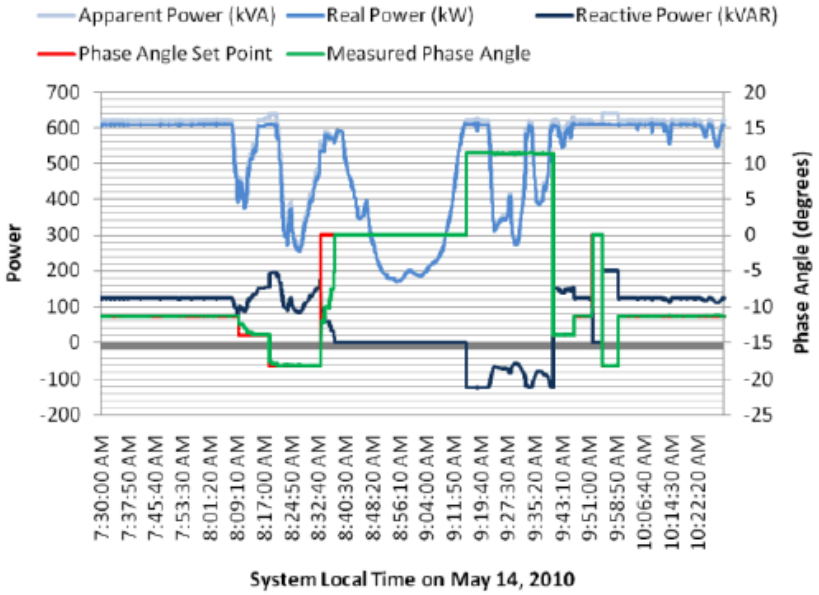




Lanai Island High Penetration PV µGrid

- Advanced functions include power factor control, active power scheduling, ramp rate control, voltage ride-through



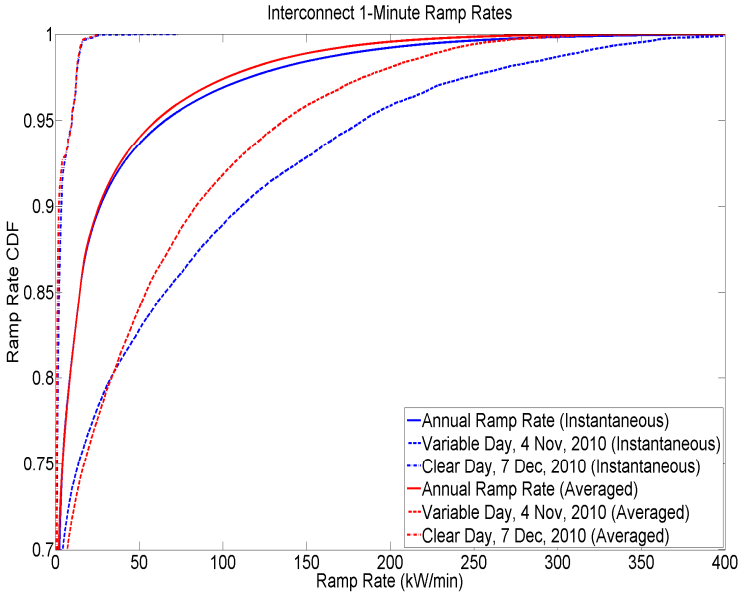


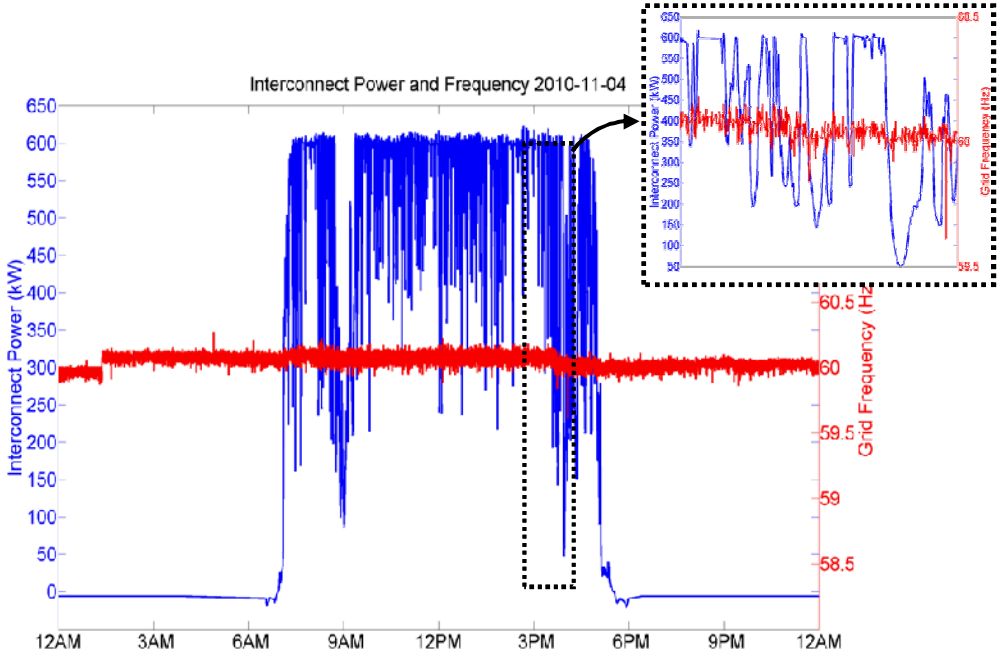
Graphics: Johnson, R. et al, “Methods for Integrating a High Penetration Photovoltaic Power Plant into a Micro grid”, IEEE PVSC 2010

- Energy storage system provides additional ramp rate control and frequency response (per interconnection agreement)

Lanai Island High Penetration PV µGrid

- Sandia research focuses on three areas
  - Assessment of Grid impacts
  - Assessment of operational experience with new technologies
  - Characterization of PV output variability

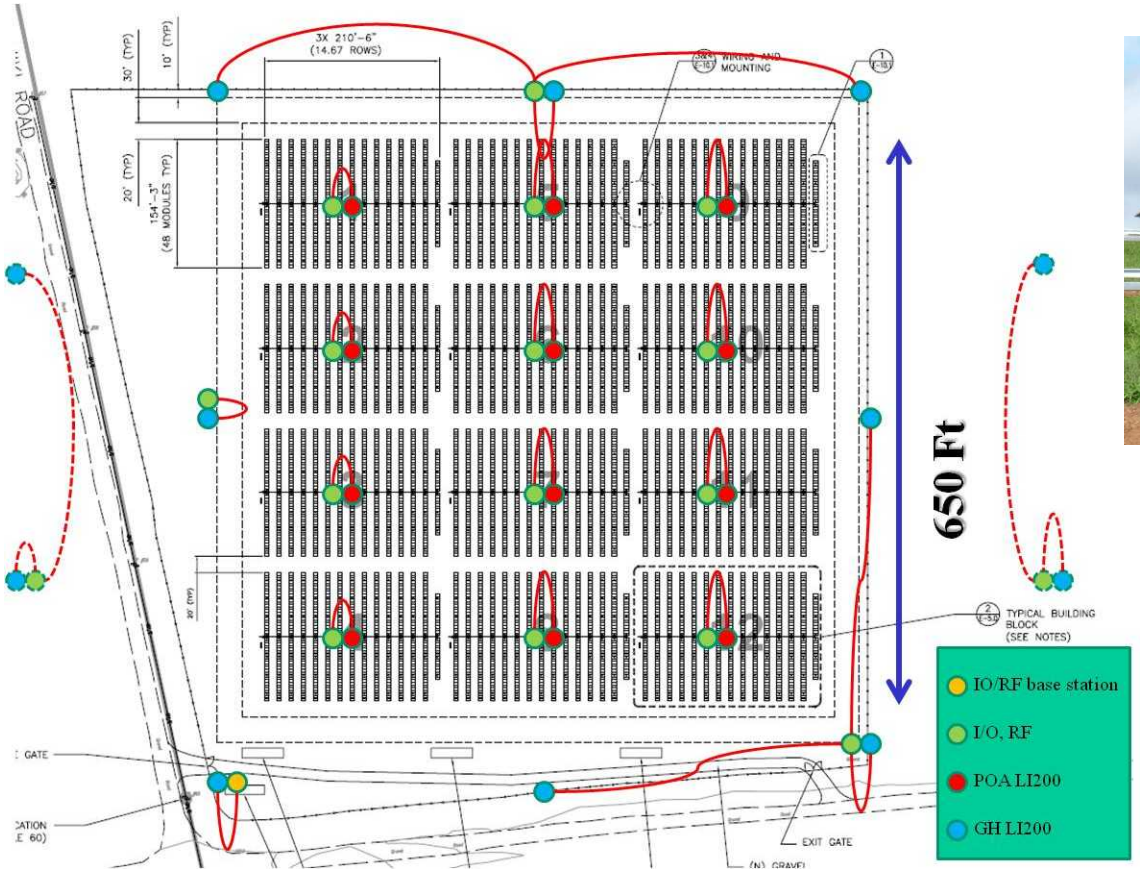




Graphics: Johnson, J., Initial Operating Experience of the La Ola 1.2-MW Photovoltaic System SAND2011-8848 October 2011

Lanai Island High Penetration PV µGrid

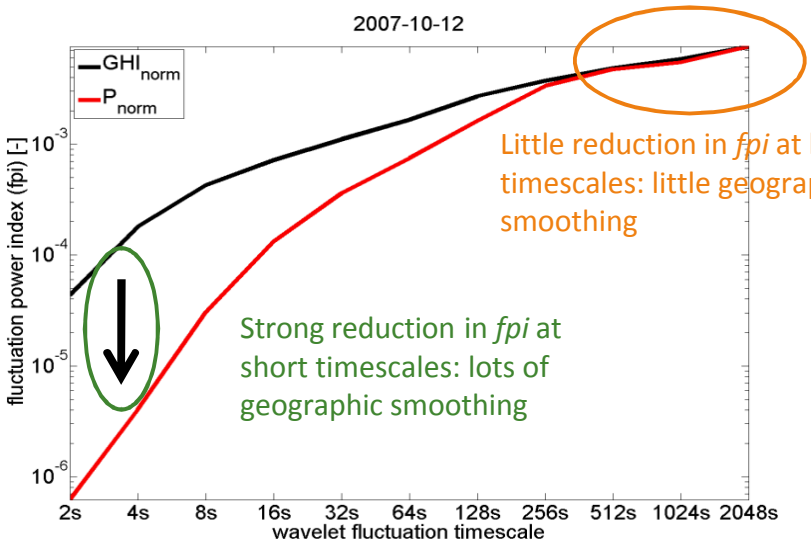
- High-speed irradiance sensor network to investigate the relationship between irradiance and plant output variability

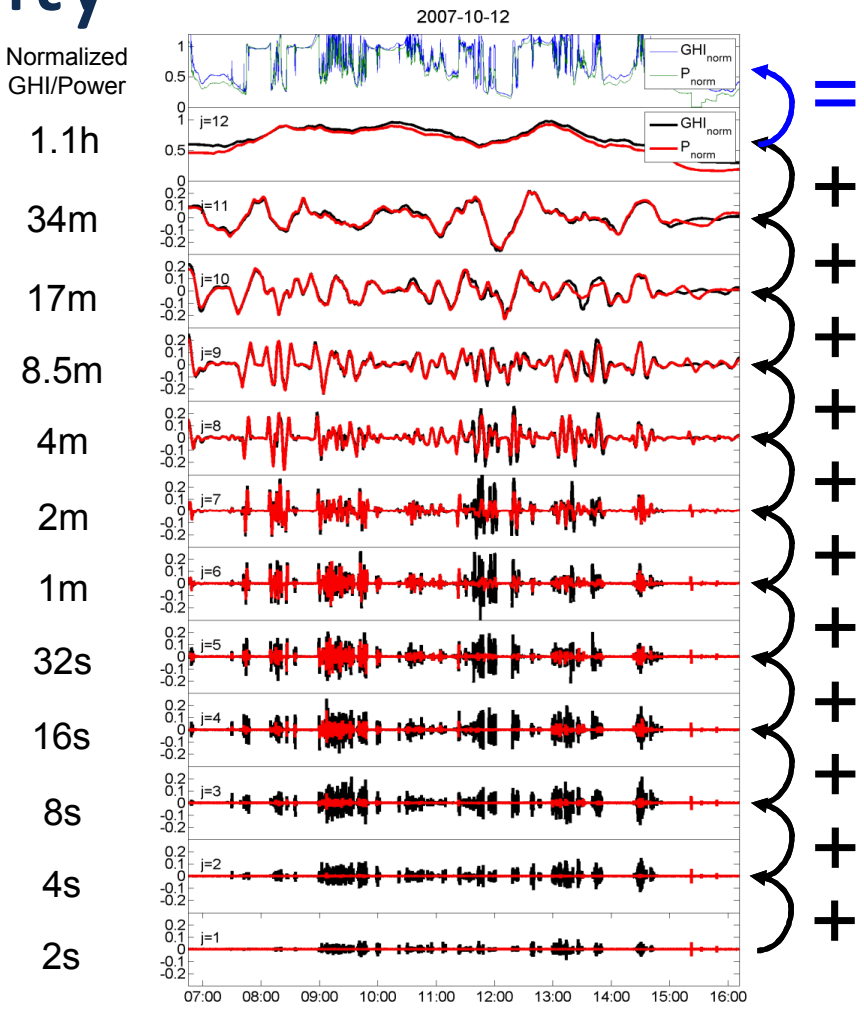


Similar sensor network installed in a commercial 18 MW PV plant in CO

Characterization and Modeling of PV Output Variability

- Wavelet-based model describes how variability scales as a function of plant footprint and timeframe

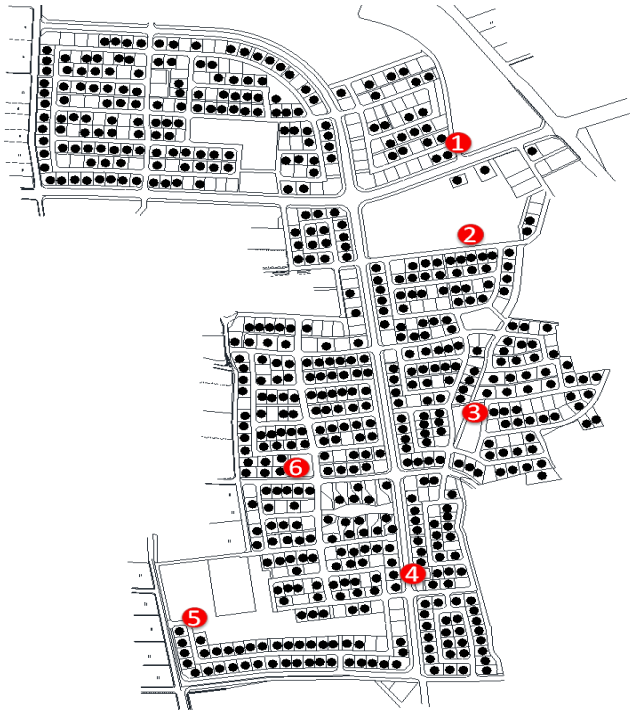




M. Lave et. al., "Simulating Solar Power Plant Variability for Grid Studies: A Wavelet-based Variability Model", Presented at UWIG Solar Users Group Meeting, Maui, Hi, October 2011

Characterization and Modeling of PV Output Variability

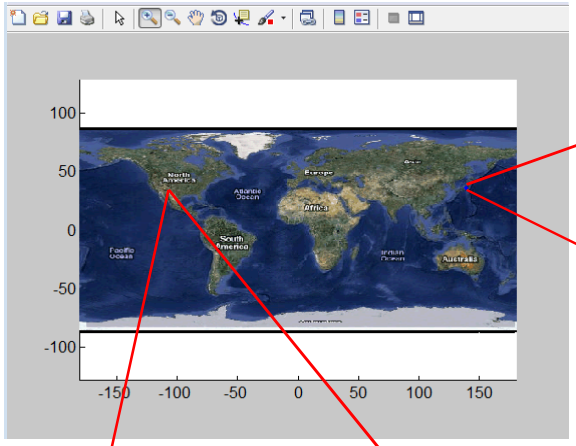
- Validation against high resolution data from multiple systems types, scales, locations

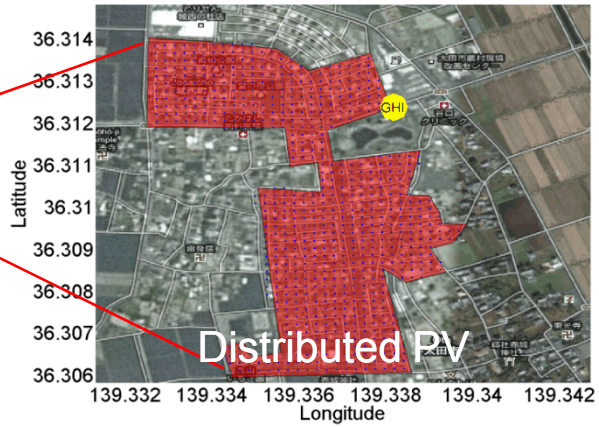


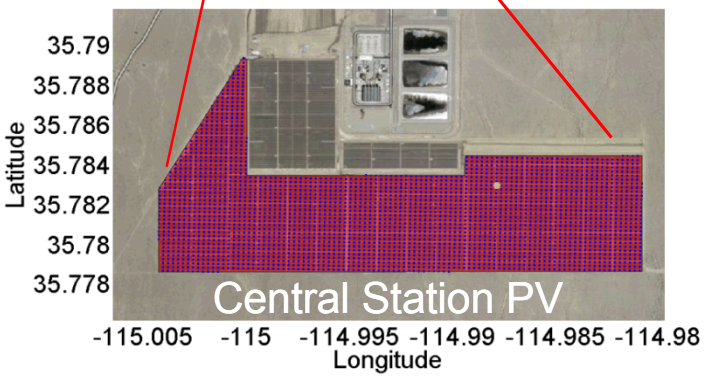
"Ota City: Characterizing Output Variability from 553 Homes with Residential PV Systems on a Distribution Feeder", SAND2011-9011, November, 2011

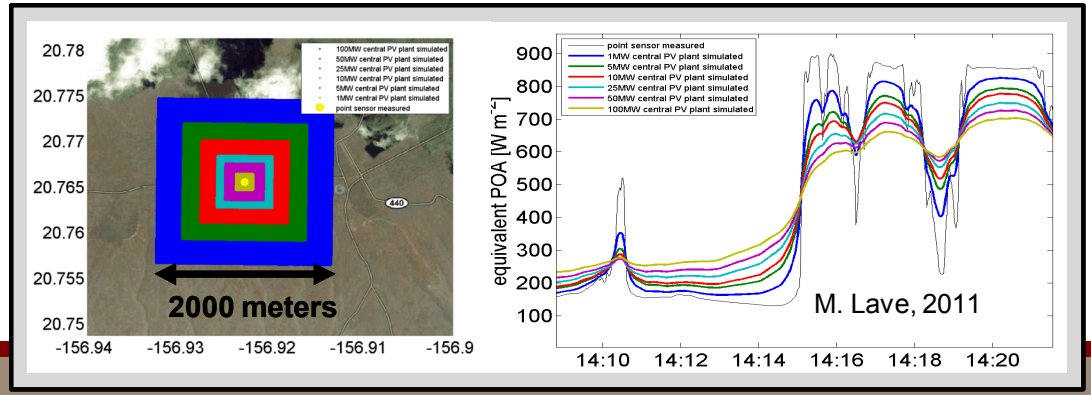
Characterization and Modeling of PV Output Variability

- One application: Estimate solar input data for analysis at any location where irradiance data is available



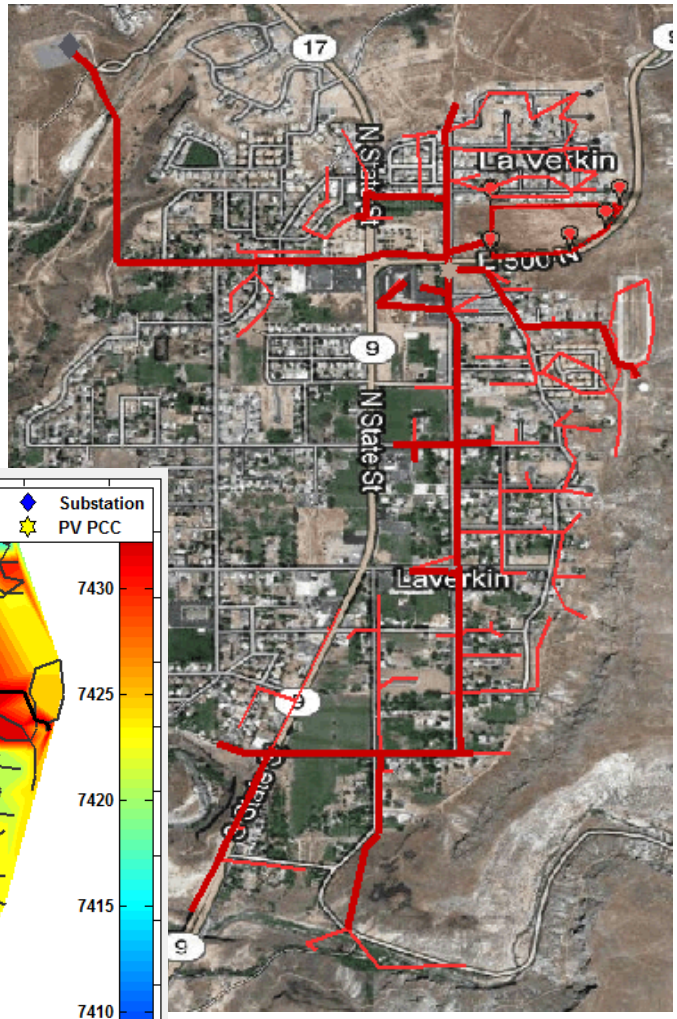


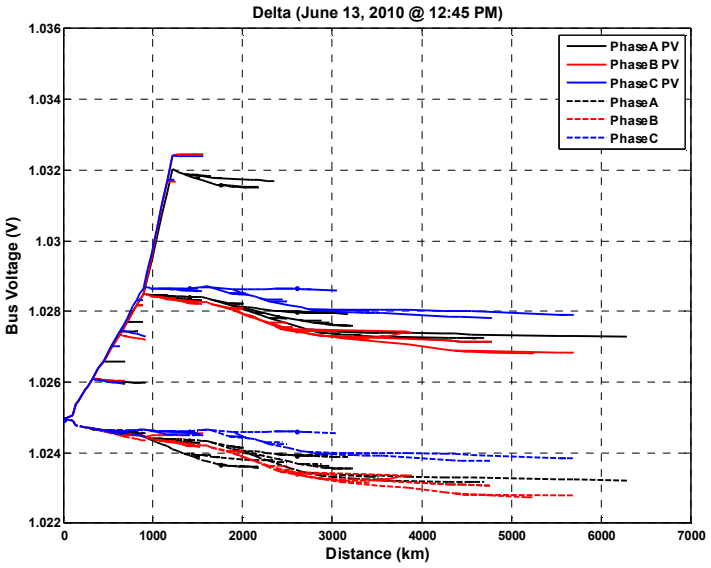


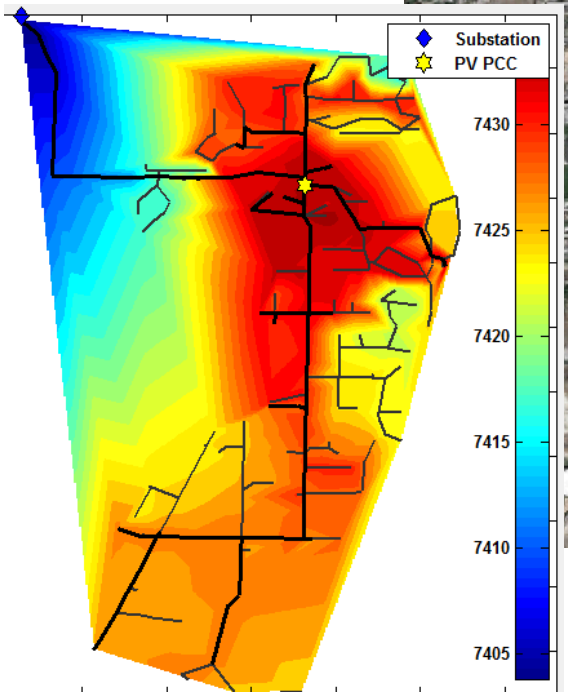


Modeling and Simulation

- Increase understanding of expected distribution system performance with high penetration PV
- Improve simulation models tools & techniques



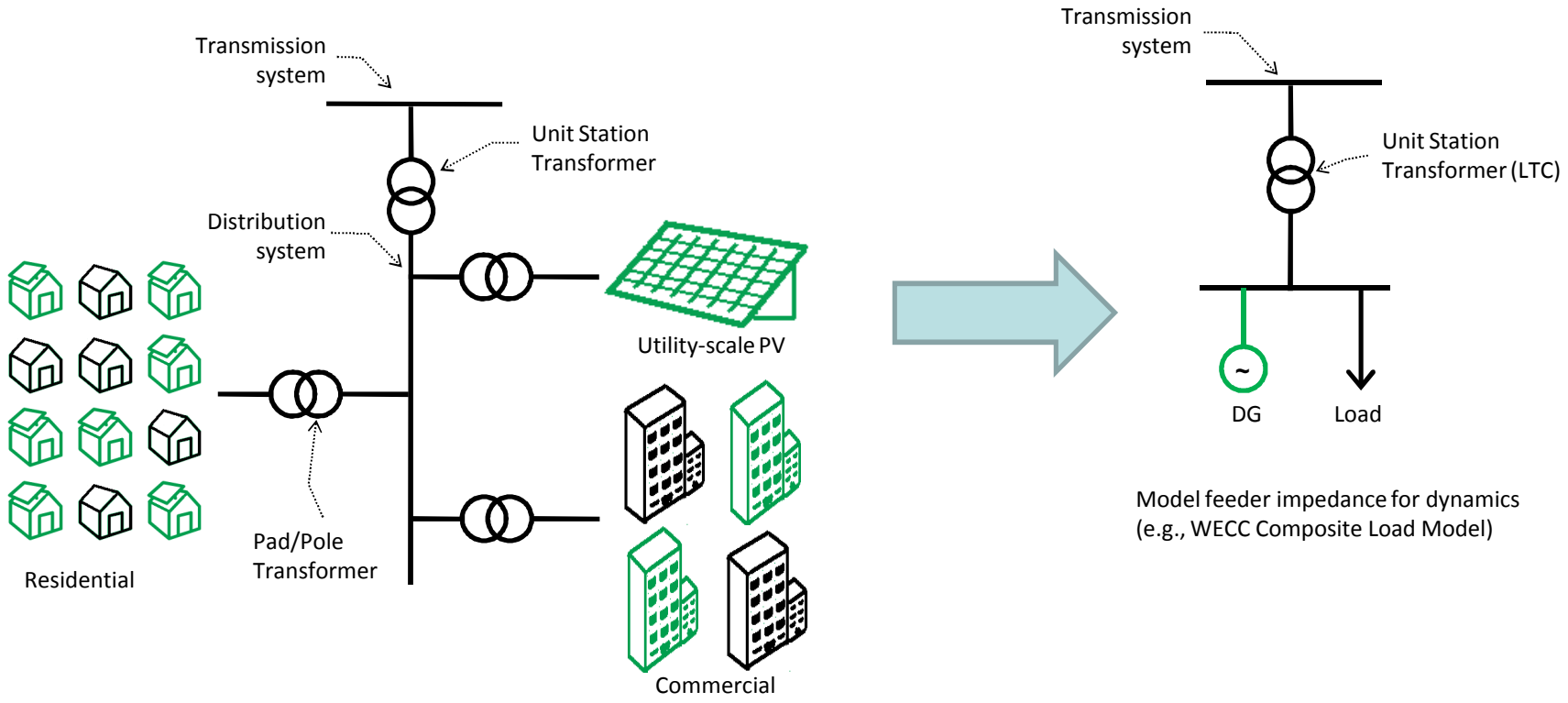




M. Reno, J. Quiroz, 2011

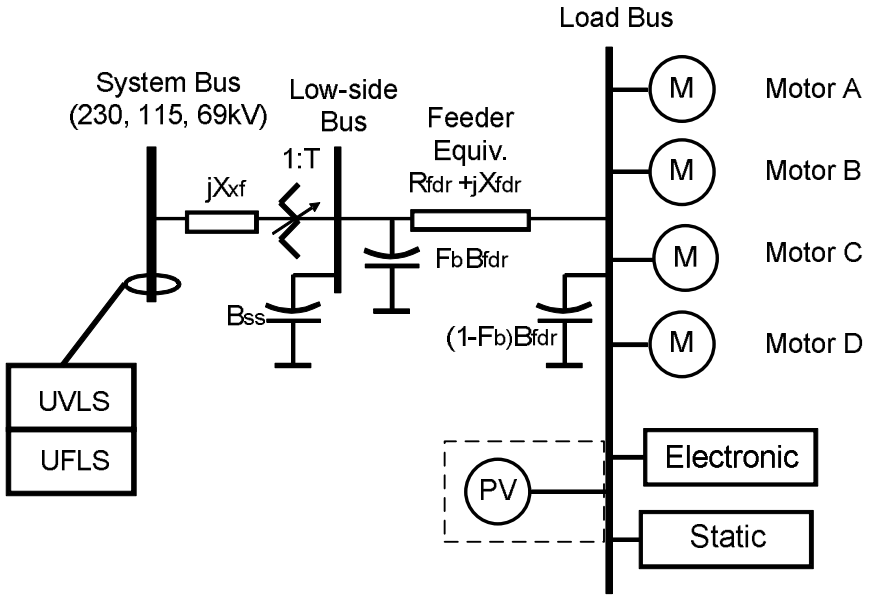
Modeling and Simulation

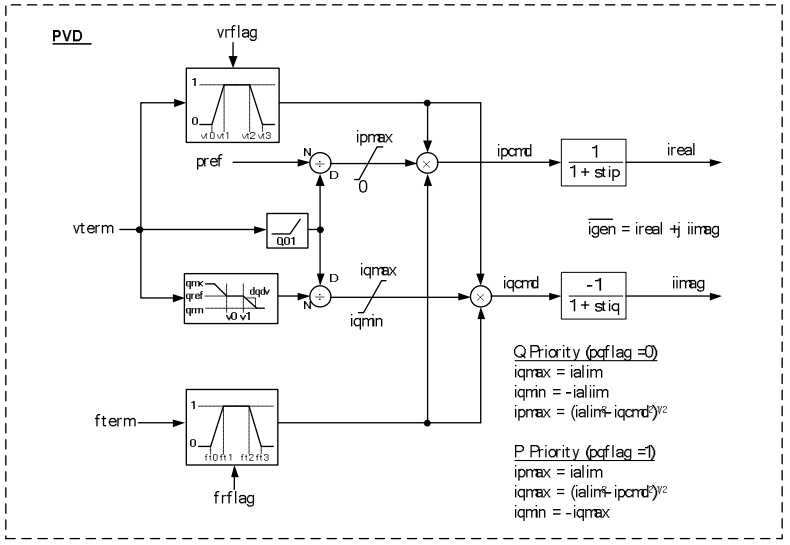
- Represent behavior of PV (and other DG) in bulk system planning studies – power flow, dynamics, short circuit
  - Effort led by NERC/WECC Renewable Energy Modeling Task Force (Sandia Coordinating)



Modeling and Simulation

- Working with software developers to implement in commercial simulation platforms
- Similar effort underway for large-scale PV and wind (also led by Sandia)
- Required for compliance with emerging NERC requirements



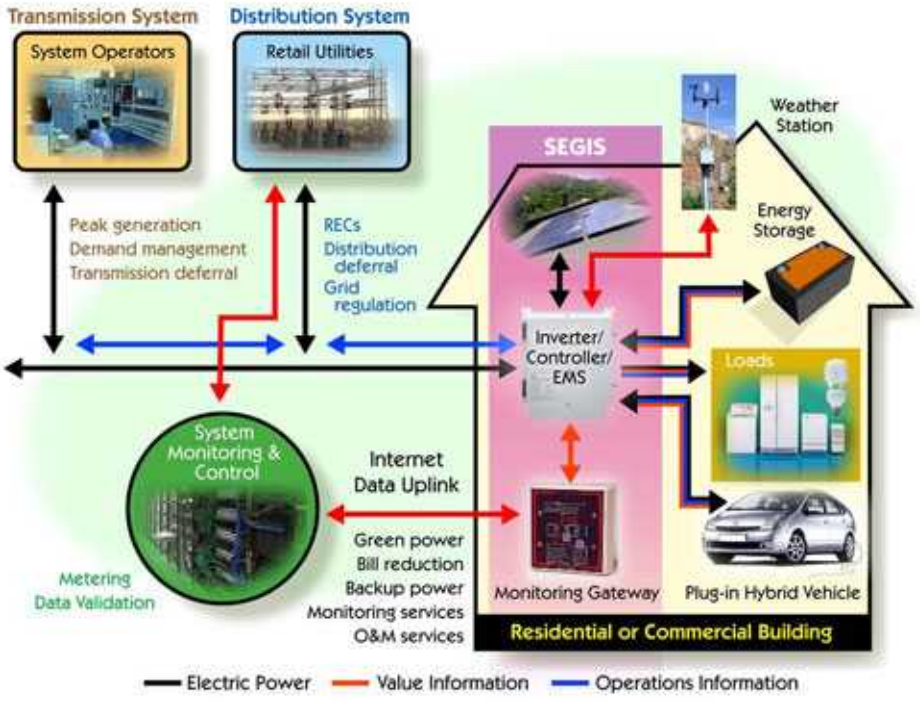


Source: A. Ellis, M. Behnke, W. Price, "Specifications for Distributed PV System Models", WECC REMTF Working Document, 2011

Solar Energy Grid Integration Systems (SEGIS) Program

- Major technology development initiative led by Sandia / DOE
- Goal: Get ready for Smart Grid and high penetration PV
- Focused on new PV inverters/controllers/EMS

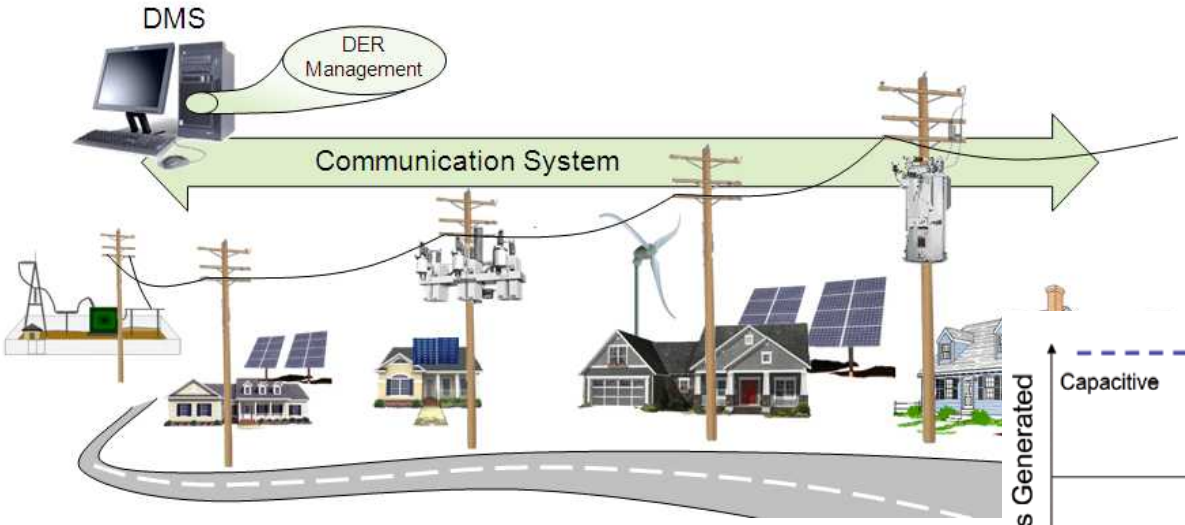
- Program
  - Public/private partnership
  - From concept to commercial product (2008 – 2011)
  - Various follow-up initiatives currently underway

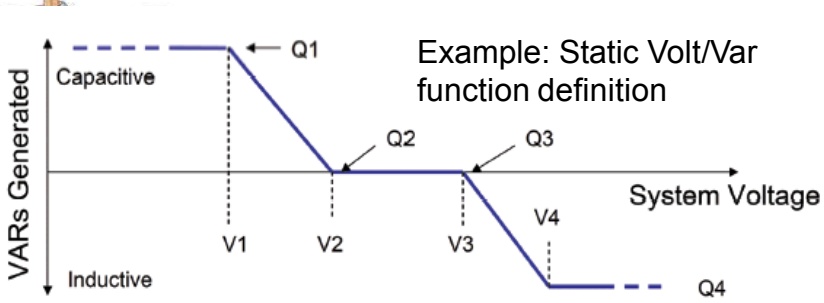


More information:
http://www1.eere.energy.gov/solar/segis_industry_projects.html

EPRI/Sandia Interoperability Project

- Goal: define interoperability requirements for emerging advanced inverter functions
  - Configurable behavior, autonomous or managed (with communications)
  - Close collaboration with NIST PAP7 and IEC-61850 stakeholders

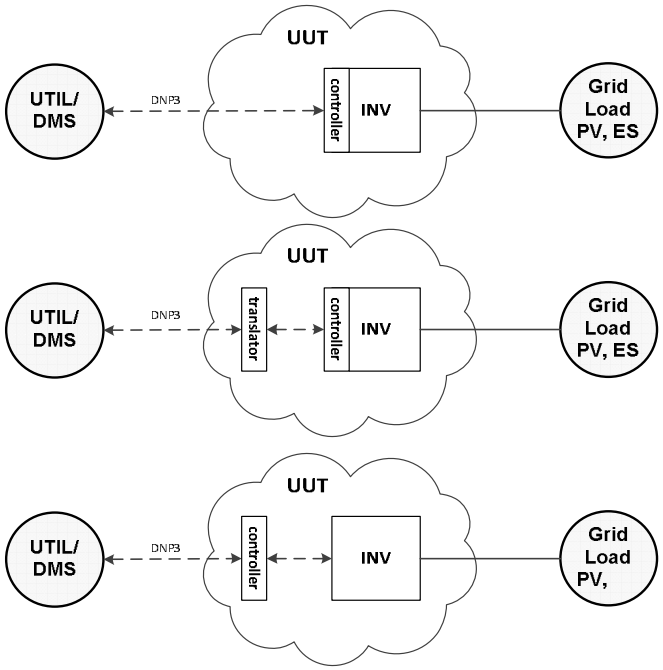


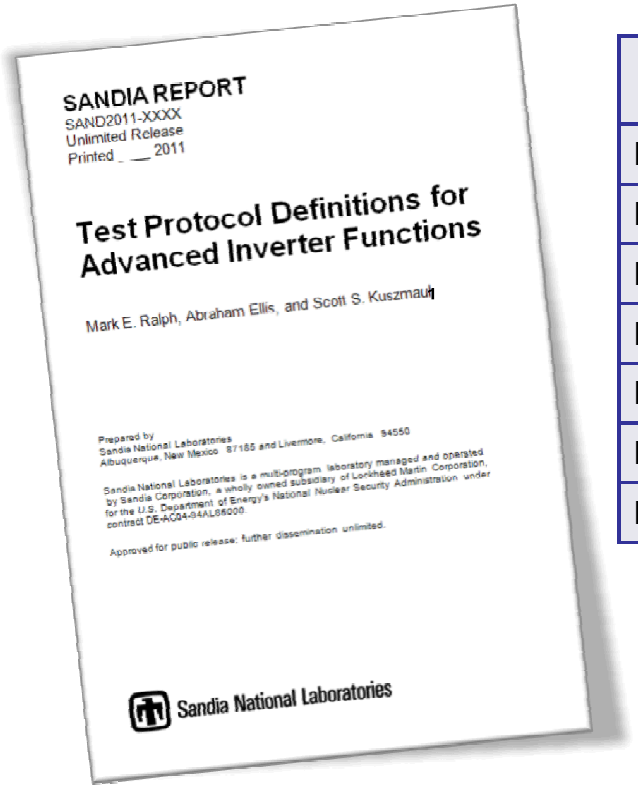


Graphics: B. Seal - EPRI/Sandia Inverter Interoperability Project

EPRI/Sandia Interoperability Project

- Sandia developing and validating test procedures
  - Communications interoperability and electrical behavior
  - Trials with actual hardware/controls underway




SANDIA REPORT
SAND2011-XXXX
Unlimited Release
Printed _ __ 2011

Test Protocol Definitions for Advanced Inverter Functions

Mark E. Ralph, Abraham Ellis, and Scott S. Kuszmaul

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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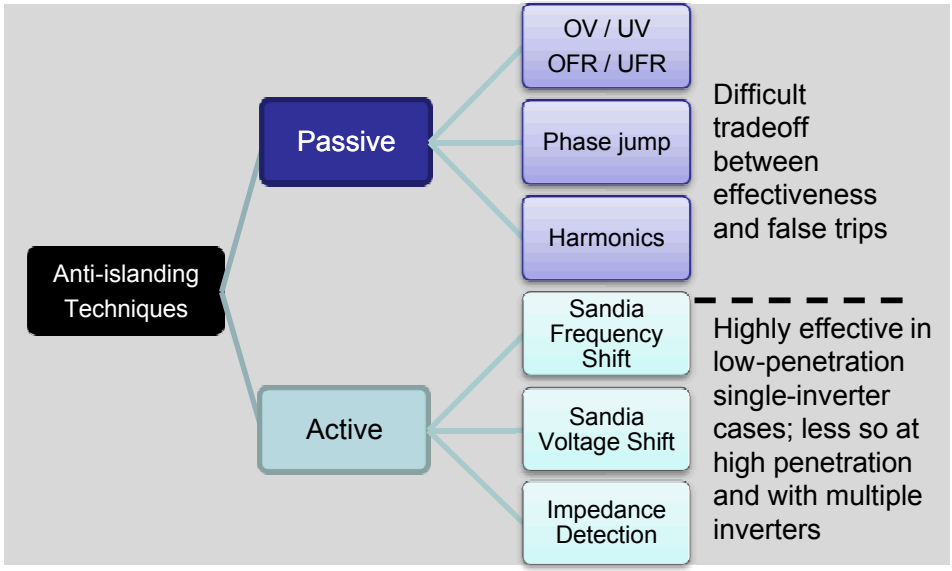
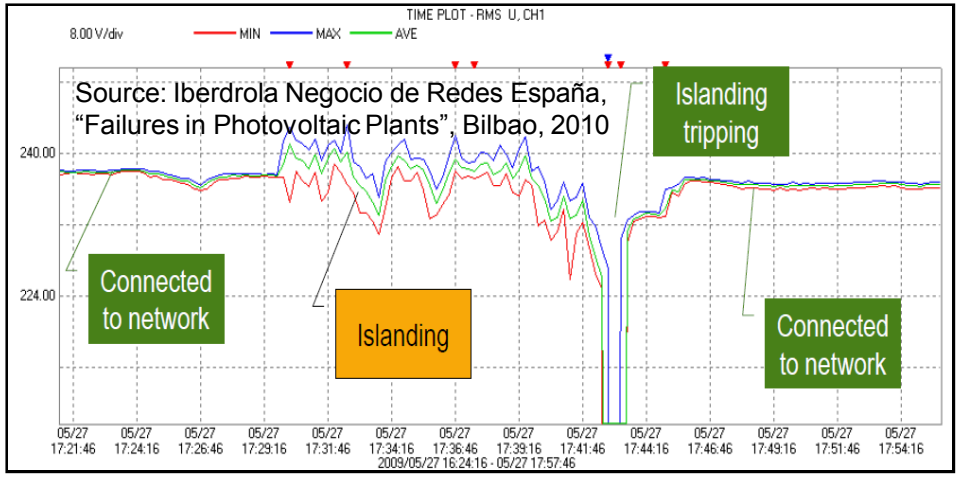
Phase 1 Interoperability Function	
PC1	Connect/Disconnect
PC2	Adjust Max Output Level
PC3	Adjust Power Factor
PC4	PV/Storage Functions
PC5	Event/History Logging
PC6	Status Reporting
PC7	Time Synchronization

A Closer Look at Anti-Islanding

- Well-established technology, but 'concerns' remain
  - Certification test does not cover multiple inverter cases
  - Some incidents (extremely rare) reported—see below, e.g.
  - High penetration PV, emerging LVRT and voltage control functionality
- Sandia's current work
  - Document field incidents
  - Screening guidelines
  - Evaluation of alternative testing methods





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Thank You!

More information:

http://energy.sandia.gov/pv

http://energy.sandia.gov/wind

http://www.sandia.gov/ess

https://solarhighpen.energy.gov