Energy & Homeland Security

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GRID MODERNIZATION RESEARCH AT SANDIA: POWER ELECTRONICS AND CONTROLS

Sandia's work in power electronics and controls supports grid modernization by developing ways to increase resiliency, performance, and efficiency.

SANDIA'S GRID MODERNIZATION PROGRAM VISION

The U.S. electricity grid is central to the nation's infrastructure, security, and economy. Modernizing this complex system of interconnected networks and enhancing its resiliency ensures seamless, efficient availability of low-cost, reliable, and secure electricity. Sandia National Laboratories supports this role as a national research leader in cross-disciplinary fields including grid integration, cyber security, power electronics, microgrids, microsystems, materials science, energy storage, and transportation.

The laboratory's grid modernization work includes the development of **full-scale integrated distributed systems** in laboratory and field environments, **threat-based modeling and simulation** of the national electric infrastructure, **evaluation of interdependencies** between the electric system and other infrastructure, and research in **security and resiliency**.

THE CHALLENGE

The U.S. Department of Energy (DOE), U.S. Department of Defense, utilities, and the public are seeking improved resilience, robustness, and performance from the electric grid of the future. Attributes of particular importance include:

- greater resilience to hazards of all types;
- improved reliability for everyday operations;
- enhanced security from an increasing and evolving number of threats;
- additional affordability to maintain our economic prosperity;
- superior flexibility to respond to the variability and uncertainty of conditions at one or more timescales, including a range of energy futures;
- increased sustainability through additional clean energy and energy-efficient resources;
- policy development/specs for interconnection;
- cost reduction; and
- a desire to leverage existing infrastructure that was not originally designed for smart grid (i.e., Internet infrastructure and existing power grid equipment).

Achieving these goals is especially challenging in the modern electric system for a number of reasons. From a generation perspective, the introduction of renewable sources such as photovoltaics and wind turbines increase the stochastic behavior of the generation. As the renewable penetration levels increase, the complexity of accurately regulating frequencies and voltages increases. This is further exacerbated by an increased number of DC busses forcing greater importance on hybrid AC/DC system design. In addition, as the ability to access more sensor data or to control more loads remotely increases, advantages can be gained by leveraging the information flow. However, additional impact on security and surety must be taken into account.

SANDIA'S SOLUTION

Sandia National Laboratories has an established history of applying engineering principles to achieve complete systems-view solutions. Our research objective is to look beyond proprietary systems and instead pursue integration at a national scale, among multiple vendors, by helping to architect congruent communication, controls, and interconnection. The lab's extensive history in physical and cyber security provides unique perspectives for designing secure scalable architectures as well as identifying vulnerabilities, risks, and mitigation strategies for existing systems.

Sandia's three-layer secure scalable microgrid grand challenge control architecture and its Virtual Power Plant developed under lab-directed research and development provide preliminary solutions to integrating multiple distributed energy resources in a closed loop control fashion through common communication links. Through this unique research, a laboratory development of a microgrid operating with 100% penetration of stochastic sources and loads was demonstrated while maintaining critical stability and specified performance requirements.

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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RESEARCH SPECIFICS

Power Electronics Devices

Sandia has made significant investments in material science and device research. Fabrication of diodes, photoconductive switches, transistors, and many other components are part of these capabilities. More recently, a Grand Challenge Laboratory Directed Research and Development project is developing “ultra” wide bandgap materials and devices. Silicon carbide and gallium nitride are the primary two wide bandgap materials, and this Grand Challenge effort is looking beyond those to aluminum nitride, which has a bandgap nearly twice that of gallium nitride and offers a theoretical performance limit more than an order of magnitude greater than both silicon carbide and gallium nitride.

Power Electronic Components, Systems, and Microgrids

Component and system research include the creation of secure scalable microgrid test bed that consists of three custom DC microgrids along with some AC component capabilities. These microgrids can be operated individually, merged into one larger microgrid, or organized as a network of microgrids. This laboratory platform enables a holistic approach to hardware, control, and energy storage system design. Centralized and distributed controls approaches can be implemented as well as algorithms for demand side management. Information flow and cyber are integral aspects of this system allowing for hardening and security techniques to be developed.

Controls and Optimization

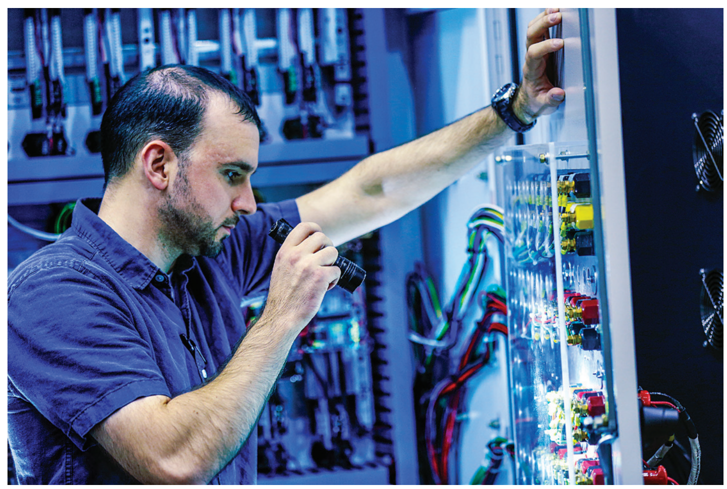
With increasing renewable penetration and traditional generation being replaced by inverter-based solutions, the dynamics of the grid will change significantly. Inverter-based systems have the benefit of extremely fast response times, but the loss of inertia from traditional rotating generation will cause grid dynamics to increase in frequency. An area of expertise is dynamic simulations, both at the transmission and distribution level, to evaluate the impacts of potential future grid topologies. Synergistic with this capability is experience designing control systems that maintain or improve stability in the face of increasing renewable penetrations. These control systems span centralized designs, distributed structures, demand side management, and optimization. Techniques that span from conventional PID, to model predictive control, to Hamiltonian Surface Shaping and Power Flow Control (HSSPFCTM) based designs.

PARTNERS

Sandia’s partners with wide band gap device manufacturers, PCS integrators, universities, and the electric utility industry. Each of these partnerships aid in accelerating technology development for industry and knowledge transfer to the next generation of engineers.

IMPACT

Sandia’s power electronics and controls program impacts ongoing research through numerous conference papers, journal papers, technical advances, patents, and R&D 100 awards. In addition, the transfer of expertise is ongoing through the education and experience gained from student interns, post docs, and professor sabbaticals. Capabilities developed by Sandia are changing the performance of grid systems as well as military power systems.



Sandia’s secure scalable microgrid test bed can be configured to simulate complex power systems.

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