Bolstering Power Grid Resiliency

The Challenge

Because the complex network of electrical infrastructure that stretches across the United States is critical to our economic well-being and quality of life, grid owners and operators work hard to ensure the system is reliable. However, strengthening grid resilience, or its ability to minimize the consequences of one or more threats, requires understanding the consequences of specific threats to the systems that rely on the grid. For example, an operator that has purchased a spare transformer to hedge against disaster may lack the analytic tools and data to use that transformer to minimize the consequences of highest concern.

Solution

To help grid operators make effective, defensible decisions about protecting local and regional communities from catastrophes related to grid damage, Sandia National Laboratories has developed the Resilience Analysis Process (RAP), a comprehensive methodology for quantifying resilience and evaluating 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 changes to the system that minimize consequences and achieve the greatest system resiliency.

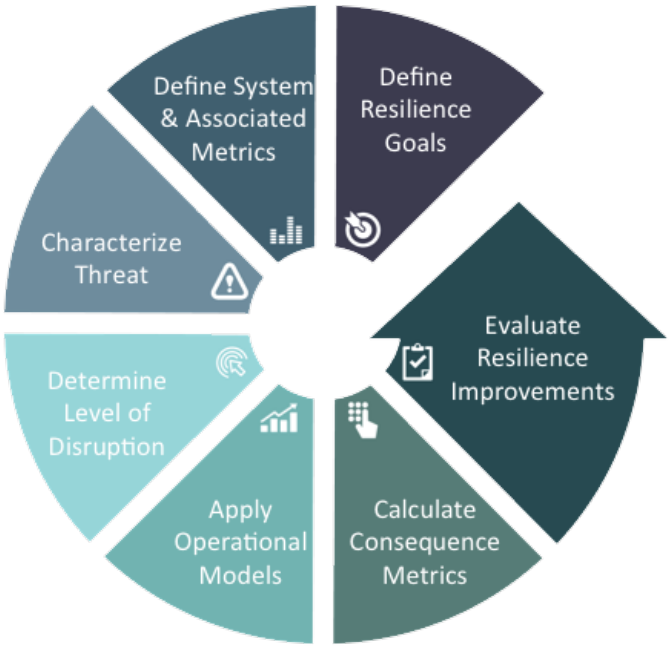
Metrics to Unify Resilience Planning

Because different stakeholders understand resilience in different ways, a key milestone in RAP development was creating a standardized metrics framework for measuring resilience that focuses on the consequences of various threats. When creating this framework, Sandia integrated a variety of attributes to ensure that RAP results would provide value to stakeholders dealing with real-world issues. Specifically, the metrics were able to

- Generate useful, quantitative information to guide risk-based, defensible decisions about both system planning and real-time operations, as well as policy
- Enable comparisons between different systems before and after resilience enhancements
- Reflect uncertainty so that decision-makers understand the certainty of resilience decisions
- Focus on specific threats and consequences that are most meaningful for a specific area and system—and for the people and businesses that depend on that system

Creating Rigor

The rigor of RAP is crucial to providing results that form the basis of risk-based, defensible infrastructure investments. Sandia teams work closely with stakeholders through the steps illustrated in the figure to create the necessary rigor.



As shown, the process begins with defining the high level resilience goals, such as minimizing financial exposure or preserving human services, that are most important to the organizations involved. Stakeholders then help set the scope of the analysis by identifying details and metrics. These could include, for example, a system's geographic boundaries and the most important consequences.

The next step involves characterizing the threats of concern, such as earthquake or cyber attack, as well as the likelihood and potential strength of possible threats—information important to understanding the amount of grid component damage likely.

Applying the information developed with the stakeholders, the analysis team generates a model (or models, as needed) of the grid system and evaluates the model against the specified threats to determine a damage outcome—or, when uncertainty is integrated, a range of damage outcomes. From this, the team calculates the consequences to transportation, healthcare, manufacturing, and other systems dependent on the grid.

With an understanding of possible consequences, the team and stakeholders can begin exploring decisions about achieving resilience goals. A final step—evaluating trade-offs between potential resilience investments using optimization algorithms—is crucial to helping stakeholders make decisions about equipment, operations, and policy that best achieve resilience goals.

RAP at Work

Sandia is applying the RAP process to two major US utilities, with results expected in late 2016. In the first project, Sandia is analyzing the resilience of part of the transmission system of American Electric Power—which serves 5 million customers in 11 states—against extreme weather events and physical security threats. In the second project, Sandia is identifying and assessing cost-effective ways to increase the resilience of a portion of the transmission system of independent system operator (ISO) PJM—which coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia—against geo-magnetic disturbances caused by solar storms.

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