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Sandia National Laboratories

Resilient Microgrid Research, Development and Demonstrations

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U.S. DEPARTMENT OF ENERGY | NNSA

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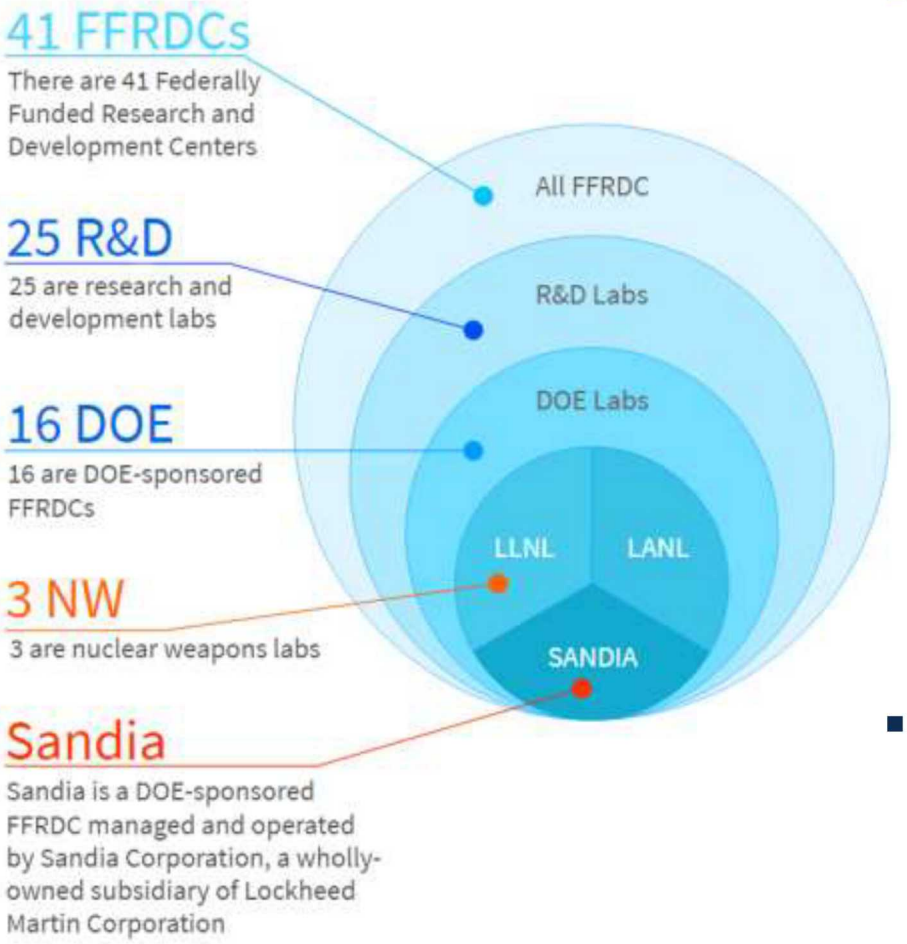
DOE National Laboratory Complex

The national lab complex represent the world's largest scientific research infrastructure. "Crown Jewels of Innovation"

Sandia and other U.S. National Labs



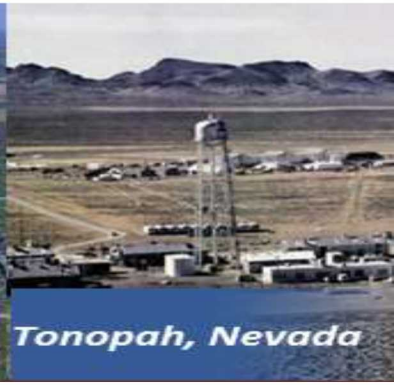
- National Labs are Federally Funded Research and Development Centers (FFRDCs) affiliated with a Gov. Agency
  - Devoted to new scientific insights
  - Operate in the public interest
  - Unique capabilities supporting missions of national significance
    - » Examples: High- performance computing, high-energy physics, large-scale environmental testing, special prototyping, …
- National Labs operate in different domains
  - Defense, homeland security, energy, aviation, space, health and human services, and tax administration

Sandia National Laboratories

- Large, multi-program research & engineering laboratory,
- Primary mission: nuclear weapons and national security
- Extensive capabilities in energy, including microgrids

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration



MICROGRID RESEARCH AND DEVELOPMENT

Sandia Microgrid R&D Portfolio

Enabling Technologies

- Power electronics
- Optimal dispatch and controls
- Protection
- Cybersecurity

Methods, Metrics & Tools

- Optimal design, analysis and decision support tools for planning & operations
- Energy resilience metrics & valuation

Demonstrations and Deployment

- Technology validation and refinement
- Performance and reliability follow-through

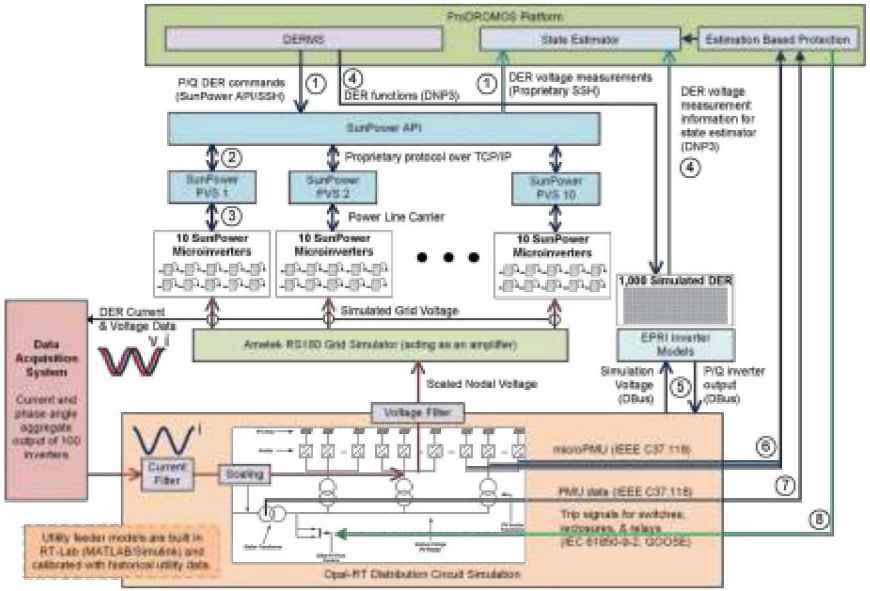
Standards and regulatory factors

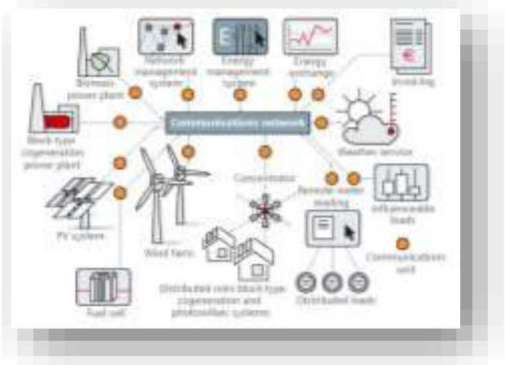
- Performance, safety interoperability & security requirements
- Interconnection procedures

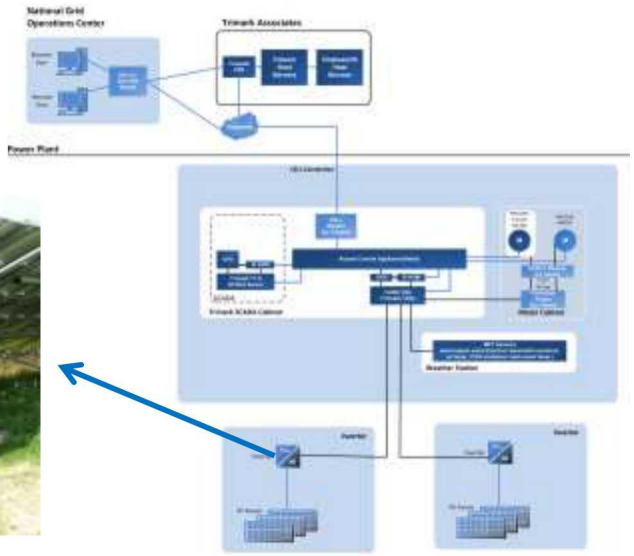
DERMS/Microgrid Controls

Sandia Virtual Power Plant (VPP) and ENERGISE Program

- Optimal dispatch and control of DER under high uncertainty
- Focus on interoperability, protection, cybersecurity, state estimation, forecasting, distributed grid support functions
- Power and control hardware-in-the-loop (p/c-HIL) methods



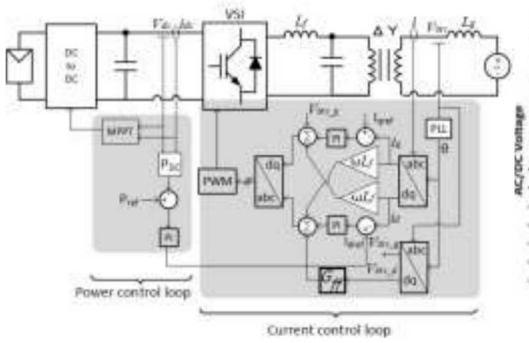


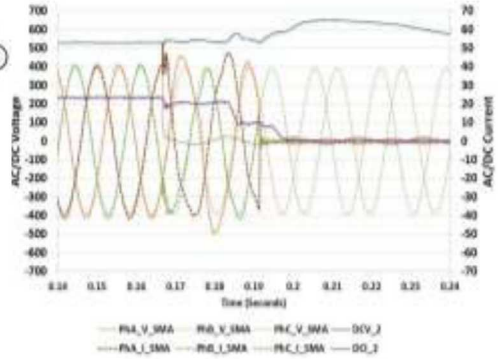


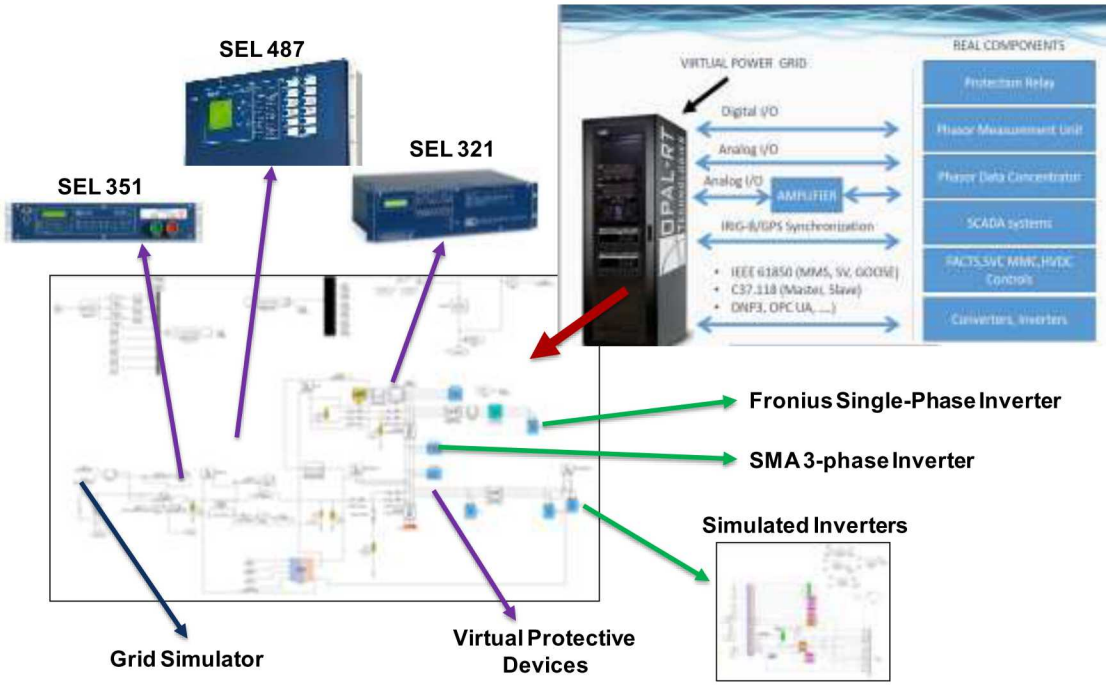
Protection Schemes for Inverter-Based Systems

Advanced Cyber-Secured Protection for Renewable-rich Distribution Systems and Microgrids

- Advanced adaptive protection schemes under high inverter-based DER penetration (low fault current)
- Applications:
  - DC and AC microgrids
  - Networked microgrids
  - Integration into ADMS
- p/c HIL methods



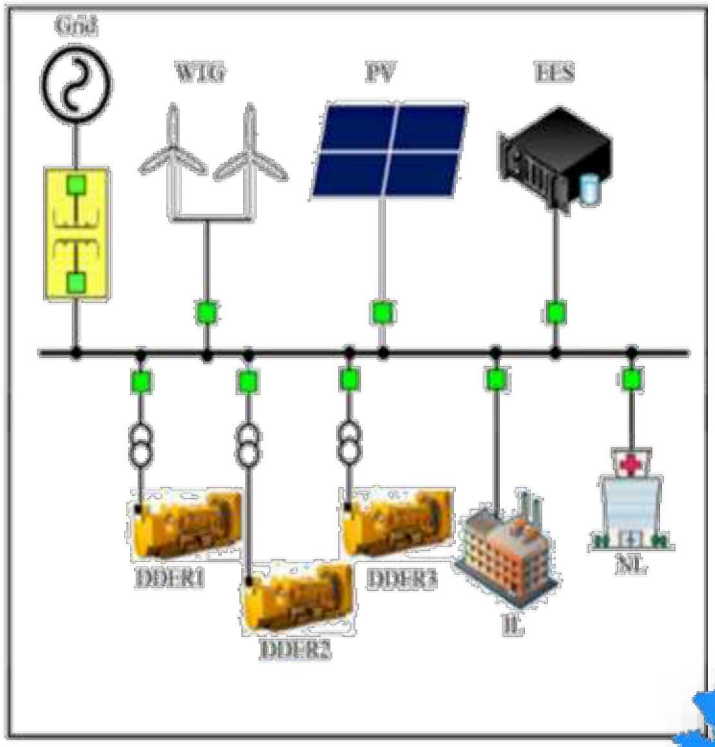




Microgrid Power Electronics & Controls

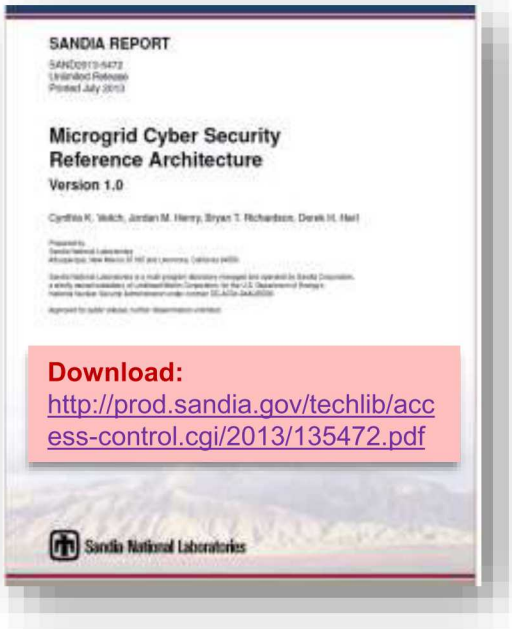
Grid Forming Inverters and for rural/island microgrids

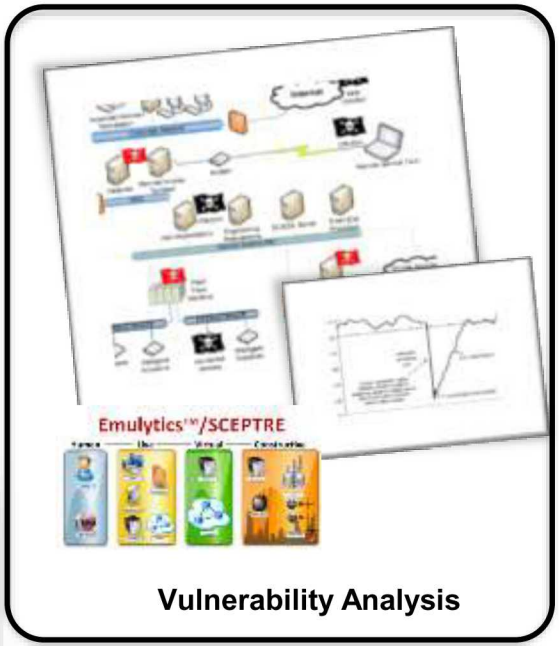
- Novel solutions to reduce or displace reliance on diesel generators
  - Grid forming inverters and energy storage as spinning reserve
  - Variable energy source incorporation
- Understand stability of networked microgrids under normal and abnormal usage conditions
- Dynamic microgrid modeling and data collection in remote Alaskan communities:
  - St. Mary's and Cordova



Microgrid Cyber Security

Design tools & cybersecurity technologies for microgrid and high-security energy systems



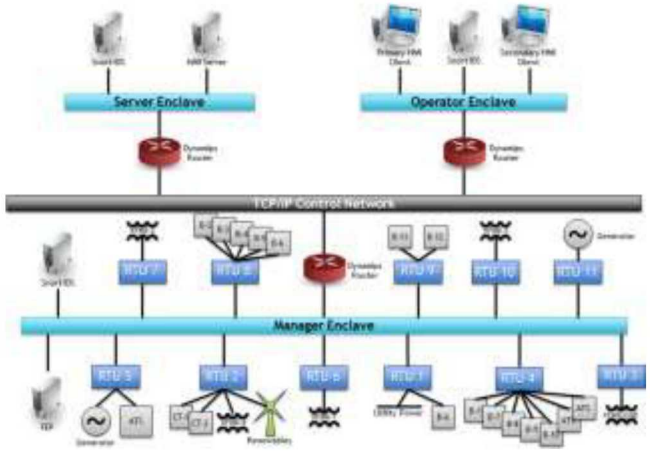


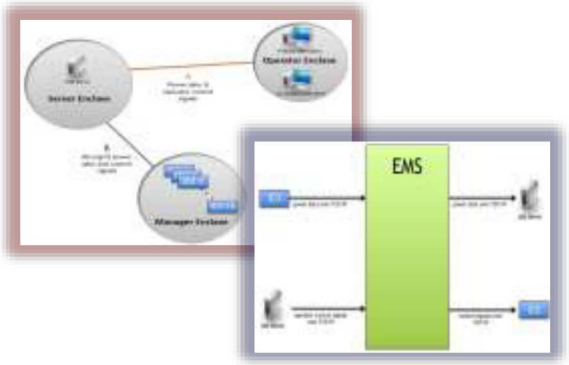
Vulnerability Analysis

Field device & network security technologies

Weaselware

Secure Control Architecture



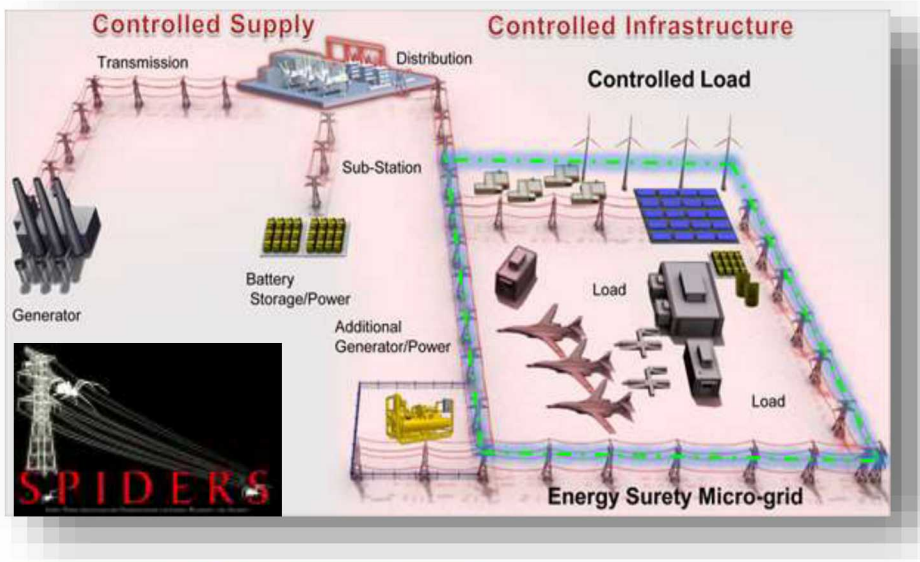


EXAMPLES OF MICROGRID DESIGN AND DEMONSTRATION

Military Microgrid Demonstrations

Smart Power Infrastructure Demonstration for Energy Reliability & Security

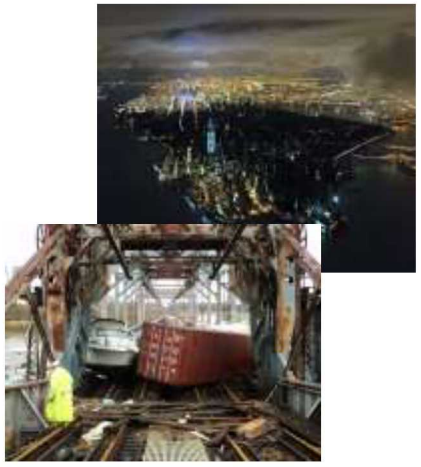
- Bolster the energy security and resilience of U.S. military installations, transfer knowledge to civilian critical infrastructure.
- Focused on four requirements:
  - ✓ Protect critical assets from cyber-attack
  - ✓ Sustain operations in long grid outages
  - ✓ Integrate renewable and other DER
  - ✓ Optimal design and operation to reduce fuel demand, emissions, and cost.
- Full microgrid deployment at three military bases in Hawaii and Colorado

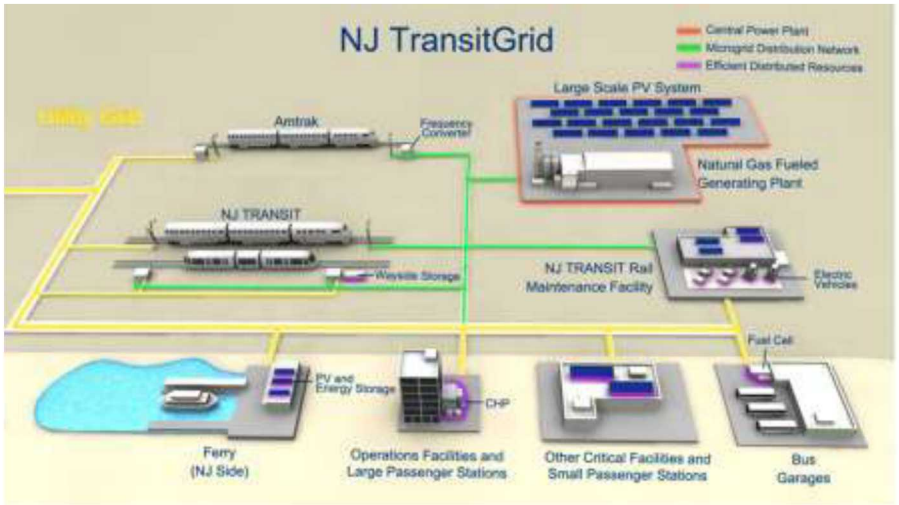


Microgrids for Civilian Infrastructure

NJ *TRANSITGrid* Project

- Superstorm Sandy caused major human and economic losses
  - The transportation in northern New Jersey and Manhattan, New York was severely disrupted for weeks, hampering evacuation and recovery efforts
  - NJ Transit and other rail operators suffered $Billions in infrastructure losses
  - Re-built infrastructure required to be resilient to future events
- Sandia is collaborating with NJ Transit to design & deploy a resilient microgrid
  - When built, it will be one of the largest microgrids in the nation

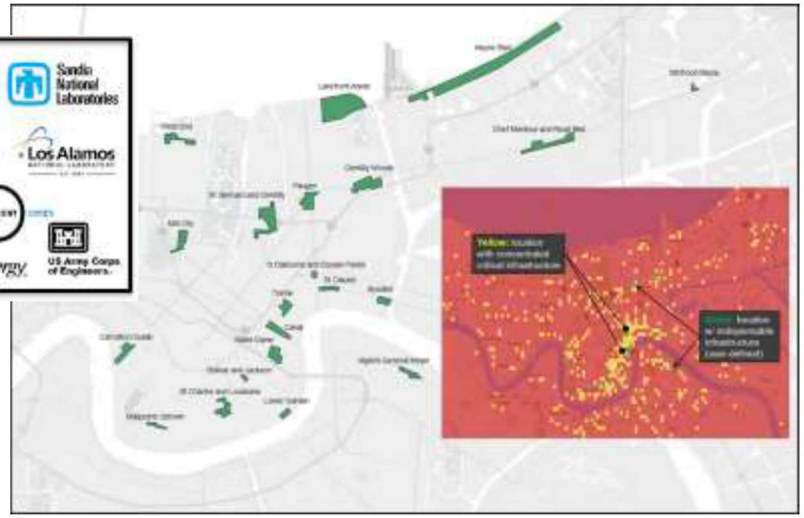




Microgrids and Infrastructure Resilience

- New Orleans, Louisiana (NOLA) faces high flooding risk
  - Levees and pumps are the main line of defense, bit they can fail

- Sandia led a project to identify options to increase resilience via resilient nodes (microgrids)
  - Emphasized community engagement
  - Quantified benefits decision-making

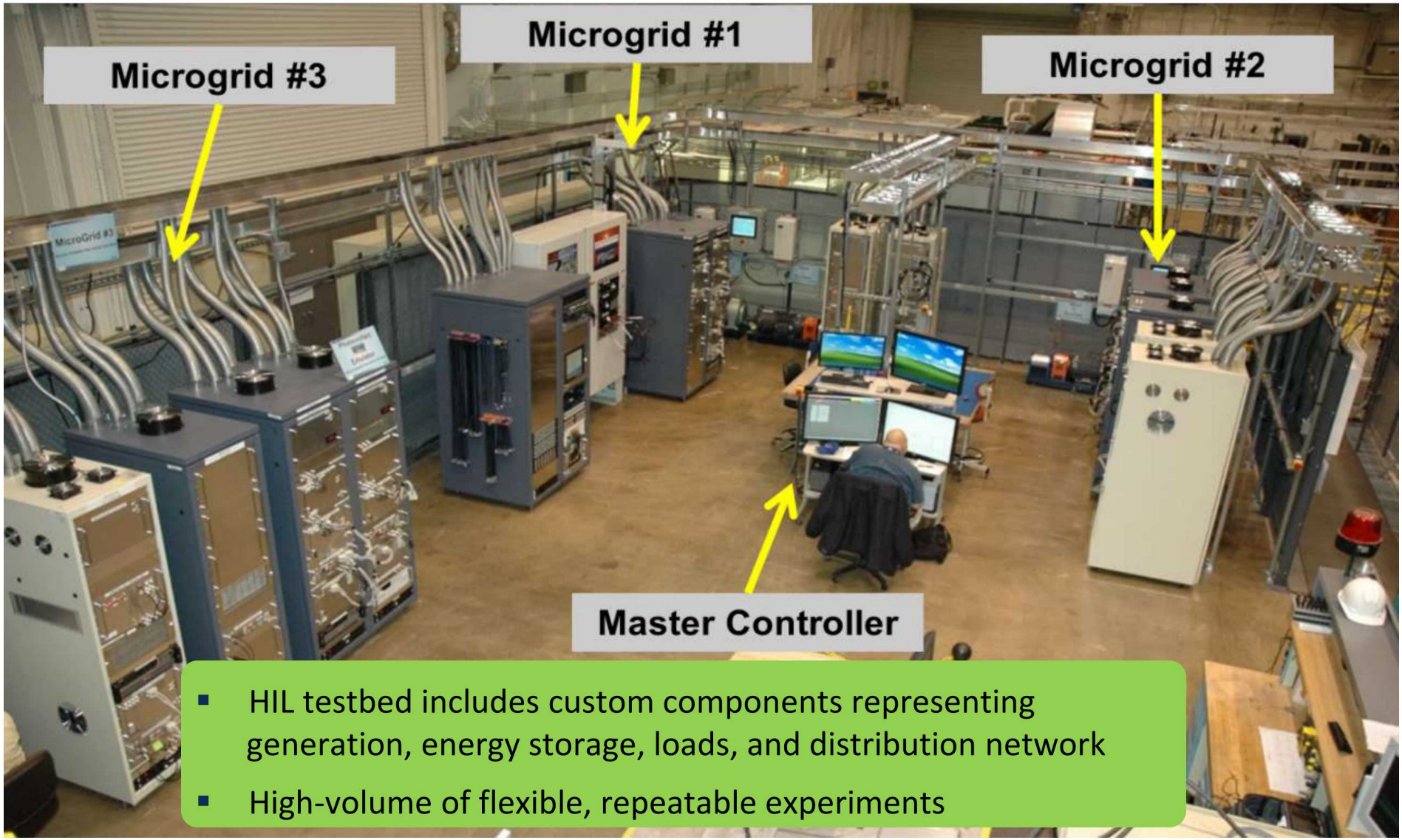


REPRESENTATIVE SANDIA MICROGRID R&D CAPABILITIES

Distributed Energy Technologies Laboratory (DETL)

- Flexible, reconfigurable, high-density, p/c-HIL, kW to MVA scale
- Specializes on DER systems integration and microgrids: inverters, energy storage, gensets, microgrids, controllers
- Efficiency, reliability, safety, interoperability, cyber-security, standards conformance

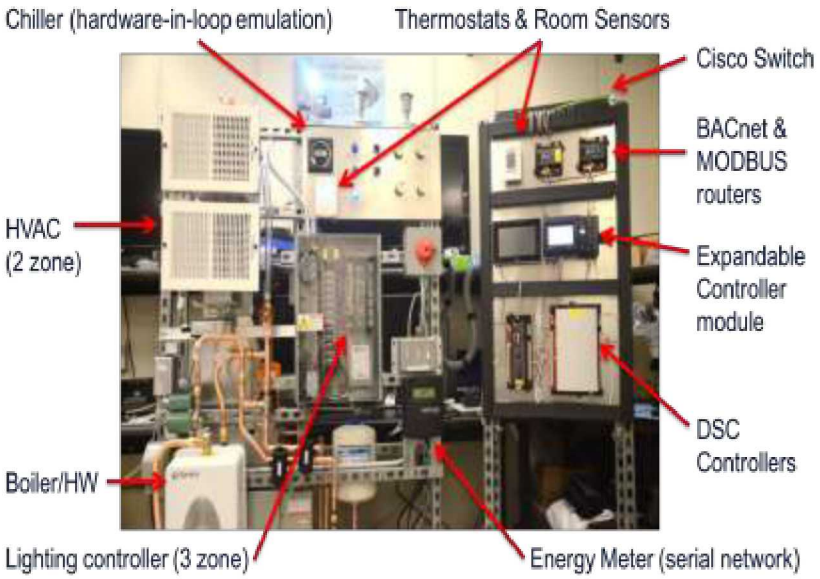
Secure Scalable Microgrid (SSM) Testbed



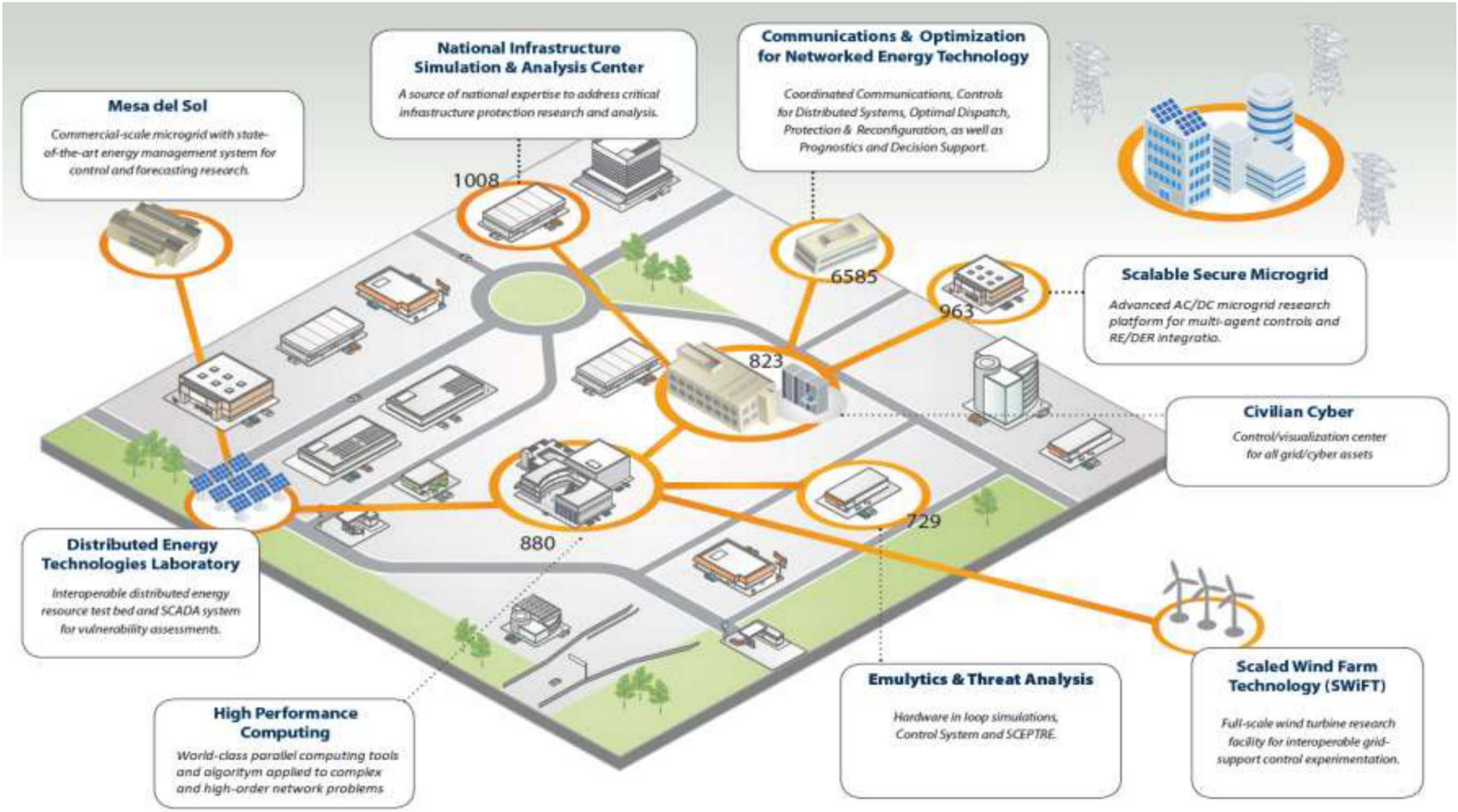
- HIL testbed includes custom components representing generation, energy storage, loads, and distribution network
- High-volume of flexible, repeatable experiments

ICS Cybersecurity R&D Platforms

- Examples of ICS cyber-physical testbeds at Sandia
  - High fidelity (actual hardware)
  - Simulated IT/OT systems



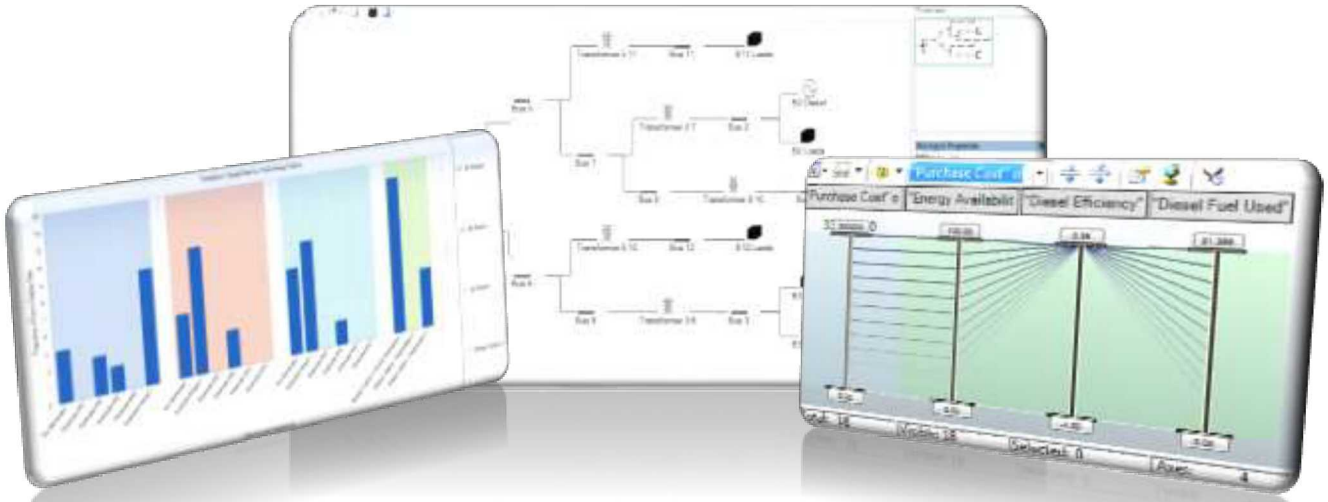
Sandia Integrated Grid R&D Platform



MDT Purpose

- The Microgrid Design Toolkit (MDT) is a decision support software tool for microgrid designers in the early stages of the design process.

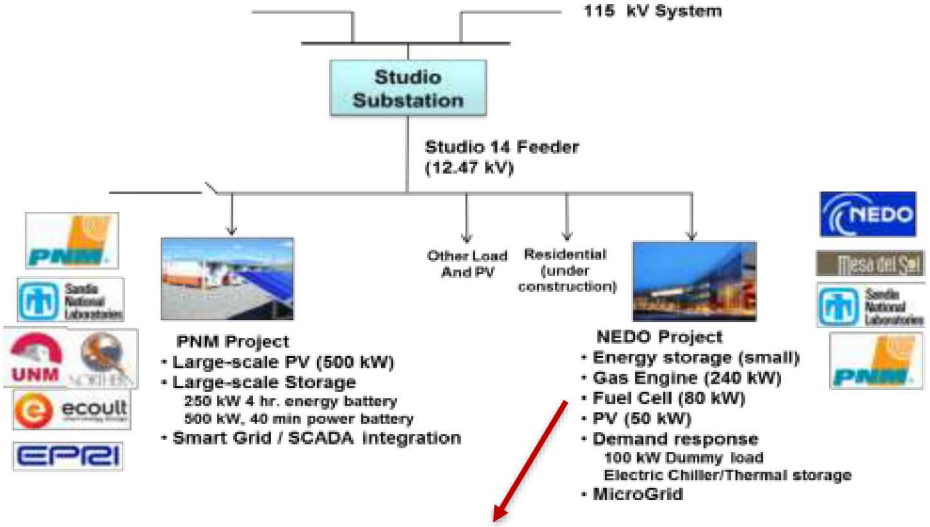
- The software employs powerful search algorithms to identify and characterize the trade space of alternative design decisions in terms of user defined objectives. Common examples of such objectives are ***cost***, ***performance***, and ***reliability***.

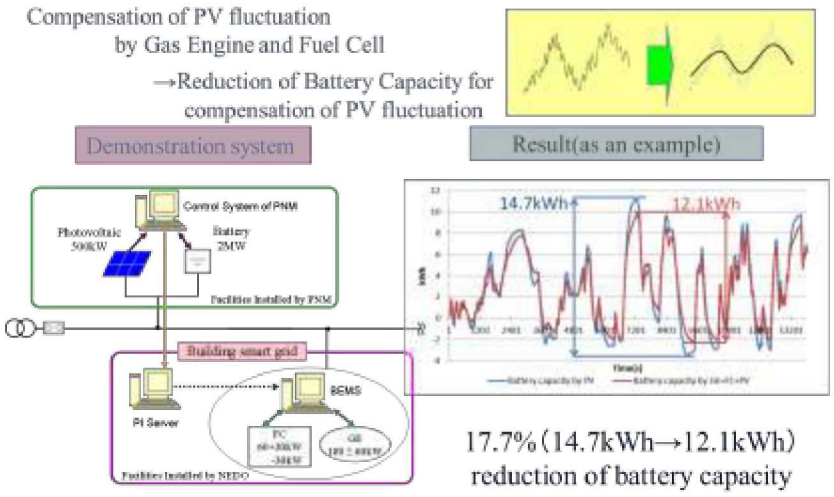


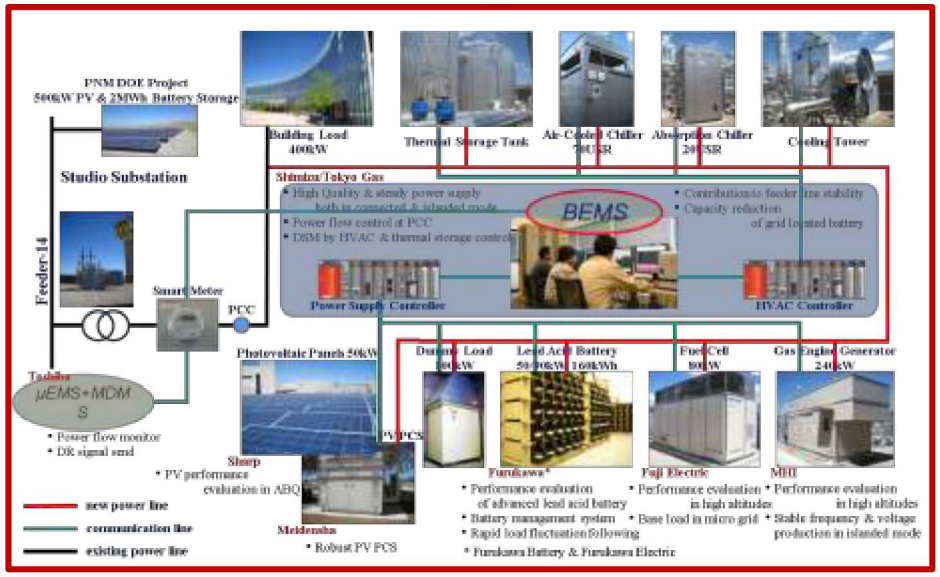
Version 1.2 is available for download from https://www.energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0

Microgrid RD&D Collaboration with UNM

- Multiple joint research projects involving **Mesa Del Sol microgrid** and **Prosperity PV/Battery system**
- Focus on coordinated management of utility and customer owned DER
  - Integration of PV, storage, demand response, BEMS, utility EMS/SCADA
  - Smooth island/grid transition
  - Thermal energy-HVAC integration







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Sandia National Laboratories

Energy Storage Research and Development

Benjamin Schenkman

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Sandia's Energy Storage Research Crosscuts Several Technology Areas

Hydrogen Storage

Hydrogen and Fuel Cells program is developing technologies to accelerate large-scale deployment of hydrogen storage.

Thermal Storage

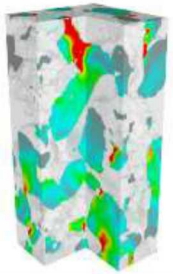
Sandia's Concentrating Solar Power (CSP) program is developing molten salt thermal storage systems for grid-scale energy storage.

Battery Materials

Sandia has a large portfolio of R&D projects related to advanced materials to support the development of lower cost energy storage technologies including new battery chemistries, electrolyte materials, and membranes.

Systems Modeling

Sandia is performing research in a number of areas on the reliability and safety of energy storage systems including simulation, modeling, and analysis, from cell components to fully integrated systems.



Systems Analysis

Sandia has extensive infrastructure to evaluate megawatt-hour class energy storage systems in a grid-tied environment to enable industry acceptance of new energy storage technologies.

Cell & Module Level Safety

Sandia has exceptional capabilities to evaluate fundamental safety mechanisms from cell to module level for applications ranging from electric vehicles to military systems.

Power Conversion Systems

Leveraging exceptional strengths in power electronics, Sandia has unique capabilities to characterize the reliability of power electronics and power conversion systems.

Grid Analytics

Analytical and multi-physics models to understand risk and safety of complex systems, optimization, and efficient utilization of energy storage systems in the field.

Wide ranging R&D covering energy storage technologies with applications in the grid, transportation, and stationary storage

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Sandia National Laboratories

Networked DC Microgrid Capability

Steve Glover, David Wilson, Jason Neely, Marvin Cook

Electrical Sciences and Experiments

Sandia National Laboratories
Albuquerque, NM 87185

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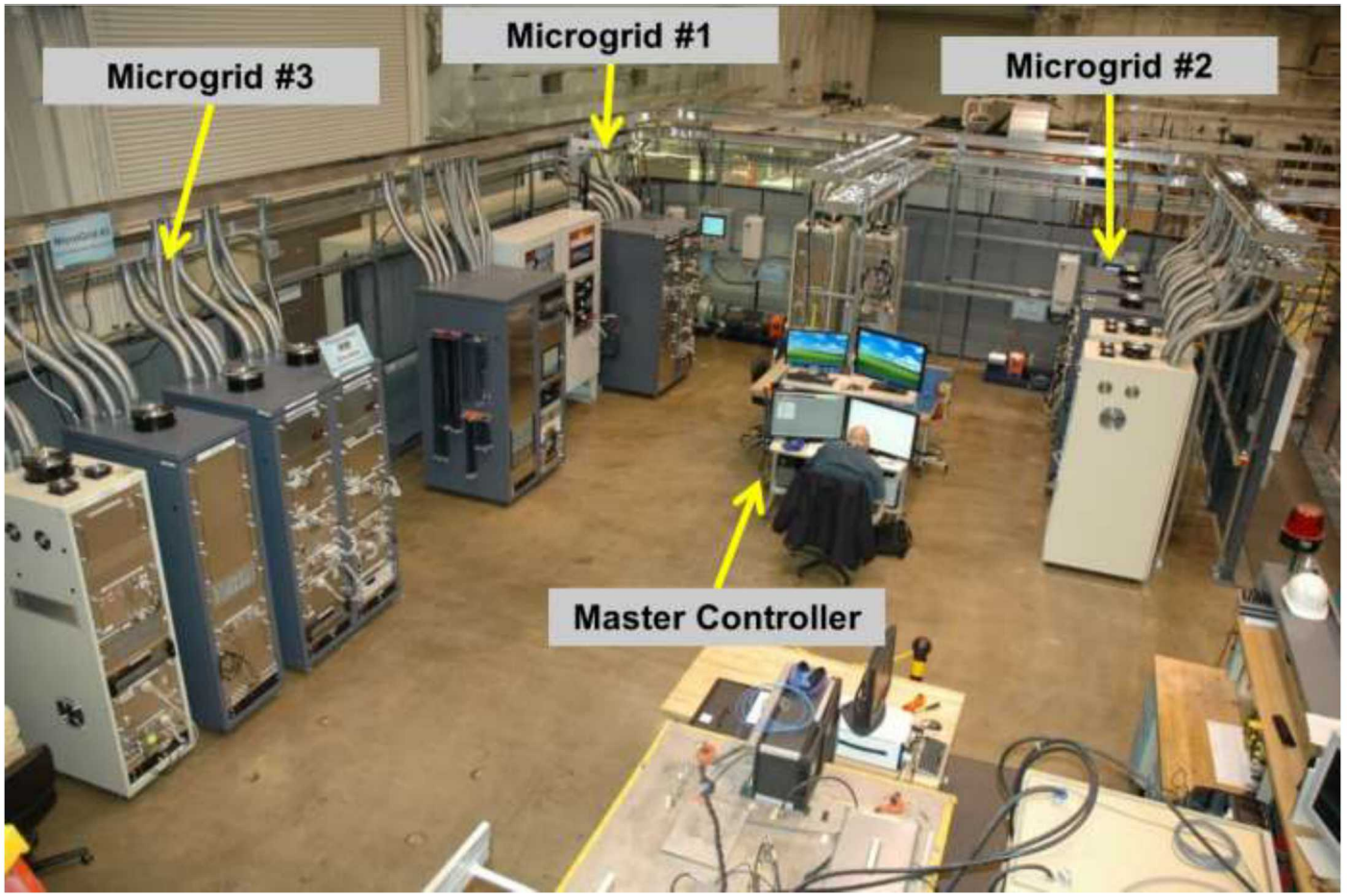
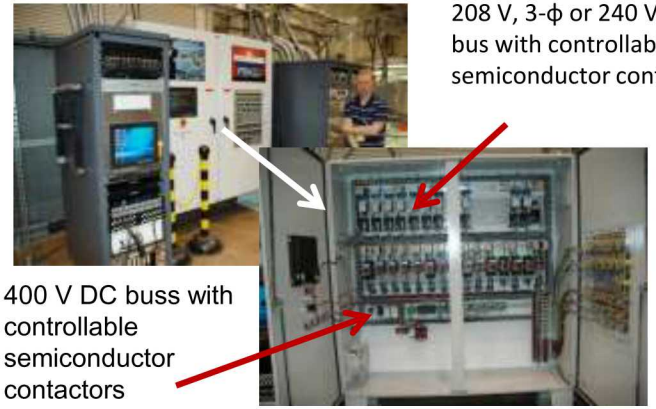
Secure Scalable Microgrid Testbed

- Hardware Testbed includes components representing generation, loads, energy storage and transmission/transfer
- Component building blocks enable a variety of system configurations



SSM Test bed Includes a Controllable Buss Enabling Adaptive Topologies

Controllable Buss Enables Adaptive Topologies

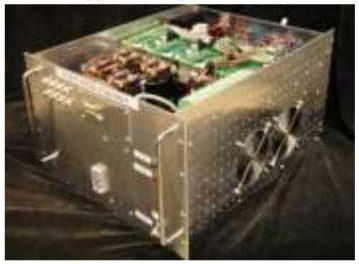


208 V, 3-ϕ or 240 V, 1-ϕ bus with controllable semiconductor contactors

400 V DC buss with controllable semiconductor contactors

Variable and pulse loads

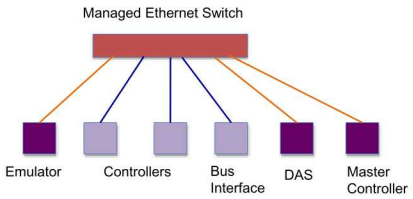
Energy storage device



Flexible converters with RC filter

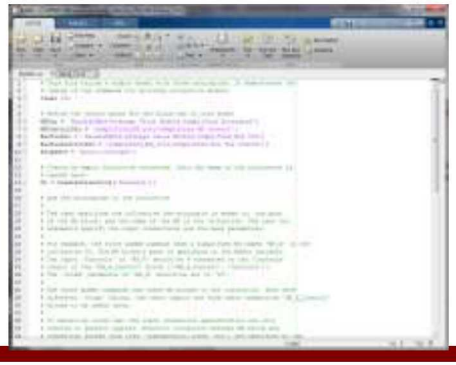
HIL programmable sources (PV, wind, hydro turbine, diesel engine)

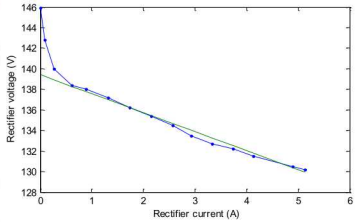
High-performance control/comm. architecture



- GB Ethernet Communication
  - Control network and Timing network
  - Allows for hierarchical control
- 30 MHz Data Acquisition
  - 2 TB hard drive, 48 channels

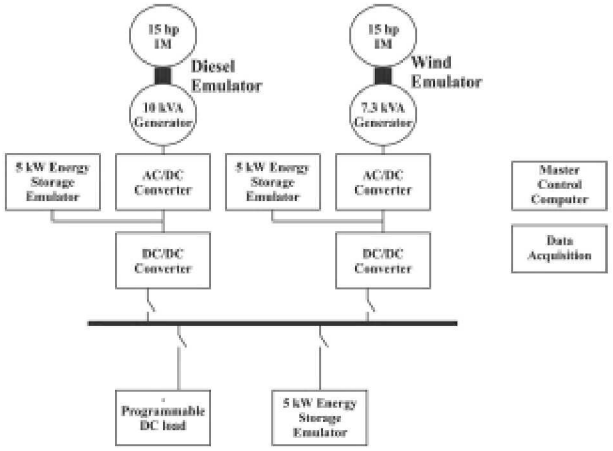
Full representation in Matlab/Simulink enviromnent

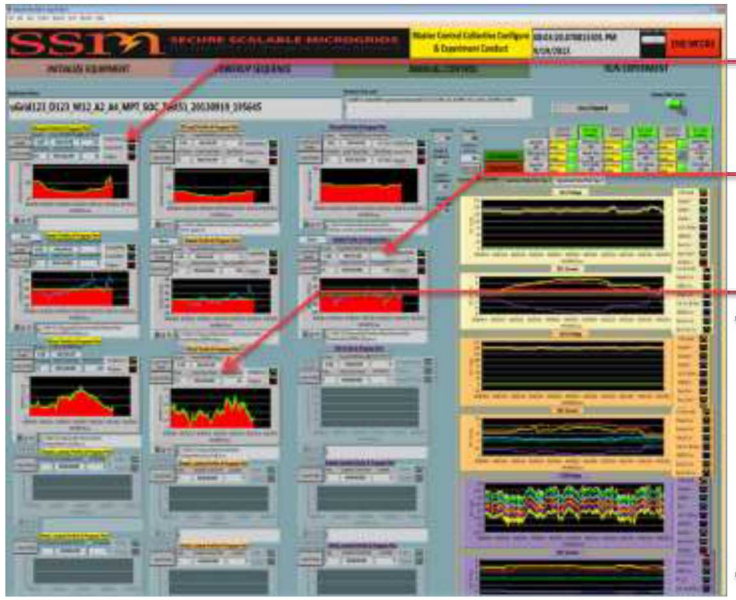




Testbed Enables Automated "Batch-run" Experiments for Control and Hardware Optimization

- Demonstrated Performance with 100% Stochastic Generation and Load is Enabled Through Controls and Storage





Microgrid 1 Load (Ω)

Microgrid 3 Diesel Engine speed (RPM)

Microgrid 2 Wind speed (m/sec)

Realtime bus voltage and current plotting