PV Grid Integration R&D at Sandia

SAND2015-2465PE

Abraham Ellis | Photovoltaics and Distributed Systems Integration | 06112

ASU – IGERT Visit | March 2015

Sandia National Laboratories

SunShot U.S. Department of Energy

Outline

- Introduction to Sandia
- Context: Renewable Energy Deployment and Grid Modernization
- DOE SunShot Program and Example of Sandia Projects
- Distributed Energy Technologies Laboratory

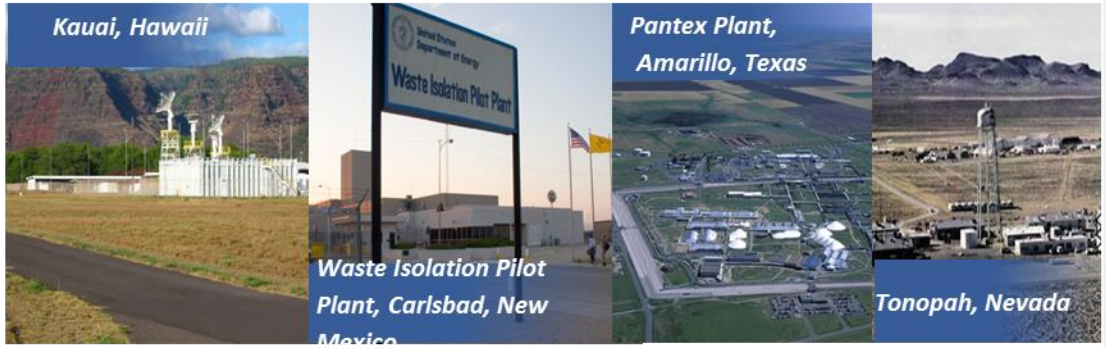
- Q&A
- Tour

Sandia National Laboratories

- Large. multi-program research and engineering laboratory
- Focusing on National Security, including energy
- Headquartered in Albuquerque, NM

National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY

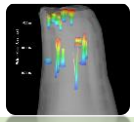


History of Sandia Energy Programs

Sandia was born as a nuclear weapons engineering laboratory with deep science and engineering competencies

Energy crisis of the 1970s spawned the beginning of significant energy work

Strategic Petroleum Reserve – geological characterization of salt domes to host oil storage caverns



DOE's Tech Transfer Initiative was established by Congress in 1991

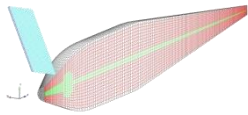
METAL HYDRIDE CENTER OF EXCELLENCE

Advent Solar

Energy Policy Act of 2005

Combustion Research Facility (CRF) & Cummins partner on their newest diesel engine

Joint BioEnergy Institute



Water Power Program

1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2007 | 2009 | 2010

Our core NW competencies enabled us to take on additional large national security challenges

Vertical axis wind turbine

NRC cask certification studies & core melt studies

Solar Tower opens

CRF opens to researchers

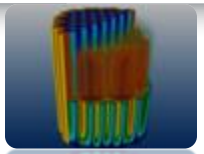
Distributed Energy Technology Laboratory (DETL) to integrate emerging energy technologies into new and existing electricity infrastructures

Power grid reliability study

SunCatcher™ partnership with Stirling Energy Systems

Sunshine to Petrol Pilot Test

Large-scale pool fire tests of liquefied natural gas (LNG) on water



Consortium for Advanced Simulation of Light Water Reactors (CASL)

Climate study uncertainties to economies

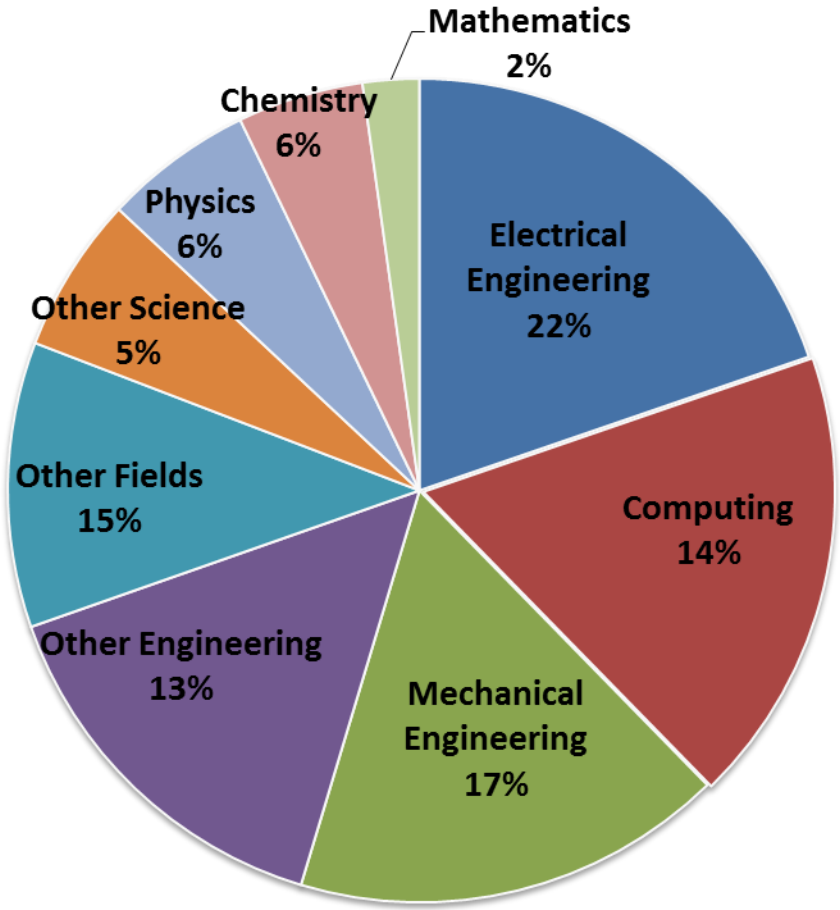
Combustion Research Computation and Visualization (CRCV) opens

Sandia National Laboratories

- On-site workforce: ~11,700
- Regular employees: ~9,500
- Total Budget: ~$2.5 billion

Data as of end of 2013

R&D staff (~4,800) by discipline



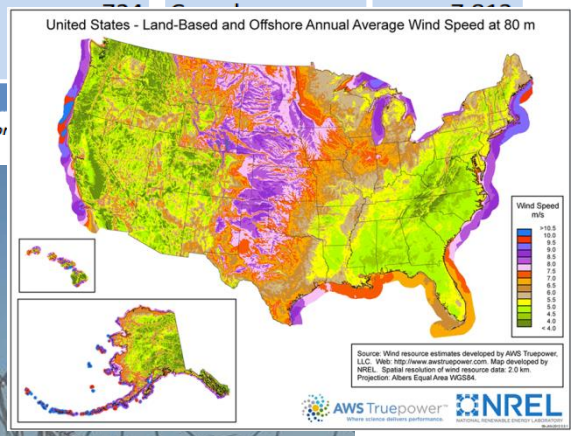
Driver: Renewable Energy Deployment

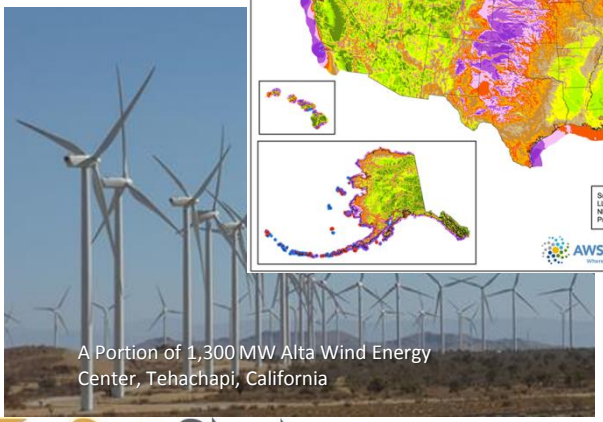
- US installed Wind and PV capacity are growing fast
  - PV: 12.1 GW, Wind at 61.1 GW (2013 figures)
- Technical potential and growth rate are very high

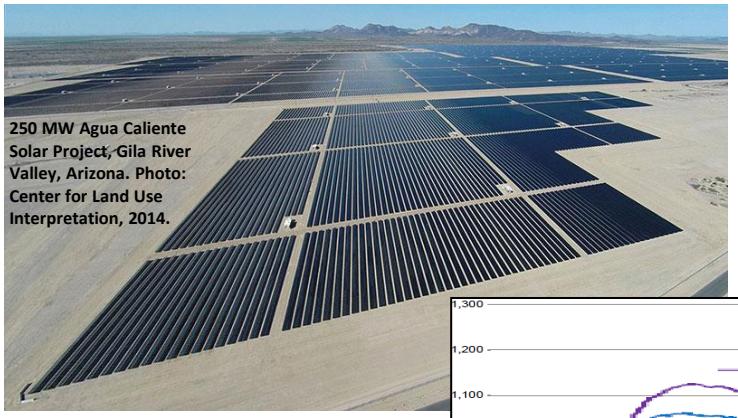
Annual Capacity (2013, MW)	
China	16,088
Germany	3,237
India	1,987
United Kingdom	1,833
Canada	1,599
United States	**1,087**
Brazil	948
Poland	894
Sweden	
Romania	
Rest of World	
TOTAL	

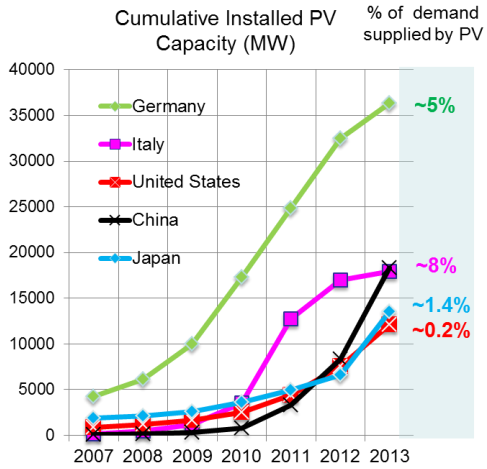
Cumulative Capacity (end of 2013, MW)	
China	91,460
United States	**61,110**
Germany	34,468
Spain	22,637
India	20,589
United Kingdom	10,946
Italy	8,448
France	8,128

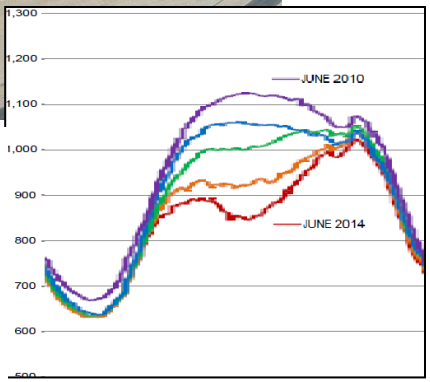
Source: Navigant; AWEA pr




A Portion of 1,300 MW Alta Wind Energy Center, Tehachapi, California


250 MW Agua Caliente Solar Project, Gila River Valley, Arizona. Photo: Center for Land Use Interpretation, 2014.





Distributed PV in Oahu, Hawaii, 2010 to 2014

SunShot U.S. Department of Energy

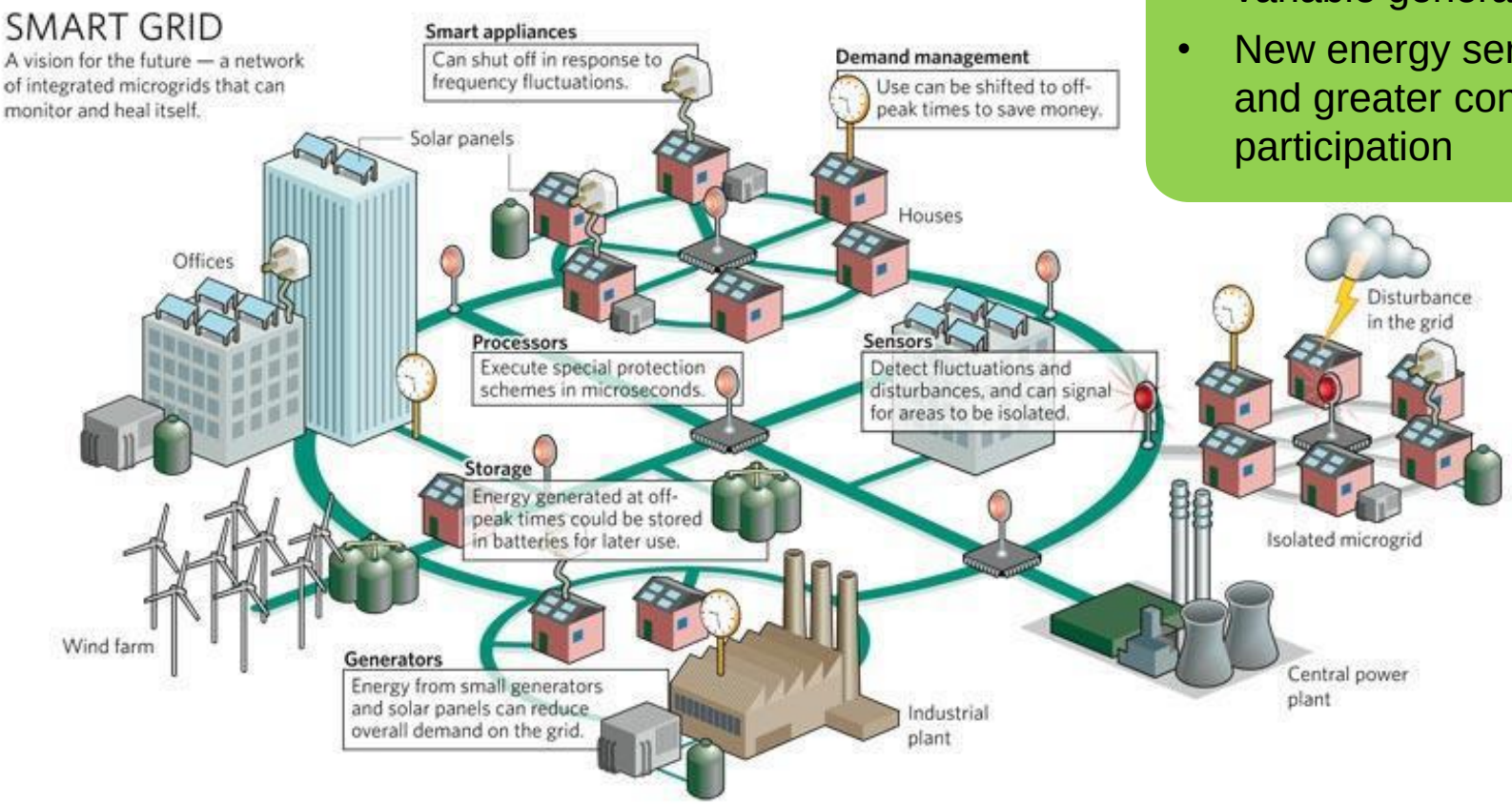
Sandia National Laboratories

DOE Grid Modernization Initiative

- A wide range of domains and technologies
- Complex policy and regulatory landscape

SMART GRID DRIVERS

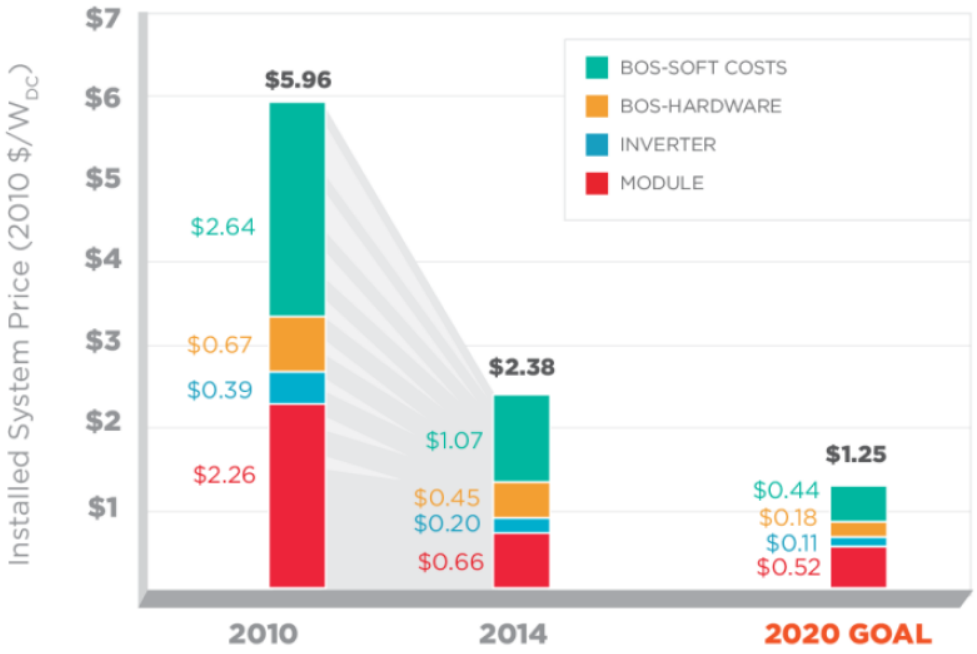
- Grid modernization
- Growing distributed and variable generation
- New energy services, and greater consumer participation



DOE SunShot Initiative

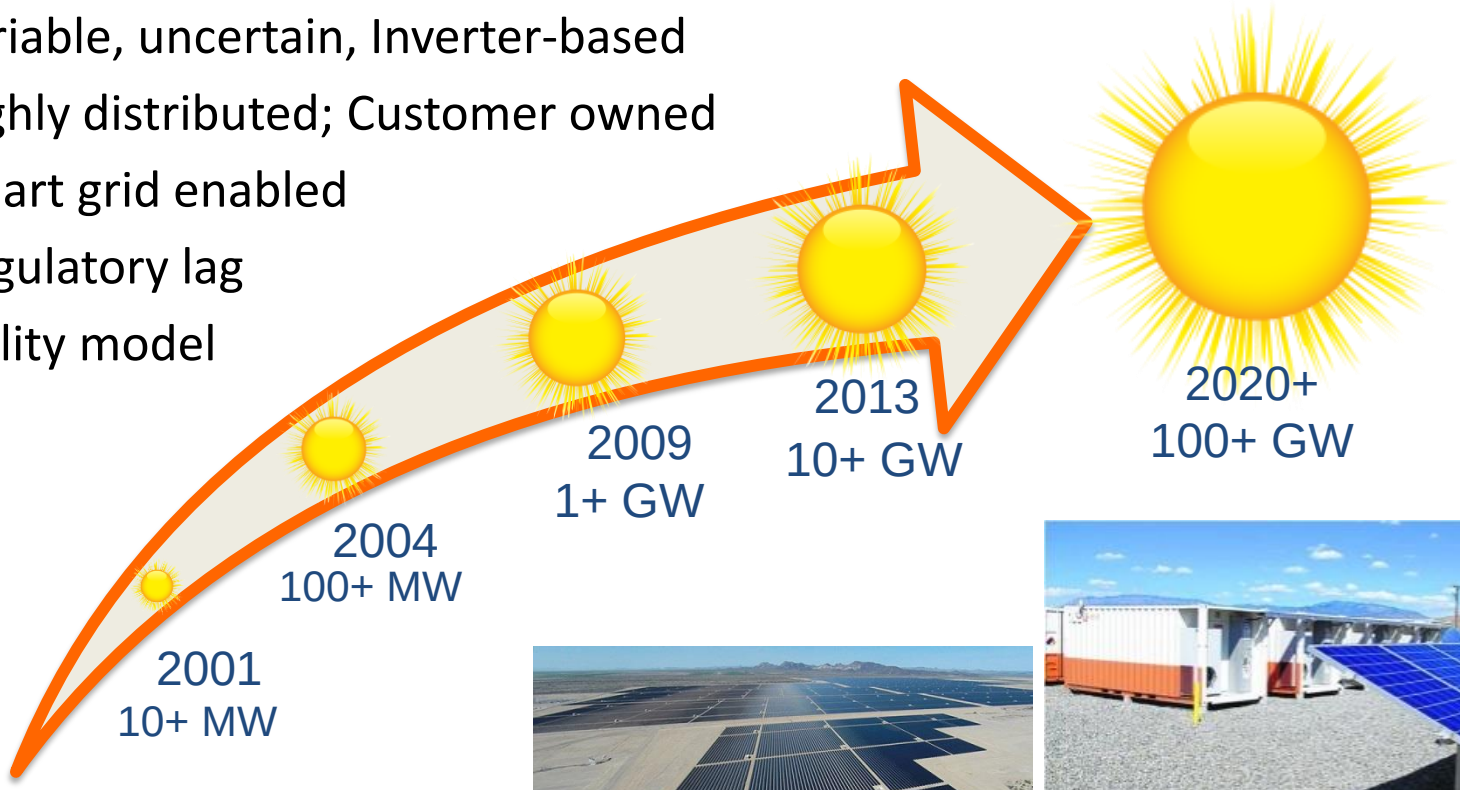
- SunShot Mission
  - Grid Parity by 2020: $0.06/kWh for utility-scale PV, and retail rate for residential/commercial
  - Robust and sustainable US manufacturing and market
  - Enable integration of 100's of GW of PV on the grid

- Challenges
  - Technology
  - Grid integration
  - Standards
  - Markets
  - Regulatory
  - Policy
  - …



SunShot Systems Integration (SI) Area

- SI focuses on safe, efficient and cost-effective deployment of large amounts of PV on the grid
- Challenging problem due to PV characteristics and context
  - — Variable, uncertain, Inverter-based
  - — Highly distributed; Customer owned
  - — Smart grid enabled
  - — Regulatory lag
  - — Utility model

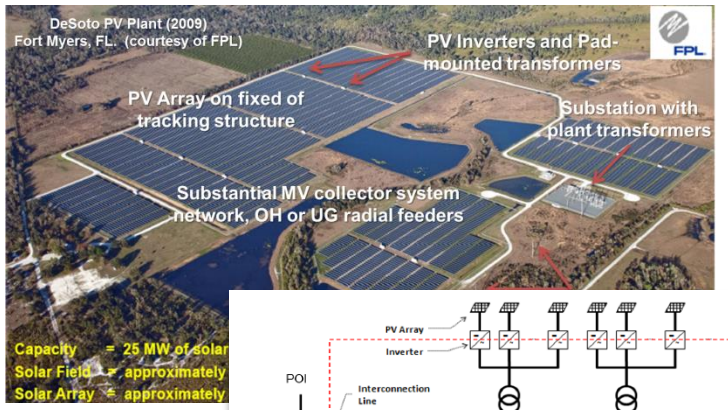


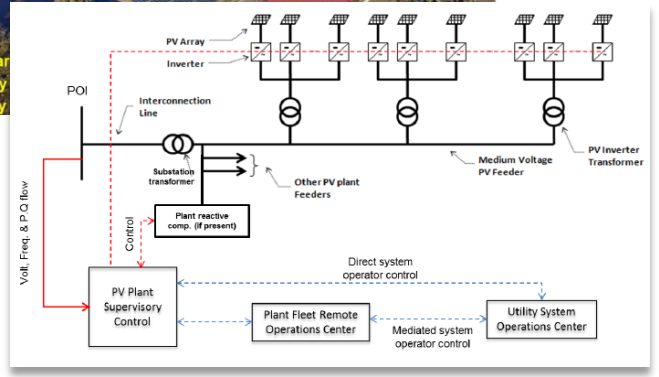
Grid Integration Challenges

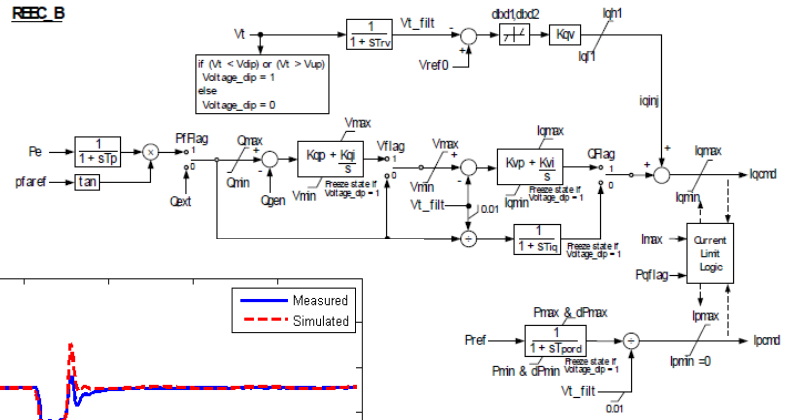
- Bulk system
  - —Generation Planning and Operations
    - Cost, ramping/cycling, reserves, dispatchability, markets
  - —Network Performance and Reliability
    - Voltage and frequency regulation, small signal stability
- Distribution system
  - —Local voltage control; Protection and safety
- Cross-cutting
  - —Technology (e.g., power electronics), mod/sim, standards, decision support tools
  - —Policy, regulatory procedures, business models

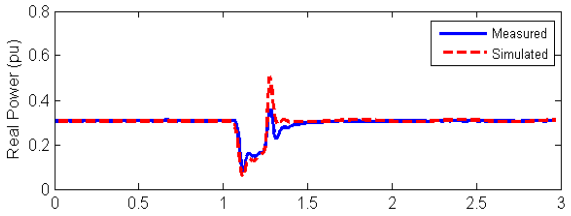
Generic PV Plant Stability Models

- Goals
  - Develop & validate power flow and dynamic models
  - Implement models in simulation software
  - Sandia also led model development for wind
- Partners
  - NERC, WECC, EPRI, utilities, manuf., software vendors
- Contact
  - A. Ellis, R. Elliott









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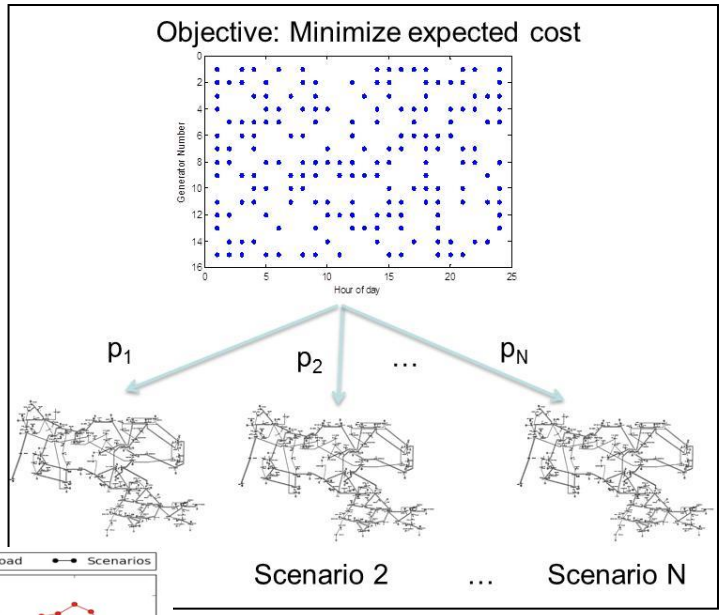
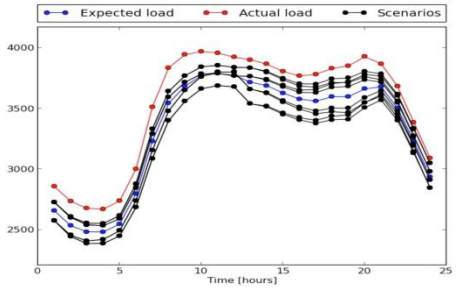
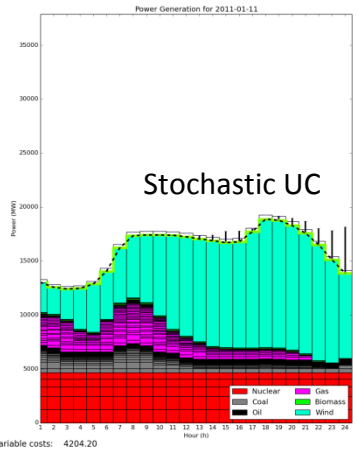
Stochastic Optimization

- Goals
  - —Optimization of power systems operations & planning decisions using stochastic methods
  - —Manage cost and risk under high uncertainty (e.g., load, variable generation, fuel prices, etc.)
- Partners
  - —LBNL, Arizona Public Service, UC-Davis





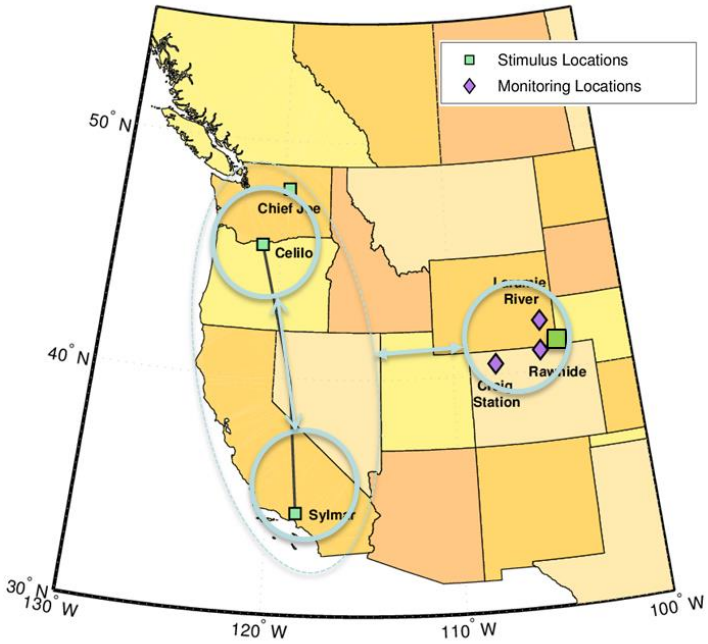
Deterministic UC

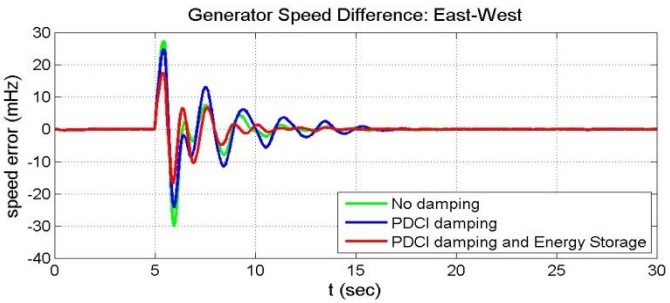


Stochastic UC

Small Signal Stability

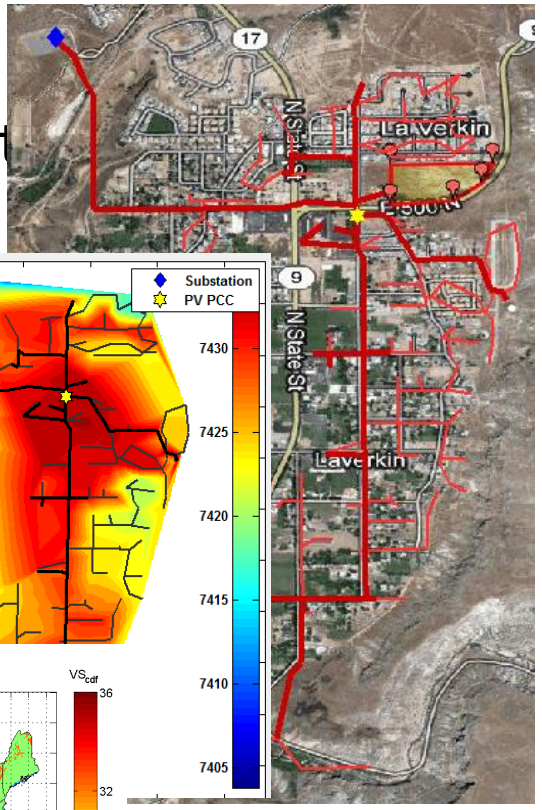
- Goals
  - Characterize effect of large-scale PV deployment on small signal stability
  - Develop new analysis methods
  - Identify possible mitigation strategies (e.g., inverter controls or energy storage)
- Partners
  - Montana Tech, BPA

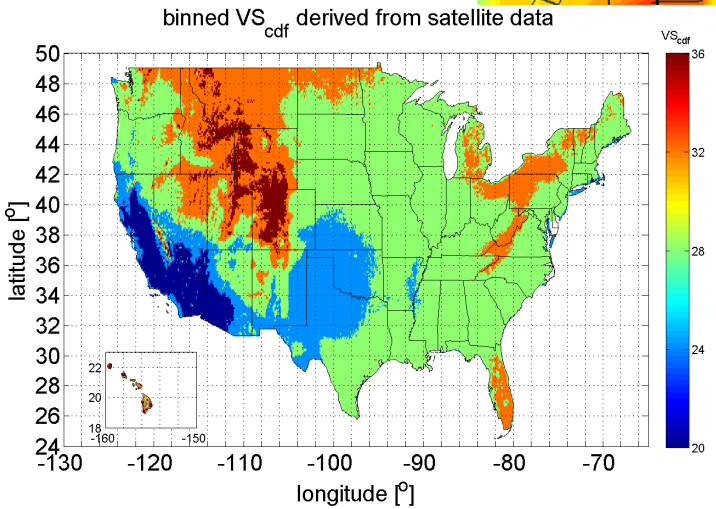




Analysis of PV in Distribution Circuits

- Goals
  - Assess impacts of high pen. PV on distribut
  - Identify mitigation options
  - Develop new analysis methods, sim load/solar data
- Partners
  - EPRI, Utilities, NREL





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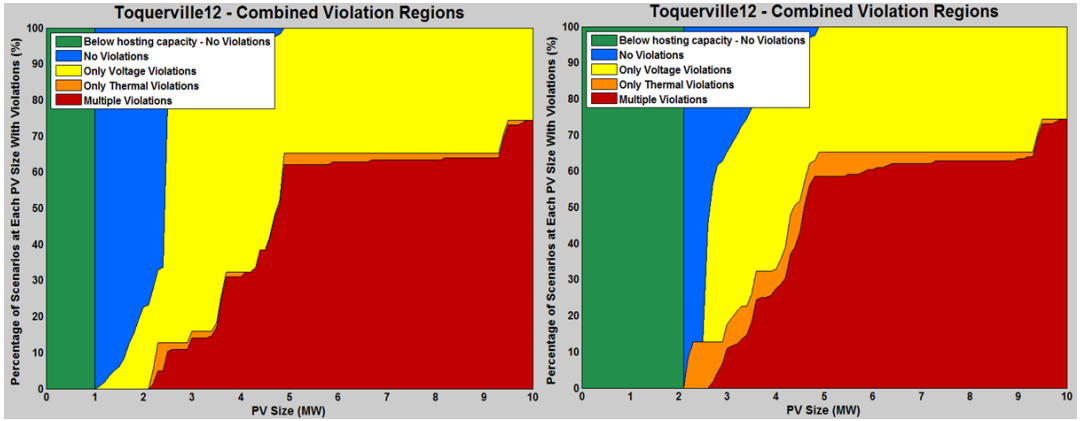
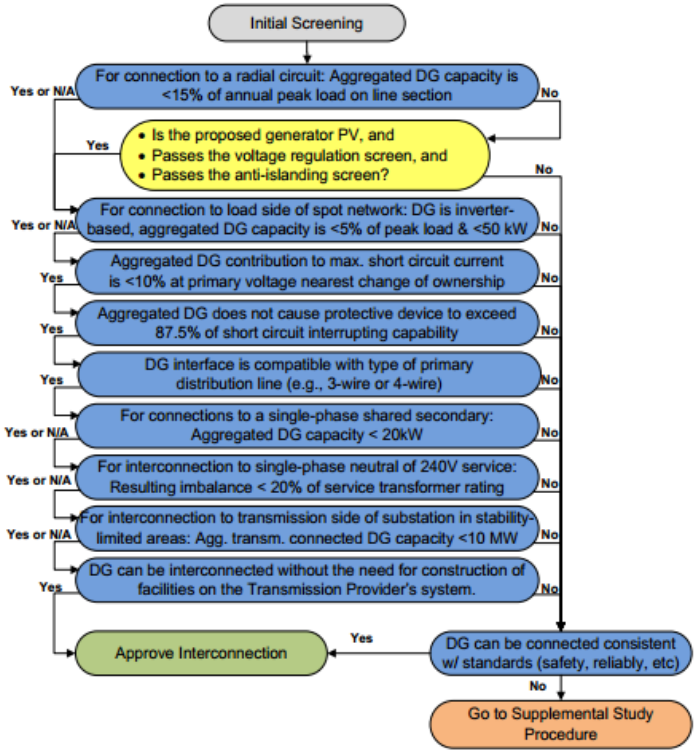
DG Interconnection Screening

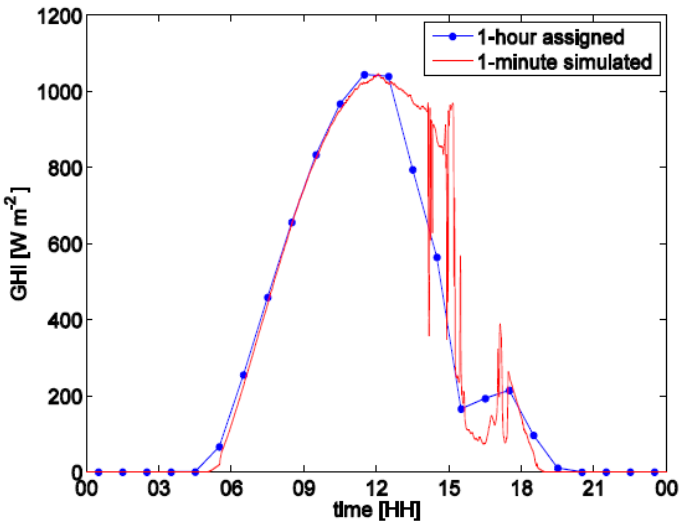
- Goals
  - —Improve interconnection screening methods for distribution-connected PV
  - —Inform federal and state regulatory implementation
- Partners
  - —EPRI, NREL, IREC

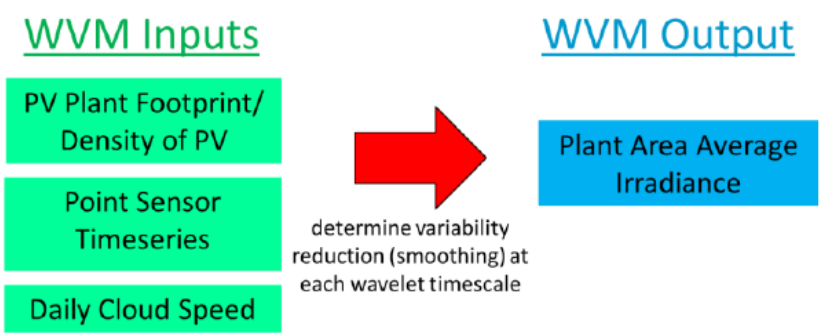


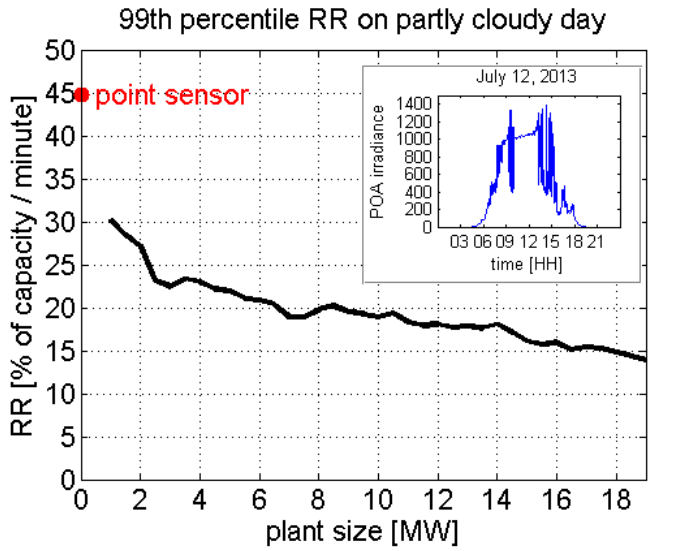


PV Plant Variability Modeling

- Goal
  - —Characterize solar output variability at plant and fleet level
  - —Develop methods to generate high resolution data at specific locations for transmission and distribution integration analyses

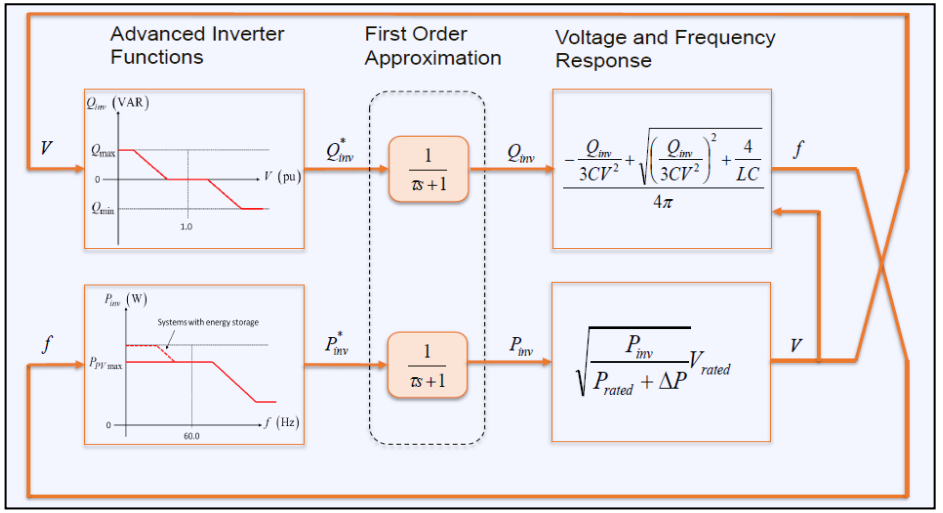




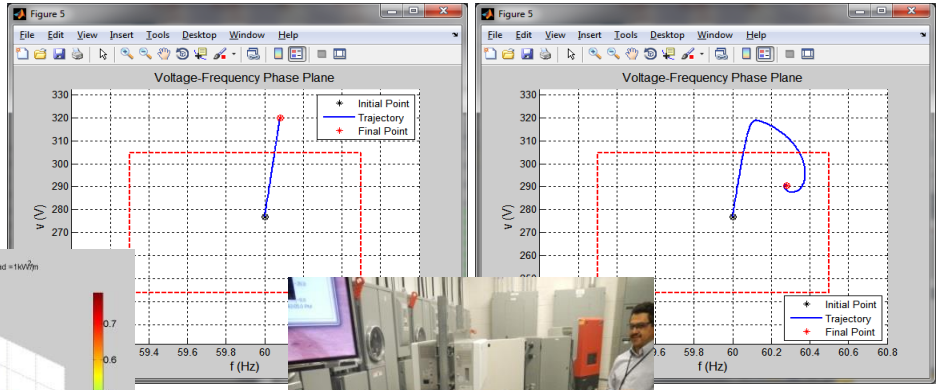


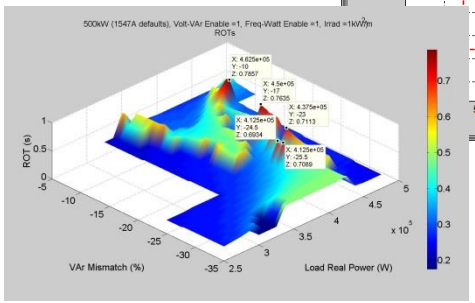
Robust Inverter Controls

- Goals
  - Demonstrate inverter controls that allow PV to support grid reliability while maintaining safety
  - Support evolution of applicable standards
- Partners
  - Inverter manufacturers, UL, IEEE



Without volt/var and freq/watt.With volt/var and freq/watt.





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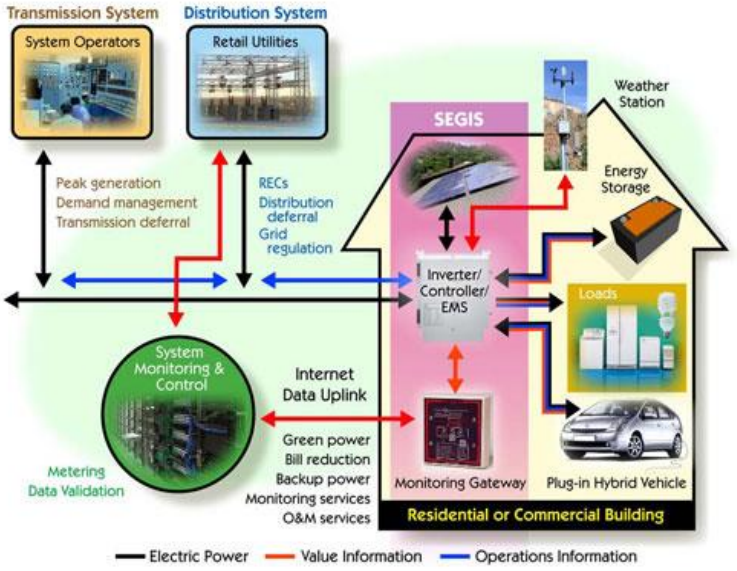
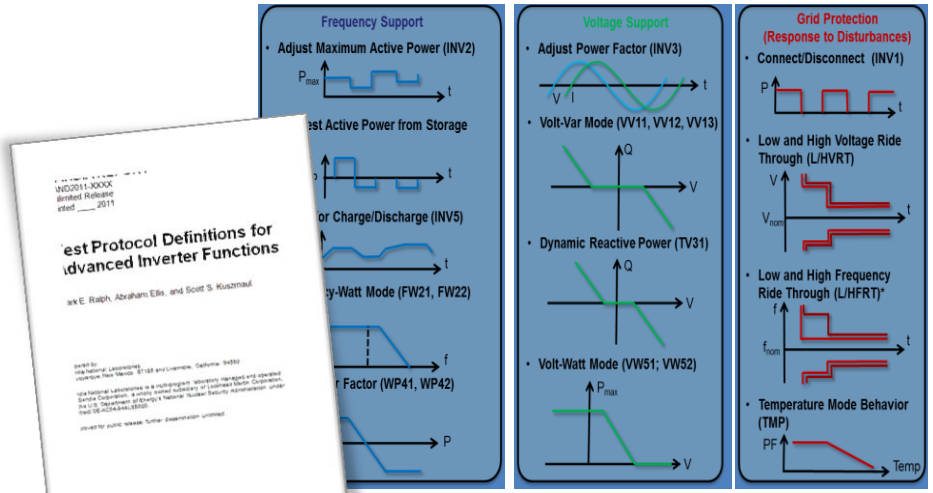
Interoperability and Testing Protocols

- Goals
  - Improve grid-inverter control interoperability
  - Develop and validate laboratory testing protocols for advanced functions
  - Update interconnection standards
- Partners
  - Inverter manufacturers

    SunSpec, US/Intl Labs

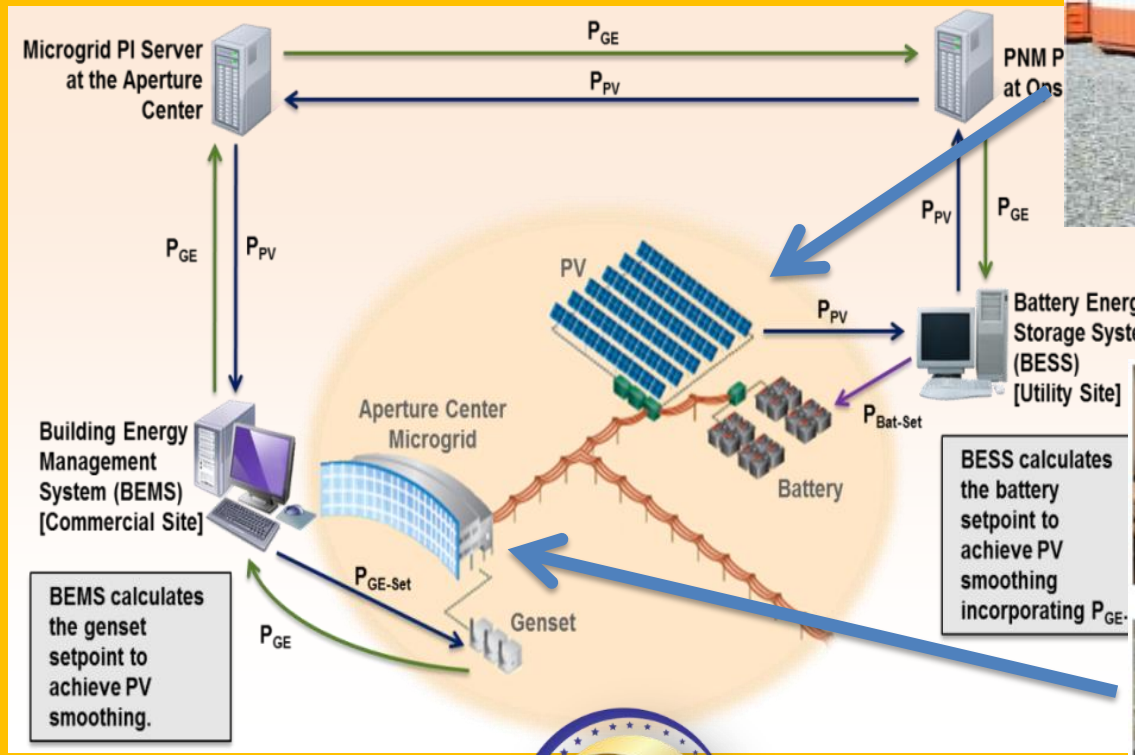




Renewables – Smart Grid Demonstrations

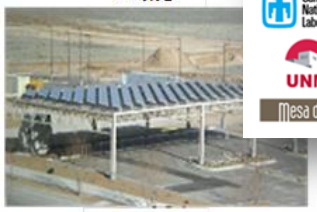
Coordinated Control Field Experiment (2013-2014)

- Customer Microgrid (Mesa del Sol project)
- Utility-operated PV/Storage (Prosperity project)




BEMS


Plant yard


PV panel


Distribution board

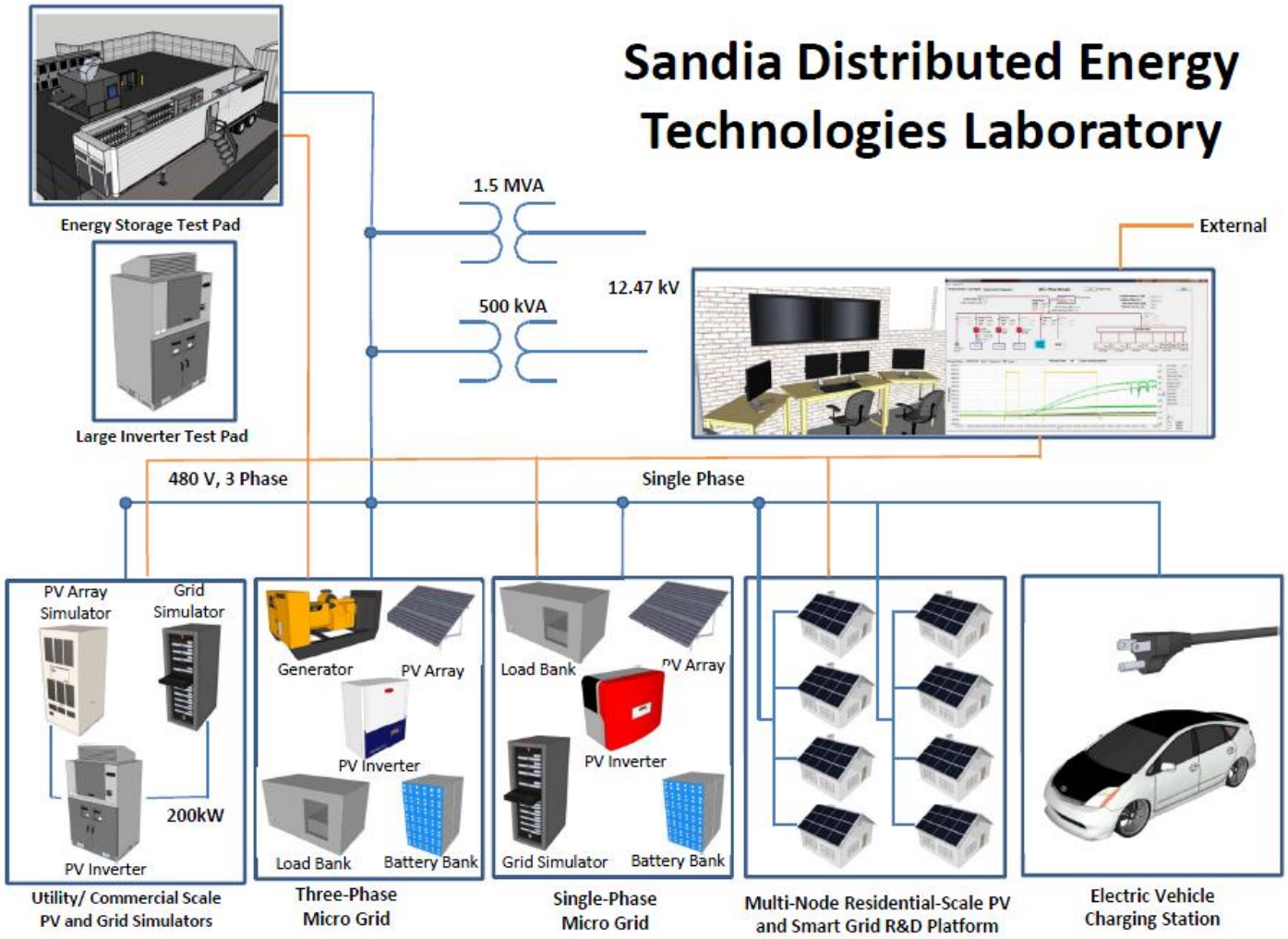
Distributed Energy Technologies Laboratory

Reconfigurable Testbed for PV and DER Technology RD&D

- Hardware and controls R&D
- Pre-commercial testing & validation
- Performance/interoperability test protocol and standards development
- Reliability and safety
- Residential, commercial, military
- Grid-connected, off-grid and microgrid
- Multiple sources, energy storage, controllable loads
- Home/building/network EMS


Gas-Fired Generator
Programmable Loads
AC and DC Grid Simulators
Large Inverter Platform
SCADA Room
Energy Storage
Residential Inverter platform
Single-phase microgrid
Design Shop
Utility Interface

DETL Components and Capabilities



- 180 kVA AC grid simulator
- 200 kW DC simulator
- Controllable RLC Load
- 135kW PV
- 700W-hr storage capacity
- 230kVA diesel genset

Thank You

Contact: aellis@sandia.gov