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GRID MODERNIZATION RESEARCH AT SANDIA: TRANSMISSION PLANNING, OPERATION, AND CONTROL

Sandia's research enables grid modernization solutions related to transmission planning, operation, and control. Aging infrastructure, increased deployment of renewable generation, and evolving resilience goals are driving transmission planning. Power system operation can be made more reliable, efficient, and resilient by applying advanced optimization and control techniques

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 researchers are working to develop tools and algorithms that enable grid modernization related to transmission planning, operation, and control. Research thrusts include:

- Advanced production cost models that better incorporate renewable variability and new market designs,
- Resilience metrics and optimization methods to design the next generation grid that is both reliable and resilient, and
- Developing new control algorithms to improve grid stability—thus increasing reliability and resilience.

These thrusts, worked in conjunction with industry partners, will enable the grid modernization solutions related to transmission planning, operation, and control. The electric grid is often recognized as the greatest engineering achievement of the 20th century and is the foundation of the nation's economic success. This research will help ensure the continued reliability and resilience of the electric power grid.

THE CHALLENGE

The electric power grid has always been an engineering marvel—reliably serving a variable load of energy at a very reasonable cost. Rapid advances in new, renewable power generation technologies combined with deregulation and ubiquitous computing and communications have created a new set of challenges for the modern electric grid.

These challenges include:

- Increasing amounts of variable renewable power generation requires complex management practices and tools to maintain or improve grid reliability.
- Resilience, the ability of the grid to withstand and quickly recover from low probability, high consequence events, is becoming a high priority. Recent motivators include Hurricanes Katrina (New Orleans) and Maria (Puerto Rico), as well as Superstorm Sandy (Northeastern U.S.).
- Inverter-based generation creates new challenges (e.g., a reduction in system inertia) but also provides new opportunities to employ advanced control algorithms.
- Low-cost sensing and communications technologies greatly improve situational awareness and enable advanced control systems, but they are vulnerable to cyber and physical attacks.



Because grid modernization is a national challenge affecting economic and national security, this area of research is a high priority at Sandia National Laboratories.

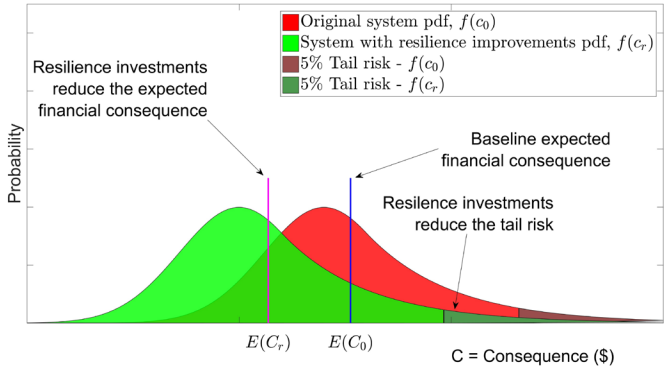
SANDIA'S SOLUTION TO IMPROVING RESILIENCE

To help grid operators make effective, defensible decisions about protecting local and regional communities from catastrophes related to grid damage, Sandia has developed the Resilience Analysis Process (RAP), a comprehensive methodology for quantifying resilience and evaluating

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An illustration of the resilience improvement after applying Sandia's Resilience Analysis Process (RAP).

competing alternatives to improve resilience. This multi-step method, which is based on Sandia's extensive experience with critical energy infrastructure security, calls for working closely with stakeholders to identify the most crucial potential threats and high-level consequences in their region. Sandia analysts then create a detailed system model and evaluate the model against the specified threats to determine system response and consequences. Finally, the analysts apply stochastic optimization algorithms to identify improvements to the system that minimize consequences and achieve the greatest system resiliency.

RESEARCH AREAS

Wide Area Damping Control

Sandia has developed a grid damping control strategy that employs real power injections at strategically located points in the grid based upon feedback from real-time Phasor Measurement Units (PMU). The primary objective of this control system is to damp inter-area oscillations in the grid which will significantly lower the likelihood of wide-area blackouts, enable higher inter-area power flows, and reduce the need for costly new transmission capacity.

A key element of the control strategy is a high-level supervisory controller that monitors the behavior of the power system, the PMU network, and the real-time control loop to ensure safe, secure, and reliable damping performance.

Geomagnetic Disturbances

Sandia has invested substantially in the development of analytic methods that can quantify resilience using risk based, probabilistic methods as it relates to geomagnetic disturbances (GMD). In this work, the high consequence events take the form of voltage stability margin or specific critical load lost. The threat or threat vector would be one or more specific GMD scenarios. This framework, using an extended version of an AC optimal power flow, enables decision makers to optimally invest in resilience improvements, preventing voltage collapse and widespread blackout.

Solar and Wind Integration

PRESCIENT, a stochastic production cost modeling tool, automatically produces probabilistic forecasts from deterministic historical forecasts for load, solar, and/or wind power production and their respective time-correlated actual values. Optimization problems for the grid are exceptionally difficult to solve stochastically, but PRESCIENT's solution method can take hundreds of scenarios and solve the system's commitment and dispatch problems in tens of minutes, showing the real value of variable generation. This tool uses commercially available solvers such as CPLEX, GUROBI, and freely available ones such as GLPK and CBC.

Designing for Resilience

Sandia has developed software tools for incorporating resilience metrics into the transmission planning process. Since resilience and reliability are often related, Sandia has demonstrated that it is possible to co-optimize resilience and reliability. This is particularly important given the current environment for utilities—they are compensated based on meeting or exceeding reliability metrics. Using Sandia's software tools, it is now possible to explore the characteristics of different investments that are required to meet reliability, but that have the maximum impact on improving grid resilience.

PARTNERSHIPS

Sandia's grid modernization research relies on partnerships with a range of stakeholders, including other national laboratories, electric utilities, industry, federal and state agencies, universities, and international advanced grid consortia. These partnerships help Sandia apply jointly developed tools and solutions, broaden technical capabilities, and gain insight into policy and regulatory issues. By expanding our capabilities with respect to transmission planning, operations, and control, we are able to minimize the probability of major grid disruptions.

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