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Electric Power Distribution System Resilience: Federal Government and National Lab Perspective

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Critical Infrastructure Resilience Definition

- Presidential Policy Directive 21 (2013) - Critical Infrastructure Security and Resilience
  - *"The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to **withstand** and **recover** from deliberate attacks, accidents, or naturally occurring threats or incidents."*

- Definition directly applies distribution grid systems

Other Definitions of Resilience

- National Infrastructure Advisory Council
  - *"The ability to reduce the magnitude and/or duration of disruptive events through capacity to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event."*
- DHS
  - "*The ability to anticipate, absorb, adapt to and/or rapidly recover from a potentially disruptive event. Three key features are: robustness; the ability to maintain critical operations and functions in the face of a crisis, resourcefulness; the ability to prepare for, respond to, and manage a crisis or disruption as it unfolds, rapid recovery; the ability to return to and/or reconstitute normal operations as quickly and efficiently as possible.*"
- DOD – Multiple definitions depending on application area (psychological, community, international)
  - Infrastructure resilience references DHS definition

These definitions have driven work to date by many of the laboratories

Programmatic efforts focused on promoting resilience

- Risk Characterization/Assessment
- Vulnerability/resilience assessments
- Reliability analyses
- System planning and design
- Post-event operation planning
- Post-event repair planning
- Situational awareness during events
- Interdependency analyses
- Hardware design, testing and integration

The national labs have programs using these approaches for different sectors and mission thrusts.

Extent of Applications on Distribution Grid Resilience

- All sector specific agencies recognize importance of continuity of electric power service to their facilities
- DHS has many initiatives aimed at improving resilience for critical facilities and systems
- DOD also is investing in energy technologies for continuity of operations
- Limited direct efforts on distribution grid resilience

Programs within the Federal Government

- DOE
  - Smart Grid R&D Program—Microgrid Initiative
- DOD
  - Smart Power Infrastructure Demonstration for Energy Reliability and Security
- DHS (and NIPP partners)
  - Regional Resilience Assessment Program
  - National Infrastructure Simulation and Analysis Center

Capability Area: Expert Elicitation

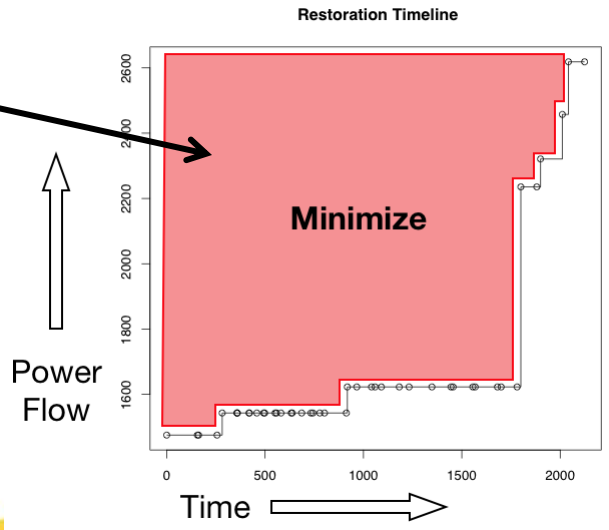
- Survey industry and distribution utilities
  - Develop understanding of system operation and support needs
  - Restoration plans, mutual aid agreements, spare parts inventory, past experience, etc.
- Resilience Scoring
  - Systematic and reproducible assessment based on survey results
- Usage
  - Evaluate proposed security measures for resiliency improvement

Capability Area: Risk Characterization and Data Collection Needs—Distinct from Expert Elicitation

- Data collection and trend analysis to define extent of current and future risk
- Assess data
  - Address data requirements of tools
  - Inference of unavailable data
- Computational tools
  - Integrate multiple disparate data feeds and sources
  - Web-enabled
- Industry and utility partnerships
- Usage
  - Improve understanding of system operation under hazards
  - Monitor current condition and network state

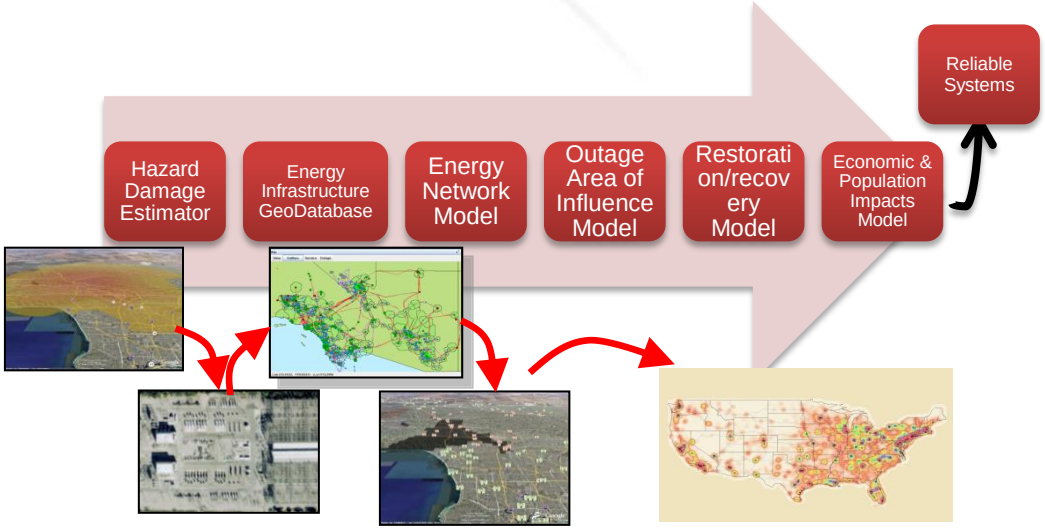
Capability Area: Metrics

- Formalize the definition of distribution system resilience
  - Focus on ability of system to meet power needs
  - Tightly connected with expert elicitation
  - Driven by PPD-21
- Examples
  - Time to restore service
  - # of critical services without power
    - Hospitals, police stations, etc.
  - # of customers without power
- Usage
  - Evaluate/Improve recovery plans
  - Evaluate/Select system upgrades



Capability Area: Pre-Event Modeling

- Vulnerability modeling
  - Monte Carlo methods for predicting damage
  - Outage modeling
  - Both natural and man-made
- Distribution system modeling and simulation
- Resource planning
  - Inventory assessment
  - Personnel scheduling/management
- System design
  - Upgrades and hardening
  - Redundancy



DHS/NISAC Pre-event process model example

Capability Area: Post-Event Modeling

- Situational Awareness
  - Dashboards, component status
  - Geo-referenced visualization
  - Data Integration
- Recovery
  - Emergency operations
  - Restoration
- Impact assessment
  - Economic activity
  - Population at risk
  - Critical facilities

Capability Area: Test Systems

- Develop platforms for testing components
  - Utility and Industry partners
  - National Lab onsite test beds
- Damage modeling
  - Build empirical and statistical models of component response to stressors
  - Small-scale system response to stressors
- Control modeling
  - Test out-of-normal conditions control configurations

Conclusions

- Considerable interest in topics related to resilience
  - Resilience of distribution grid systems has received less attention than other sectors

- Goals
  - Identify unique aspects of distribution systems that requires new capability development
  - Leverage and expand existing resilience capabilities to include distribution systems