Electric Distribution System Resilience

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by

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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

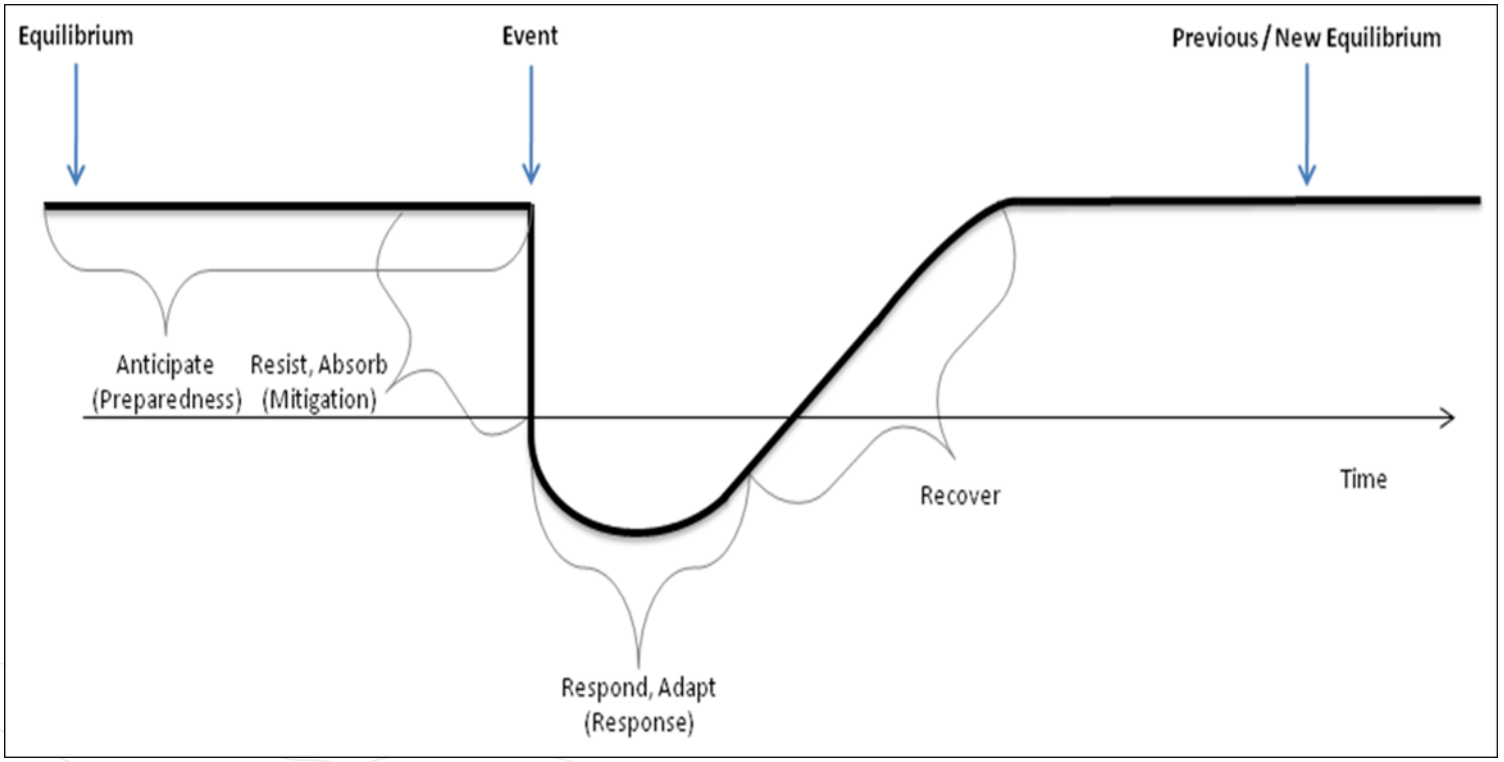
- Develop a tool that collects information from electric distribution utility operators and **estimates a measure of the resilience of the distribution system** to **extreme weather events**

- 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/)
- 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/)
- Flexibility
  - **Capacity to** reorganize rapidly, shift inputs and resources, and **sustain some acceptable level of functionality** as the disruption unfolds (http://www.fastcompany.com/1257825/resilience-face-crisis-why-future-will-be-flexible)

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

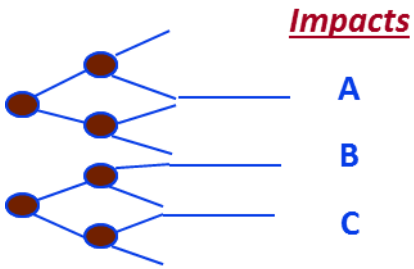
- Use of **Decision Analysis** and **Multi-Attribute Utility Theory** principles

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

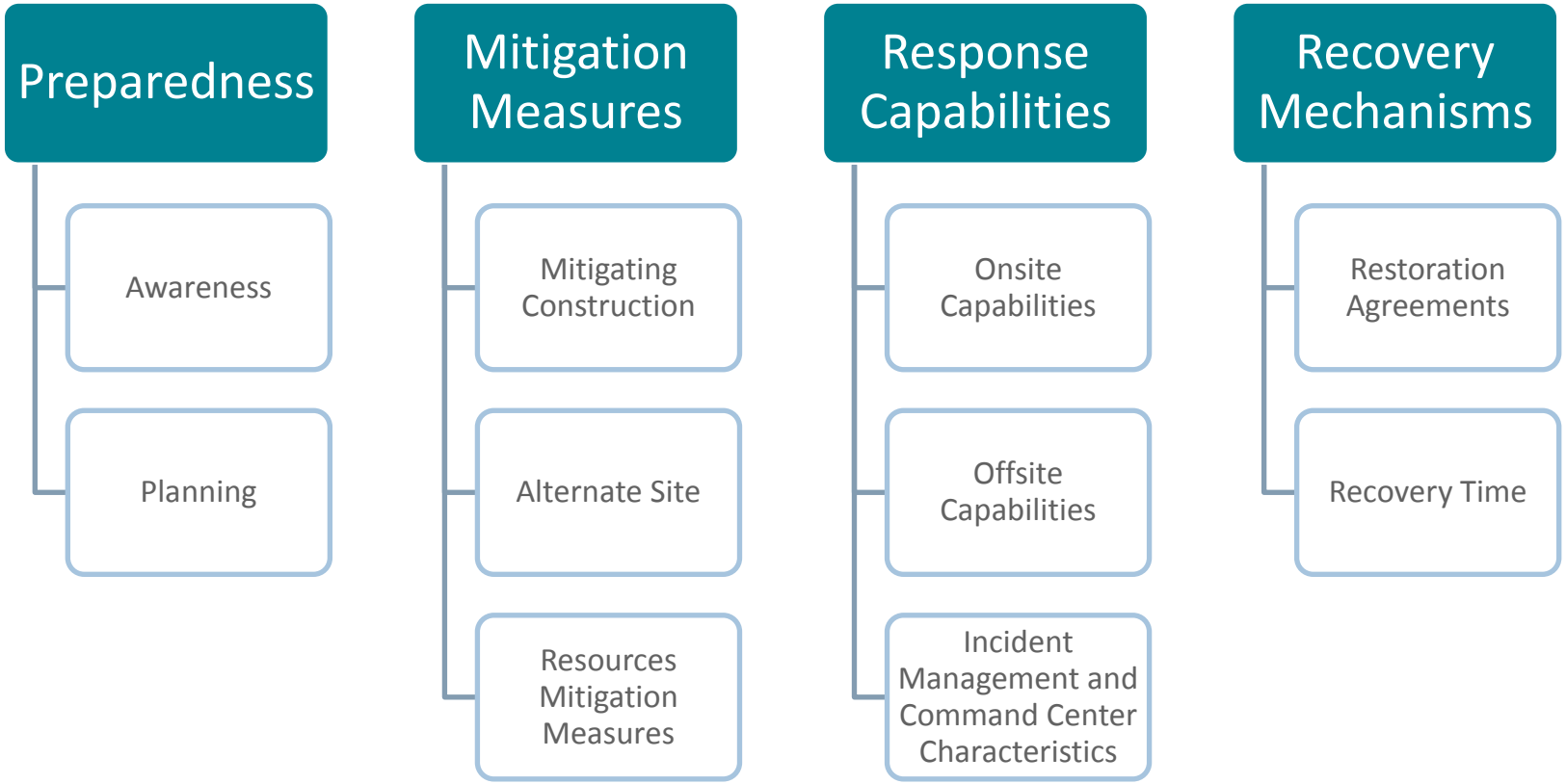
Application of Decision Analysis

- **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)



Rank	Alternative
1	D
2	P
3	A
⋮	⋮

Application at Facility Level



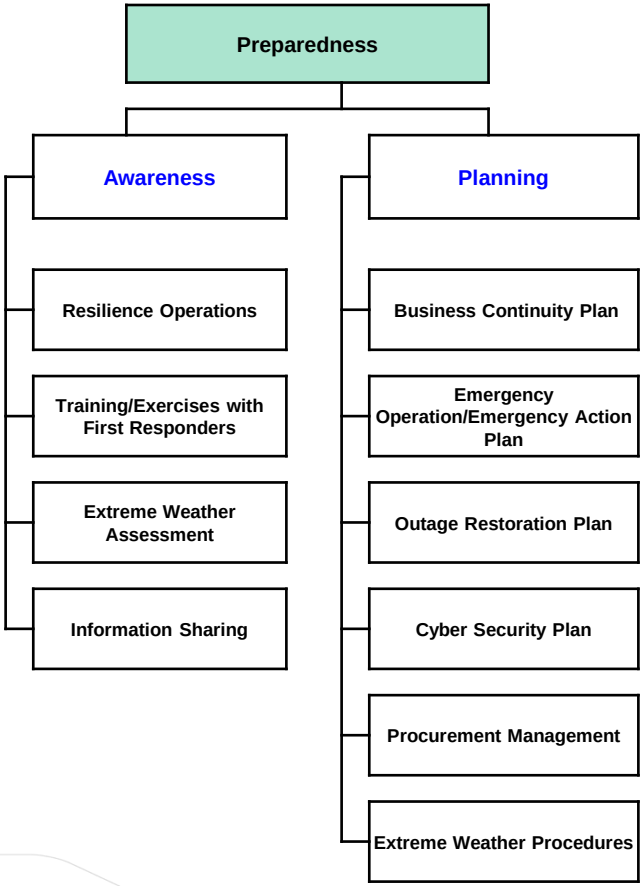
Application to the Electric Distribution System (1/2)

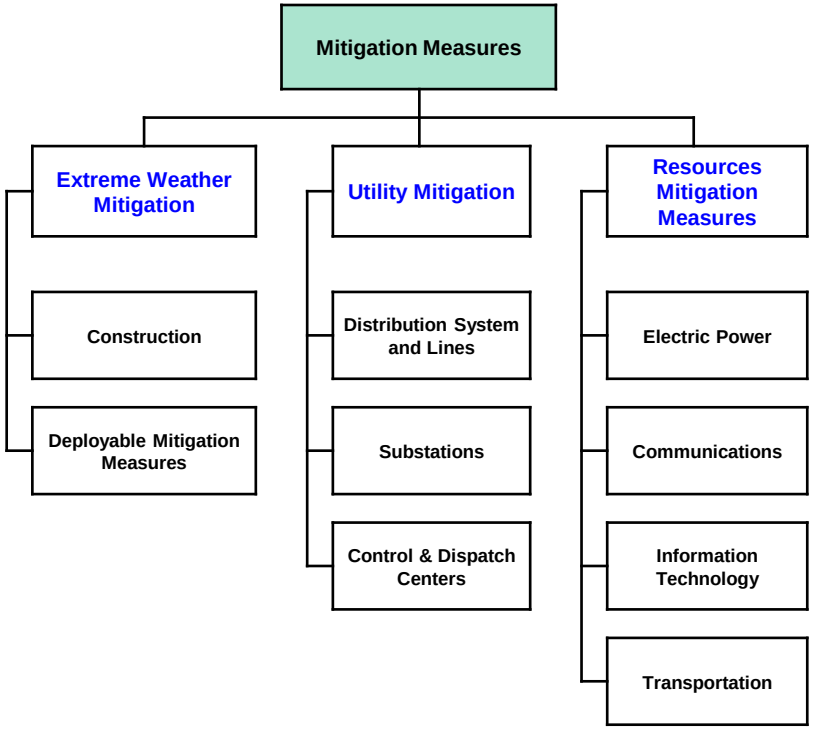
- What are the **requirements/expectations** for a resilience assessment tool at system level?
  - Information Sharing / Best Practices
  - Internal, regional, and Sector Wide Comparisons
- What **capabilities** should be included in the tool?
  - Agreements
  - Planning
  - Dependencies
- What **elements of the distribution system** should be considered in the tool?
  - Lines
  - Substations
  - Control Systems

Application to the Electric Distribution System (2/2)

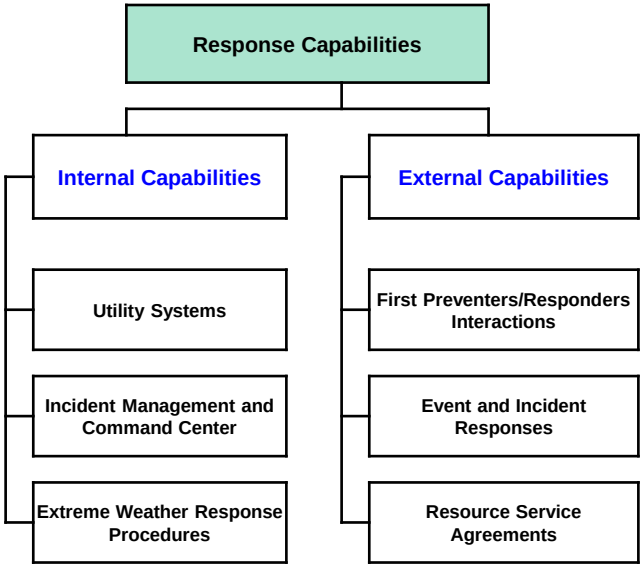
- What are the **elements contributing to the resilience** of the distribution grid?
  - Similar to Resilience at Facility Level
  - Adaptability, Transformability, Flexibility
  - Current metrics, reliability index
- What **type of final products** would be beneficial to the owners and operators?
  - Overall index
  - Resilience options for consideration
  - Dashboard
  - Curves

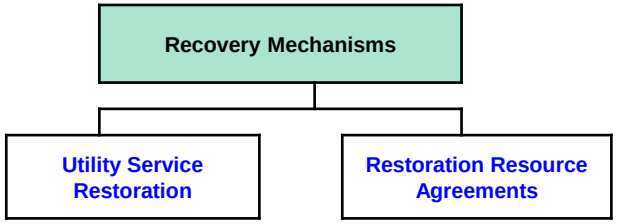
Electric Distribution System Resilience Index (1/2)





Electric Distribution System Resilience Index (2/2)





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**

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