Energy Delivery Resilience: Safety, Reliability, and Recovery

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Dominion Energy Profile

One of the nation’s largest producers and transporters of energy.

- 15,000 miles of natural gas transmission, gathering and storage pipeline
- 1 trillion cubic feet of natural gas storage operated
- 2.3 million natural gas customers in 5 states
- 2.6 million electric customers in VA and NC
- 6,600 miles of electric transmission
- 26,200 MW of electric generation (includes ~765 MW of solar generation)
- Atlantic Coast Pipeline (subject to regulatory approval)
- 1.4 million non-regulated retail customers in 17 states (not shown)
Maintaining Safety, Reliability and Resiliency Among Today’s Electric Grid Challenges

- **Natural events**
  - Hurricanes, tornadoes, derecho events
  - Geomagnetic disturbances
  - Earthquakes
  - Polar vortex

- **Man-made events**
  - Terrorism (physical/cyber)
  - Electromagnetic
  - Copper theft

- **Changing location and mix of generation**
  - Planning horizon is reduced causing less time for construction of long-term solutions
Key Considerations for Recovery

*Customer Expectations for extreme events*

- **Transmission Restoration**
  - Network integrity is initial focus
  - Must provide offsite power to nuclear plants

- **Transmission service to Distribution substations**
  - Provide power within 3 days (Customers’ accept)
  - Provide power within 5 days (Customers’ not happy)
  - Provide power greater than 7 days (Utility has failed mission)

- **Dominion looks for 7 days as Maximum transmission restoration for ALL events – Natural or Man-made**
Resiliency Strategy: A Layered Approach

Adapting to Escalating Threats
- Cyber Attacks
- Physical Breaches
- Extreme Weather
- The Unknown

Mobile Substations

DOMINION RESILIENCY STRATEGY

ASSESS
PREVENT
RECOVER
DETECT

HEMP and Cyber Security Protection
Operations and Design Philosophy

Short Term Design Avoidance Economic Needs

Long Term Mitigation Fast Recovery Regulatory Responsibility
Take Advantage of Worldwide Experiences

Engineers Active with IEEE and CIGRE
Natural Disasters
Building for Resiliency
Earthquakes

*Understand potential and prepare accordingly*

- Work with USGS to develop hazard potential map
- Based on potential - modify designs to reduce potential for damage
  - Resin Impregnated Bushings
  - Seismic Battery Racks
  - Review Control Building design
  - Replace certain electromechanical relays with digital relays
Hurricanes / Flooding

Preparation In Advance

- Use of NOAA Slosh Model to develop flood potential maps
- Elevate critical equipment during facility upgrades using this data
- Prepare with temporary measures such as temporary barriers
Short Term Mitigations
Long Term Flooding Evaluation

Substation Locations are evaluated for the timeframe of Equipment Design Life
Cold, Snow and Ice

Weather extremes challenges outdoor insulation

1.5 inches of ice
Cold, Snow and Ice

Designs to reduce outage impact

Use of Resistive Glaze Insulators
Or Stepped Shed Designs

Gas Insulated Switchgear mounted indoors
Extreme Winds

*Tornadoes, Hurricane, Derecho events*

- **Harden designs**
  - Control enclosures to handle 120+ MPH wind
  - Use of Steel or Concrete transmission structures with additional wind loading criteria
- **Insulation designs**
  - Use of redundant insulation for critical crossings
  - Use of polymer insulators
  - Consider contamination impacts for coastal environments
# Substation Design Vulnerabilities

**Design to reduce outage risk – Eliminate Single Point Vulnerability**

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Physical Hardening Risk Assessment Modeling
Introduction

Models – A Critical Step

- Models needed to define resiliency risk
- Models provide clarity to stakeholders of need
- Existing Models are too cumbersome for the future we now face
- Dominion Engineers worked with Oak Ridge National Laboratory and PJM Interconnection to develop a new Resiliency Model that has been shared with the industry.

EVENT
Natural or Man-made

Immediate Collapse
(Instability)

No Immediate Collapse
(Solution found)

CASCADING

Uncontrolled Separation

Collapse
(Instability)

No Cascade

Cascading is the catalyst to determine instability and uncontrolled separation
Physical Security
Physical and Cyber Security at Key Locations

- Perimeter barriers
  - Anti-cut, anti-climb, anti-ram, IEMI benefits
- Ballistic protection
- Increased electronic surveillance
- Latest in cyber security controls, systems and network operations
- Layered protection at substations for EMP/IEMI hardening
- Fleet of mobile equipment for rapid restoration of service
Dominion Energy’s New System Operations Center

Now OPERATIONAL!

- Resiliency and hazard mitigation part of core design
- Design and performance requirements
  - Simplicity and flexibility
  - Standards:
    - Uptime Tier Levels, TIA-942
    - LEED
    - Physical and cyber security
    - Hardened for earthquakes, tornadoes and EMP
Electromagnetic Pulse (EMP)
Background on EMP and IEMI

• **High-altitude Electromagnetic Pulse (HEMP):**
  Partnering with EPRI on project P34.114: “EMP Grid Resiliency: Transmission Vulnerability and Mitigation” to continue the academic and industry research to understand the characteristics of HEMP, and its impact to power systems, communication systems, and transportation systems.

• **Intentional Electromagnetic Interference (IEMI):**
  Partnering with EPRI on project P37.114: “Physical Security and EMP/IEMI” to study the impact of IEMI to electric substations and the best mitigation strategies.

• **EPRI introduction video of EMP project:**
  [https://www.youtube.com/watch?v=D31RFJ00sd8&feature=youtu.be](https://www.youtube.com/watch?v=D31RFJ00sd8&feature=youtu.be)
Dominion Energy EMP Mitigation

• Large Power Transformers designed for GMD / EMP withstand
• Digital protection & control systems designed for greater transient withstand
• Lightning protection on our T&D systems help with EMP
• Primary distribution voltage of 34.5kV is less susceptible to insulator damage from EMP event
• Additional transmission mobiles and spare power transformers geographically spread to speed restoration, if needed
• New System Operating Center hardened for EMP
Geomagnetic Disturbances (GMD)
Dominion Energy GMD Mitigation Plan

Provides EMP-E3 Protection

Situational Awareness

- NOAA Space Weather Scales
- Situational Awareness System
- DVP GIC Visualization Tool
- Real Time Harmonics Alarm

Operations

Dominion’s GMD Operational procedures follow:

- DVP SOC EMER002: Solar Magnetic Disturbances Procedures
- PJM Manual 13, Section 3.7: Emergency Operations
- NERC Standard EOP-010-1: Geomagnetic Disturbance Operations
- NERC Standard TPL-007-1: Transmission System Planned Performance During Geomagnetic Disturbances
Dominion Energy GMD Mitigation Plan

Provides EMP-E3 Protection

GIC Study and Modeling

- GIC mapping and power flow
- Event analysis from real-time monitoring data
- Transformer thermal assessment with consideration of local enhancement

Equipment Enhancement

- Improved EHV transformer design & manufacturer testing
- Improved capacitor bank protection scheme
- Future: On-site test on DE’s EHV transformers
- Transmission Mobile Transformers
Industry Collaborations

Geomagnetic Disturbances

- Sitting on the NERC TPL-007 GMD Standard Drafting Team
- Sitting on the IEEE GIC Working Group
- Collaborating with USGS on GMD forecasts, and 3-D ground conductivity modeling and its implementation in GIC calculation
- Collaborating with NOAA on using a refined method to generate 1-sec resolution geo-electric field data from Fredericksburg, VA
- Collaborating with NASA on measuring local geomagnetic events via monitoring device near our Electric Transmission lines
- Collaborating with EPRI on SUNBURST GIC monitoring program
Recovery and Restoration
Protected Storage Facilities

Three new protected regional storage facilities for emergency materials for faster response
Mobile Substations

Attributes and benefits

• Dominion Energy’s mobile substation includes standardized protection packages to allow for simple integration with existing protection schemes.
  • Temporary deployments enjoy same reliability as permanent installations.

• Dominion Energy’s mobile substation is modular and can be used individually.
  • A breaker failure or loss of a single phase transformer can be resolved in a fraction of the time using just the breakers or single phase units of the mobile fleet.

• Our underground cable links allow for a large array of connections to be made – minimizing our need for disruptions to the surrounding environment and maximizing safety to personnel and the public.

• Mobile substations are a component of Dominion Energy’s layered resiliency strategy.
Mobile Equipment: Versatile and Adaptable
Mobile Equipment and Mobile Substations

Connecting to the Grid

- Rapid restoration of service (equipment and design)
- Unusual/emergency system conditions
- Provides additional flexibility