Electric Distribution System Resilience

Prepared for
The 2nd National Symposium on Resilient Critical Infrastructure, Resilience Week 2015, Philadelphia, PA
by
Julia Phillips, Frédéric Petit, and Celia Porod
Risk and Infrastructure Science Center, Global Security Sciences Division
Motivation

- Resilience of the electric grid has gained a rising amount of attention over the past seven years since the Energy Independence and Security Act of 2007. (http://www.gpo.gov/fdsys/pkg/PLAW-110publ140/html/PLAW-110publ140.htm)

- The President’s Climate Action Plan, released in June 2013, continues to highlight the importance of modernizing the electric grid and to prepare for and mitigate the impacts of climate change. (https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf)

- In April 2015, the Quadrennial Energy Review (QER) on energy transmission, storage, and distribution infrastructure sought to identify vulnerabilities in the system and proposes major policy recommendations and investments to replace, expand, and modernize infrastructure where appropriate. (DOE EPSA http://energy.gov/epsa/quadrennial-energy-review-qer)
Objectives

- Develop a tool that collects information from electric distribution utility operators and estimates a measure of the resilience of the distribution system to extreme weather events.

- Develop a methodology to quantify this information and display the results in a decision-aiding tool.
Definition of Resilience

- Ability of an entity (e.g., asset, organization, community, region) to anticipate, resist, absorb, respond to, adapt to, and recover from a disturbance (Carlson et al., 2012)
Important Capabilities for the Resilience of the Grid

- **Adaptability**
  - **Capacity** of actors in a system to manage resilience, either by moving the system toward or away from a threshold that would fundamentally alter the properties of the system, or by altering the underlying features of the stability landscape ([http://www.ecologyandsociety.org/vol9/iss2/art5/](http://www.ecologyandsociety.org/vol9/iss2/art5/))

- **Transformability**
  - **Capacity to create a** fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable ([http://www.ecologyandsociety.org/vol9/iss2/art5/](http://www.ecologyandsociety.org/vol9/iss2/art5/))

- **Flexibility**
Approach

- Use an **approach similar to the Resilience Measurement Index**
  - Resilience Index developed at **facility level**
  - **Aggregate measure of four operational dimensions**: Preparedness. Mitigation Measures, Response Capabilities, and Recovery Mechanisms
  - **Indices based on selected questions**
  - Used by the US Department of Homeland Security

- Use of **Decision Analysis** and **Multi-Attribute Utility Theory** principles
What is Decision Analysis

- A **systematic and logical set of procedures** for analyzing complex, multiple-objective problems

- Consists of philosophy, theory, methodology, and professional practice

- Characteristics:
  - Utilizes “divide and conquer” approach
  - Develops meaningful and useful metrics (attributes) for objectives
  - Examines tradeoffs among conflicting objectives
  - Incorporates uncertainty and risk attitudes
Application of Decision Analysis

- **Prioritization of alternatives** (e.g., protective measures in order of greatest vulnerability reduction)

- **Resource allocation** (e.g., among grant applicants)

- **Portfolio selection** (e.g., maximize risk reduction within budget limit)

- **Policy and strategic analysis** (e.g., compare economic and health consequences)
Application at Facility Level

- **Preparedness**
  - Awareness
  - Planning

- **Mitigation Measures**
  - Mitigating Construction
  - Alternate Site
  - Resources Mitigation Measures

- **Response Capabilities**
  - Onsite Capabilities
  - Offsite Capabilities
  - Incident Management and Command Center Characteristics

- **Recovery Mechanisms**
  - Restoration Agreements
  - Recovery Time
Application to the Electric Distribution System (1/2)

- What are the requirements/expectations for a resilience assessment tool at system level?
  - Information Sharing / Best Practices
  - Internal, regional, and Sector Wide Comparisons

- What capabilities should be included in the tool?
  - Agreements
  - Planning
  - Dependencies

- What elements of the distribution system should be considered in the tool?
  - Lines
  - Substations
  - Control Systems
What are the elements contributing to the resilience of the distribution grid?
- Similar to Resilience at Facility Level
- Adaptability, Transformability, Flexibility
- Current metrics, reliability index

What type of final products would be beneficial to the owners and operators?
- Overall index
- Resilience options for consideration
- Dashboard
- Curves
Electric Distribution System Resilience Index (1/2)

Preparedness

- Awareness
  - Resilience Operations
  - Training/Exercises with First Responders
  - Extreme Weather Assessment
  - Information Sharing

- Planning
  - Business Continuity Plan
  - Emergency Operation/Emergency Action Plan
  - Outage Restoration Plan
  - Cyber Security Plan
  - Procurement Management
  - Extreme Weather Procedures

Mitigation Measures

- Extreme Weather Mitigation
  - Construction
  - Deployable Mitigation Measures

- Utility Mitigation
  - Distribution System and Lines
  - Substations
  - Control & Dispatch Centers
  - Information Technology

- Resources Mitigation Measures
  - Electric Power
  - Communications
  - Transportation
Electric Distribution System Resilience Index (2/2)

Response Capabilities
- Internal Capabilities
  - Utility Systems
  - Incident Management and Command Center
  - Extreme Weather Response Procedures
- External Capabilities
  - First Preventers/Responders Interactions
  - Event and Incident Responses
  - Resource Service Agreements

Recovery Mechanisms
- Utility Service Restoration
- Restoration Resource Agreements
Conclusion

- Increased attention to the resilience of electric grid to all hazards

- Principles of decision analysis and Multi-Attribute Utility Theory can be used to develop a system resilience index

- Necessity to not duplicate existing capabilities and to consider information sharing processes
The work presented in this article was partially supported by Argonne National Laboratory under U.S. Department of Energy contract number DE-AC02-06CH11357. The submitted manuscript has been created by UChicago Argonne, LLC, Operator of Argonne. Argonne, a U.S. Department of Energy Office of Science laboratory, is operated under Contract No. DE-AC02-06CH11357. The U.S. Government retains for itself, and others acting on its behalf, a paid-up nonexclusive, irrevocable worldwide license in said article to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the government.