

Grid Modernization Research at Sandia: Renewable Energy & Distributed Systems Integration

Sandia conducts multi-disciplinary research and development to enable grid modernization and large-scale deployment of renewable and distributed energy resources.

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, cybersecurity, power electronics, microgrids, microsystems, materials science, energy storage, and transportation.

Sandia has pioneered work in renewable energy (RE) since the 1970s, with a growing focus on supporting the cost competitiveness and energy security advantages of renewable and distributed energy resources (DER). The lab's work helps address challenges to modernizing the grid and electricity, such as voltage and frequency disturbances caused by increased renewable energy penetration, power systems operations and planning, and control and security of microgrids.

The Challenge

The existing power grid delivers electricity one-way from large dispatchable generators to distant load centers. Increased deployment of DER and RE is fundamentally transforming the grid. To ensure that the future grid will meet the nation's need for high performance, reliability, sustainability, safety and cost-effectiveness, technical innovation is necessary.

Sandia's Solution

To enable future large-scale deployment of DER and RE, Sandia develops disruptive solutions including advanced simulation tools, new power electronics concepts, adaptive control and protection systems, and new testing methodologies and standards. Sandia maintains

and continually improves research and development (R&D) capabilities, including technical expertise and state-of-the-art testing facilities to address complex technical challenges, in partnership with government agencies, national laboratories, universities, and industry stakeholders.

Research Areas

Advanced Modeling and Simulation

Sandia develops and applies advanced modeling and simulation tools to analyze the impact of large-scale DER and RE deployment on the grid and to develop innovative strategies and technical solutions. Sandia develops and validates multi-domain models for grid analysis and advanced decision support tools for T&D operations and planning. Sandia also pioneers quasi-static time series (QSTS) power flow, state estimation, and stochastic analysis techniques that are computationally efficient and scalable. Using these tools, researchers study challenges such as emerging dynamic behavior introduced by smart inverters, distribution feeder hosting capacity, optimal decision-making under high uncertainty, and interconnection frequency performance with high-shares of variable renewable generation. We partner with utilities and software providers to ensure these advances are applicable and widely available.



Power Electronics and Controls Research and Development

Sandia's comprehensive power electronics and controls R&D program focuses on improving capabilities, efficiency, and reliability of next generation inverters and converters. The lab also designs cyber-secure controls that aggregate RE and DER optimally

aggregated into microgrids or virtual power plants to support resilience and grid support. Sandia's solutions include communications-based island detection using power line carrier and synchrophasor schemes, development of controls that enable grid support functions and island detection, and development of interoperability test protocols.

Sandia is pioneering solutions for anti-islanding technology, grid compatibility, validation of interoperability and advanced inverter functionality, and associated standards.

Technology Validation and Demonstration

Sandia works with industry, utilities, and government agencies to validate and demonstrate advanced smart grid technologies in laboratory environments and real-world demonstrations. Sandia applies automated testing platforms to evaluate cybersecurity, interoperability, grid compatibility, controls performance, reliability, and safety of RE and DER devices and systems. Technology validation and demonstration activities also make use of control and power hardware-in-the-loop capabilities, including Sandia's SCEPTRE emulatics platform that combines controls, cybersecurity, communications, and power systems domains. The System Validation Platform (SVP) tool to accelerates the development, certification, and standardization of DER technologies through rapid and fully automated laboratory evaluation. Finally, Sandia conducts full-scale demonstrations involving customer and utility assets.

Standardization

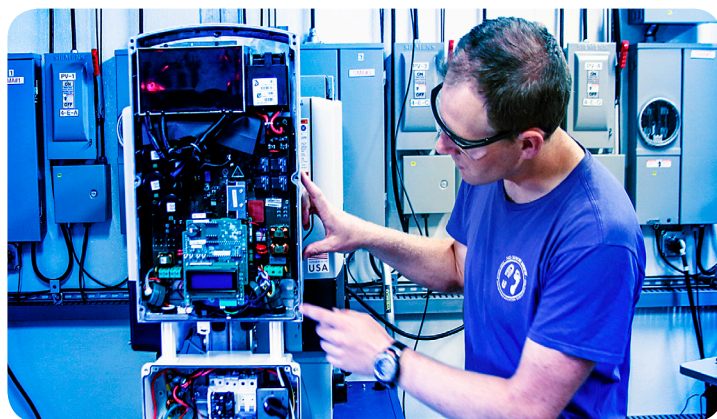
With major stakeholders, Sandia pursues standardization or implementation of best practices related to interconnection, interoperability, and safety of RE and DER. Sandia has been a major contributor to standards related to arc fault detection and mitigation, interoperability, disturbance tolerance, and grid support functionality. Sandia's contributions span scientific basis, development of testing procedures, and harmonization across the industry. With national and international partners, Sandia leads working groups under the International Smart Grid Action Network Smart Grid (ISGAN) International Research Facility Network (SIRFN), IEEE 1547, Smart Inverter Working Group, UL 1741, Smart Grid Interoperable Panel (SGIP), and multiple other collaborations.

State-of-the-Art Facilities

Sandia maintains integrated laboratory facilities that provide capabilities for real-world research and development of RE and DER technologies, including the Distributed Energy Technologies Laboratory (DETL), Secure and Scalable Microgrid (SSM) Testbed, Scaled Wind Farm Technology Facility (SWIFT), Control & Optimization of Networked Energy Technologies (CONET) Laboratory, Energy Storage Test Pad (ESTP), and Emulatics and Threat Analysis Laboratory. These facilities, combined with technical expertise in power electronics, cybersecurity, high performance computing, visualization, controls, and reliability science, provide a test platform to support advanced research and development on a wide variety of DER and RE technologies.

Impact

Sandia's work in renewable energy and distributed energy systems advances standardization and certification of advanced inverter performance, solves safety and compliance issues, enhances interoperability and interconnection, and integrates cybersecurity. The results of the lab's research can support the modernized grid by facilitating increased deployment of RE and distributed energy systems and helping to ensure seamless availability of reliable and secure electricity.



Distributed Energy Technologies Laboratory

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