TVA’s Grid Resiliency Direction

Clayton Clem, Tennessee Valley Authority
VP Transmission Strategic Projects & Initiatives
Update June 18, 2018
Tennessee Valley Authority

• Created in 1933 by the TVA Act
• A federally-owned, self-financed corporation
• Mission: Provide navigation, flood control, electric power, and economic development in the Tennessee Valley region
• Largest public power system
• Service Area:
  o Parts of 7 states
  o 80,000 square miles
  o 9 million people
• Primarily a wholesaler of power serving distributors and large industries.

What We Manage
• 16,194 miles of lines
• 513 substations.switchyards
• 104,275 transmission structures on 237,398 right-of-way acres
• 1,321 individual interconnection & customer connection points
• 2,700-mile fiber network

to deliver
• 33,500 MW peak load
• 155 x109 kWh
Transmission Grid Resiliency

**reliability** - the ability of the system and its components to withstand instability, uncontrolled events, and cascading failures, during normal operation and routine events*

**resiliency** - the ability of the system and its equipment and human components to minimize damage and improve recovery from non-routine disruptions, including high impact, low frequency (HILF) events, in a reasonable amount of time*

Resiliency is an essential element for grid owners and operators as responsible custodians of the public trust.

Key Elements are:
- Design standards
- Operating procedures
- Emergency planning
- Emergency inventory
- Restoration Activities

* From NATF
Transmission Grid Resiliency

16 Critical Infrastructure Sectors: all depend on electricity.

Our industry has changed

• Public expectations have changed.
• Excess transmission capacity is largely gone.
• We don’t have the same workforce.
• Challenges to resiliency today are much broader.

Natural or human events can cause much more severe damage in a densely developed modern infrastructure. Even if unlikely, risks must be considered.

Recent examples:
- Hurricane Sandy
- Fukushima
- Malware, ransomware (Iran, Ukraine, UK)
Transmission Grid Resiliency

Worst storms in U.S. history

<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Category</th>
<th>Deaths</th>
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<tbody>
<tr>
<td>1. Galveston Hurricane</td>
<td>1900</td>
<td>4</td>
<td>8000</td>
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<tr>
<td>2. Lake Okeechobee</td>
<td>1928</td>
<td>4</td>
<td>2500</td>
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<tr>
<td>3. Maria</td>
<td>2017</td>
<td>5</td>
<td>1500 (?)</td>
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<tr>
<td>4. Katrina</td>
<td>2005</td>
<td>3</td>
<td>1200</td>
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<td>5. Cheniere Caminanda</td>
<td>1893</td>
<td>4</td>
<td>1100-1400</td>
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Costliest

<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Category</th>
<th>Damage (U.S.)*:</th>
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<tr>
<td>1. Katrina</td>
<td>2005</td>
<td>3</td>
<td>$161 billion</td>
</tr>
<tr>
<td>2. Harvey</td>
<td>2017</td>
<td>4</td>
<td>$125 billion</td>
</tr>
<tr>
<td>3. Maria</td>
<td>2017</td>
<td>5</td>
<td>&gt;$90 billion</td>
</tr>
<tr>
<td>4. Sandy</td>
<td>2012</td>
<td>3</td>
<td>$71 billion</td>
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<tr>
<td>5. Andrew</td>
<td>1992</td>
<td>5</td>
<td>$46 billion</td>
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Source: NOAA Hurricane
Underground Source:
Transmission Grid Resiliency

Recent Legislative, Regulatory, Government Publications following Sandy (2012)

• 2013 - The Oregon Resiliency Plan, Washington State Resiliency Plan
• 2013 - Maine Act to Secure the Safety of Electrical Power Transmission Line
• 2014 - NERC Reliability Leadership Summit (September 11, 2014) “Preparing for the Worst (Resiliency & Recovery)”
• 2014 - NATF & EPRI proposed a model for utilities to use in October 2014.
• 2015 - TVA utilizes NATF format for Grid Resiliency Story
• 2015 – National Electrical Safety Code Summit discusses resiliency
• 2015 - NIST, Community Resiliency Program
• 2016 - FAST Act
• 2016 - The National Defense Authorization Act (NDAA) for Fiscal Year 2017, H.R.4909
• 2016 – DOE, EPRI: Joint Electromagnetic Pulse Resilience Strategy
• 2016 – DHS: EMP Protection and Restoration Guidelines for Equipment and Facilities
• 2017 – DOE: Transforming The Nation’s Electricity System: The Second Installment Of The Quadrennial Energy Review
• 2018 – DOE: Grid Security Emergency Orders: Final Rule
Transmission Planning Strategy – Resilient

Essential part of being responsible custodians of the public trust as grid owners and operators

- State Public Service Commissions establishing emergency response scorecards for Preparation, Response, and Communication

- Transmission & Power Supply Role - Assess/Harden/Recover

Assess TVA Exposure Across Wide-Range of Events

- Cyber Attack
- Earthquake
- Electromagnetic Pulse*
- Gas-Electric Interdependency
- Geomagnetic Disturbance*
- Major Equipment
- Physical Attack
- Severe Flooding
- Severe Storms
- Single-Point Failure
- Workforce & Support
- Community Resiliency

* Elected officials and state government showing great interest based on public health impacts. Multiple meetings held with Tennessee officials.

12x12 interactive matrix linked reference material for rapid access reference for knowledge transfer
## Interactive

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<tr>
<th></th>
<th>CYBER ATTACK</th>
<th>EARTHQUAKE</th>
<th>EMP</th>
<th>GAS ELECTRIC INTERDEPENDENCY</th>
<th>GMD</th>
<th>MAJOR EQUIPMENT</th>
<th>PHYSICAL ATTACK</th>
<th>SEVERE FLOODING</th>
<th>SEVERE STORMS</th>
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SEVERE STORMS – Overview

The Tennessee Valley Authority has transmission facilities in seven states in the Southeastern United States. The climate in general is mild with neither extreme heat or cold. However, the Tennessee Valley lies in the middle third of the United States that is prone to severe tornado activity, as shown in the map below. Parts of the valley, also receive significant accumulations of ice on a regular basis that can disrupt the transmission system.

The Transmission Engineering group has assessed the storm events that have occurred in the Tennessee Valley and have developed specific loading criteria above the National Electric Safety Code (NESC) requirements to prevent and minimize the potential of severe storm damage. The historical TVA severe storm data provides insight into strategic methods of hardening the transmission system.

Weather and transmission alerts are issued when damage or derates to TVA and/or TVA Partners, Local Power Companies (LPC) or members of the TVPPA has occurred. The Transmission group considers a storm severe when damage has occurred in more than one Transmission Service Center. At this point, the Transmission Emergency Operations Center (TEOC) will become activated, so that resources can be planned to restore the transmission system at a system level. Members of the emergency team from operations and maintenance, planning, telecommunications, logistics, public communication, finance and safety congregate in the TEOC to make strategic decisions.
Cyber Attack

Problem:
Potentially system-wide, unexpected loss of communication and control, possibility of equipment damage

Response:
• Defense in depth
• Procedures – NERC CIP, NIST/FISMA
• Continuous monitoring 24/7
• Security monitoring (internal / external, system integrity)
• Incident Response and Recovery plans / Drills
• Vulnerability Scans and Assessments
• Equipment reviews
• Audits, assessments & revised protocols
• Partner with federal, state and local law enforcement & key industry security groups such as E-ISAC

Reported attacks are escalating – energy sector is an obvious and strategic target
Cyber Attack

- Cybersecurity threats are increasing in number, sophistication, and consequences.

- Electric utilities and government agencies are popular targets.

- Attacks can have cascading effects, disrupting public safety, government, and business.

- TVA has a comprehensive cybersecurity program in place that proactively helps predict, protect, detect and respond, focused on being proactive and risk-based rather than simply compliant with regulations.

- The program includes multi-tiered threat analysis capability, continuous monitoring, penetration testing, and vulnerability assessments.

- Critical systems are housed within an isolated network, separated from corporate networks and inaccessible from the internet.

- TVA partners with other government agencies, such as FBI, Department of Homeland Security and Department of Energy.

- TVA adheres to the following Federal and industry regulatory standards:
  - North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) Standards
  - Nuclear Regulatory Commission (NRC) Cyber Security Requirements
  - Sarbanes-Oxley Act (SOX)
  - Federal Information Security Management Act (FISMA)
  - Federal Privacy Regulations
Earthquake – New Madrid & East Tennessee Seismic Zones

**Problem:**
Potentially widespread, unexpected, coincident damage (water, transport, injuries), involves equipment with long replacement times.

- USGS estimates 1811-1812 event has a 7-10% probability in 50 years.
- M6 has a 25-40% probability in 50 years.

**TVA Response:**
- Tie-down large power transformers
- Structurally harden masonry switch houses to provide two 500-kV and one 161-kV paths back into Memphis / West TN area.
- Replace old equipment with seismically resistant.
- Revise procurement specifications to require seismically qualified equipment.
- Shake table tests on a 500-kV transformer bushing to determine resiliency and conductor slack for bus connection.
Earthquake – Hardening the Switch Houses (Weakley)
Earthquake – Hickory Valley 161-kV Switch House Enhancements

Original

Enhanced

During Construction
Earthquake – Other Enhancements & Mitigation
Earthquake – Maintaining Sources Into Memphis / West TN

Switch House Enhancement Projects

500-kV:
• Cordova - In Progress
• Shelby – Complete
• Weakley – Complete

161-kV:
• Hickory Valley 161-kV – Complete

* Note: Cordova, Shelby, & Weakley 500-kV Substations are located in higher seismic zone
Problem:

- Potentially widespread injection of Geomagnetic Induced Current (near-dc) causing harmonics and overheating of transformers. There will be reasonable notice of impending storms (new DSCOVR satellite) but magnitude always imprecise.

TVA Response:

- Operating procedures to ensure operator awareness
- Replaced vulnerable relays on capacitor banks
- Network of >12 Sunburst detectors and 12 magnetometers
- Research blocking device design
- Modelling and assessment of 144 500-kV transformers for saturation and heating
- GIC system model and studies in advance of TPL-007-01
- Review transformer temperature monitoring
- Plan operating response for extreme events
GMD – Planning for >1/100 Year Storm

Presently expect no problems for 1/100 storm
- Studies to date show only one TVA location over 8 V/km benchmark, 3 more at extreme levels.
- Theoretical maximum storm presently unknown. TVA studies up to system collapse are in agreement with EPRI EMP E3 studies.

Current Issues
- Participate in NERC/EPRI R&D project, contribute communications hardware
- Validate system models from GIC and field measurements
- Implement magnetometer network to obtain storm field dynamic structure
- Implement real time system monitoring
- Assist with response to FAST Act/DOE Final Rule

Future Schedule
- Evaluation of harmonics and extreme VAR effects
- Develop advanced procedures for operations
- Prepare for next storm cycle peak ~ 2025
# GMD – Recent Experience from EPRI Sunburst System

<table>
<thead>
<tr>
<th>Date</th>
<th>Sites &gt; 10A</th>
<th>Max GIC</th>
<th>TVA Reading</th>
<th>NOAA K</th>
<th>Sudden Imp</th>
<th>Mag Var</th>
<th>Cause</th>
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<td>Sept 7-8, 2017</td>
<td>5</td>
<td>-29.4A Meadowbrook (VA):</td>
<td>Montgomery (TN): -15.4A to 17.8A</td>
<td>K-8</td>
<td>70</td>
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<td>July 16, 2017</td>
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<td>February 17, 2016</td>
<td>2</td>
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<td>3</td>
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<td>5</td>
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<td>6</td>
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GMD – NERC/EPRI R&D Project

- Work is underway on all Order No. 830 research objectives
- Support TPL-007 standard
- EPRI will publish technical reports for each objective
GMD – FAST Act

• DOE Grid Security Emergency Final Rule of Jan 10, 2018

• The statute authorizes the Secretary of Energy to “order emergency measures, following a Presidential declaration of a grid security emergency, to protect or restore the reliability of critical electric infrastructure or defense critical electric infrastructure during the emergency.”

• Applies only to cyber, physical, and EMP attacks, severe Geomagnetic events. NATF group developing suggested templates for Grid Security Emergency Orders starting with GMD.

• Initiating event would be unusually severe coronal mass ejection observation. Prior to arrival at earth severity is uncertain.

• Existing notification process from NOAA would be supplemented by notification from Secretary for potential emergency events. Since severity is unknown prior to CME impact, warning would permit relaxation of operational regulatory constraints as noted in the statute.

• Existing TVA Operating Procedures include use of Conservative Operations in the event of advance warning – will be extended.
GMD – FAST Act - Conceptual Announcement from Secretary for Energy

“An unusually severe CME has been observed moving towards the earth that may have the potential to affect the electric grid beyond NERC Planning guidelines. Grid operators should consider transitioning to a GMD-resistant conservative mode. When this CME impacts the earth, if predicted or actual fields* exceed (add parameters – V/km, nT, K) then any operations deemed necessary to protect essential equipment which may result in interruptions to electricity supply shall not be subject to NERC Regulatory penalty.” (list relevant standards)

*prior to latitude and ground resistivity adjustments

Conservative Operations for Anticipated Severe GMD

• Halt planned outages & maintenance
• Commence emergency load curtailment
• Increase spinning reserve
• Notify nuclear stations to be prepared to go on diesels
• Notify personnel to man blackstart stations and substations along blackstart paths.
• Man 500kV substations
• Open emergency centers
• Notifications – LPCs, other
• Open communication with State
EMP and IEMI

The Problem:

A high altitude nuclear weapon interacts with the atmosphere and magnetic field to cause a very high electric field over a wide area.

The electric field has the potential to damage low voltage equipment and electronics.

Changing Environment:

New players with attack capabilities, evolving technology has increased vulnerability.


Possible Consequences:

All critical infrastructure that is dependent on electricity is at risk. Potentially very widespread, unexpected, coincident damage (water, transport, communications).

There are many unknowns regarding the effects of EMP on existing infrastructure.
**EMP and IEMI**

**Planning Issues:**
- It is impossible to shield or harden the entire power grid against widespread radiation.
- Nothing will be possible without adequate communications.
- The EM Pulse can be considered in components E1-E2-E3. E2 and E3 should be largely addressed with GMD and lightning protection although precursor E1 may be an issue.
- A likely scenario following HEMP is a widespread blackout and loss of communications. It will also be difficult to recognize what equipment is non-functional. Heavy transmission equipment is likely to survive but electronics and LPC equipment may not. Distribution system damage is a concern but critical load locations are being documented.
- There are many unknowns including the effects on complex structures such as power plants. The EPRI Project is quickly improving understanding and guidance for system resilience.

**TVA Response:**
- It will be essential to restore power to crucial loads quickly to essential needs. (military, nuclear plants, water and sewer). Coordination with State emergency actions will be an issue.
- Core essentials must be available for system restart (black start generators & lines) with priorities for supply to new normal. Plan to use hydro and limited hardening as a nucleus for rebuilding. Pre-plan emergency operating parameters.
- Short term: ensure emergency communications capability, coordinated plans to restart from basic resources. Establish shielded spares for test, communication, protection.
- Longer term: evolution to hardened design – switch-houses, shielded cables, hardened electronics, shielded key facilities (fiber network, operating center, diesels).
- EPRI Project includes relay and communications equipment EMP testing.
EMP and IEMI - EPRI EMP Project

Reports to date:
- MHEP Assessment of Continental US Grid – GIC & Transformer Thermal Analysis
- MHEP Assessment of Continental US Grid – Voltage Stability Analysis
- Guidelines for Hardening Bulk Power Systems Against MHEP
- Systems Requirements for EMP Hardened Mobile Control Centers
- HEMP Protection of Substation Control Houses
- MHD-EMP (E3) Assessment of the Continental U.S. Electric Grid: Voltage Stability Analysis
- E3 Fields for Benchmark Scenarios: Los Alamos National Labs
- HEMP E1 Testing of Power System Protection Relays

Near-term:
- HEMP E1 Testing of Power System Protection Relays
- Coupling of Early-time HEMP Into Above Ground Conductors
- Effects of HEMP on the BPS and Potential Cost-Effective Mitigation Options.
EMP and IEMI - EPRI EMP Project – Radiation & Direct Injection Testing

RS-105
Charlotte, NC

Direct Injection
Knoxville, TN
EMP and IEMI - Strategic Fiber Initiative

Scope: Up to 3500 Miles of additional fiber*
Cost: Up to $300 Million*
Schedule: 5-10 Years

*Subject to yearly review, approval of routes, and necessary environmental reviews

- Increases communication paths across the TVA system to add redundancy and diversity of location
- Enables ongoing communication during an emergency event
- Enhanced visibility, physical and cyber security, and control
- Enhanced reliability of transmission system
Problem:
Gas supplies are vulnerable to source disturbance (Katrina), pipeline damage, alternative demand due to cold weather

- Importance to TVA:
  - Gas generation (CC & CT) 9.95 GW capacity – most with dual fuel
  - 10% of TVA energy in 2005, 23% in 2025
  - 10 pipeline companies, 65 pumping stations (16 electric powered)

TVA Response
- Use of firm delivery options
- Interaction studies – large generating plant loss (alternative fuel makeup), pipeline loss (pipeline redundancy, dual fuel, storage)
- Assess individual supply to electric-powered pumping stations, restoration priority
- Recent: EIPC, NERC, current national studies
Gas-Electric Interdependency

Operational awareness used to prioritize restoration efforts
Problem:
Large equipment is vulnerable to physical and electrical disturbances, difficult to relocate, requires a long time to repair and replace.

TVA Response:
• Appropriate seismic requirements specified for major equipment per IEEE 693 (ex. power transformers, circuit breakers, instrument transformers)

• Wind loading requirements and regional ice loading requirements for specific major equipment and interconnected bus work and insulators.

• Provide slack in jumper connections to transformer bushings for seismic movements
Major Equipment

Standardization enables a robust transformer spares program

• 2003 - TVA did a fleet wide transformer assessment.

• Established a standardized replacement program with limited replacement designs

• Designs can be manufactured in multiple factories worldwide.

• Over 10 years of transformer standardization

• Over 90 Alpha and Bravo Class standard transformers

• Used for replacement and all new stations

• Makes transformers across the fleet interchangeable

• Provides a significant number of system spares

• Makes our extensive spare inventory useable fleet-wide

• Studies add ability to exchange some dissimilar transformers as well.

Micafil RIP Bushing on Transformers

• Limits damage if the transformer blows up

• Better for taking on gunfire

• Does not launch or explode like Porcelain
Standardization enables fast restoration after loss of 500-kV or 161-kV station.

- Simplifies Restoration Emergency Inventory
  - 500-kV Vertical Reach Switches
  - 500-kV Voltage Transformers (VT)
  - Coupling capacitor VT (CCVT)
  - Wavetraps
  - 161-kV Power VT (PVT) for station service
  - 4000 A, 0.22 ohm Reactors
- Temporary control houses in shipping containers
- Mobile transformers and mobile GIS switch gear
Major Equipment

Transformer Threat Study.

• Phase 2 of DOE evaluation study*
  o Considered all 500kV transformers (6) and spares lost within 30 miles of Nashville
  o Number and location of replacement transformers for initial (3) and then complete restoration
  o Adequate oil treatment and transport equipment available in-house
  o Physical transport will require contractor assistance
  o Physical condition of road bridges, railway sidings a dynamic issue
  o Limited road and rail transporters

• Recommendation to include special transporters in Infrastructure Act

• Review of highway transport permissions and priorities

* Phase 1 Study found adequate spares available
**Physical Attack**

**Problem:**
Electric power grid facilities are widely dispersed and very difficult to protect against physical attacks. Damage to critical substations potentially could trigger cascading outages.

**Response:**
- Implemented plans for requirements of ES-ISAC Aurora advisory, NERC CIP-002 – CIP-011, CIP-014
- Physical & process barriers for detection, intrusion and tampering
- Card readers, alarm contacts, video monitoring, etc.
- Enhanced camera installation with analytics & 24x7 monitoring
- TVA Police & local law enforcement coordination
- **Installed higher, anti-cut, anti-climb, anti-ram fencing**
Physical Attack

CIP-014-2:

- Automation tools used to evaluate multiple methodologies to determine cascading scenarios.
- Each methodology simulated the total loss of a substation as a result of a physical attack in steady-state and dynamic analyses.
  - Three-phase faults at all voltage levels at a substation isolated remotely with normal clearing
  - Single-phase faults at all voltage levels at a substation isolated remotely with delayed clearing
- Instability & cascading criteria determined by internal analysis and industry benchmarking which align with NATF survey results.

Response:

- Implementing protection scheme modifications at all critical stations to remove potential for cascading
Problem:
- Extreme weather can cause flooding and threaten grid equipment. Example: 15 inches of rain in 2 days of May 2010 caused a river crest 25.5 feet above flood stage.

Response:
- Transmission assets reviewed using FEMA flood data as layers in TVA GIS map
- Multiple Flood Hazard scenarios were considered including:
  - 1% annual chance (100 year flood)
  - Regulatory floodway
  - Special floodway
  - 0.2% annual chance (500 year flood)
  - Future conditions 1% annual chance
  - TVA’s Zone A Probable Maximum Flood for the Tennessee River
- Relocate assets to areas that will not flood. In the example above, a 161-kV substation was relocated.
Flooding – Nashville 2010
Flooding – TVA Substations Located Within FEMA Flood Zones
Storms

Problem:
• Extreme weather including tornadoes and ice storms can cause mechanical loads on substations and transmission structures to exceed design limits.

Response:
• Maintain and mobilize crews in advance, anticipate communication and support requirements (food, lodging) during restoration.
• Replace wood poles with steel for new construction and preventive maintenance, use robust alumoweld shield wire. Apply icing criteria to minimize faults when re-energizing.
• Developed steel inventory plan for restoration utilizing a limited number of standard TVA tower types to reduce inventory.
• Collaboration with the U.S. Army Cold Regions Research and Engineering Laboratory to create the Region 2 Ice Maps as basis for NESC 250D - Extreme Ice.
Storms - February 8-12, 1994 Ice Storm
Storms - Kentucky Ice Storm 2009
Tornadoes of April 2011

153 tornados
109 lines
351 structures
11 generation plants
128 customer connections
850,000 customers
Emergency Spares and Inventory

Several national efforts around spares

- Inter-utility agreement (TVA Joined 1996)
- NERC (Cancelled at the Spring 2017 NERC PC meeting)
- STEP (EEI driven post 9/11 attack effort)
- RESTORE (Southern Company driven)
- GRID ASSURANCE (For Profit)
- DOE Transformer Threat Evaluation

TVA Programs:

Structural – Plan initially developed in 1990s
Conductor – Long lead core wire is stocked for emergency processing
Major Equipment –
  Transformer standardization
  Major Equipment availability at EHV level - In revision
Emergency Spares and Inventory

**Major Equipment Philosophy**
Maximize recovery capability
Include Transmission Substations and Generating Plants
Need is not hypothetical – historical events
  - TVA storm recovery efforts include emergency rebuilding efforts at three 500kV sites
    - East Point – April 2014
    - Freeport – April 2011
    - Limestone – July 2006
New normal for emergency preparedness goes beyond storm recovery. Must consider physical attack

**Our Approach (3 years, ≤$13M)**
Assume loss of switch gear and yard components
Complete rebuild not necessary/possible. Consider just Essential Elements (A line, generator or transformer bank without any additional contingency)
Majority 500kV & 161kV equipment
Plan includes:
  - Five 500kV Breakers
  - Eight 161kV Breakers
  - Three 45MVar Banks of Capacitors
  - Additional supporting/required equipment (VT, disconnect switch, etc.)
Emergency Spares and Inventory

Ability to use one type tower interchangeably to minimize inventory stock

TVA G24 Tower replaces these other TVA tower types in an emergency

- E24
- F24
- G24
- G20A
- F20A
- E29

<table>
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<th>ITEM</th>
<th>DESCRIPTION</th>
<th>OLD QTY</th>
<th>NEW QTY</th>
<th>WEIGHT EACH</th>
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After each storm event the steel stocking plan is reviewed to access potential changes in quantities.
Emergency Spares and Inventory

Conductor Steel Core Stocking Program

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<tr>
<th>Conductor Description</th>
<th>Conductor Compatibility</th>
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<td>IBIS/ACSS/MA3</td>
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<td>397.5 kCM 26/7 ACSS</td>
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<td>GROSBEAK/ACSS/MA3</td>
<td>636 kCM 26/7 ACSR</td>
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<td>636 kCM 26/7 ACSS</td>
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<td>795 kCM 26/7 ACSR</td>
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<tr>
<td>CARDINAL/ACSS/MA3</td>
<td>954 kCM 54/7 ACSR</td>
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<tr>
<td></td>
<td>954 kCM 54/7 ACSS</td>
</tr>
</tbody>
</table>

TVA Standardized Direct-Embed Pole

- Transitioned to steel poles in early 1990s and replaces approximately 1000 wood poles/year
- TVA designed its own direct-embed transmission poles in 2011
- Allows different vendors to build identical poles (same properties and dimensions) for quick emergency recovery
- TVA established contracts with multiple vendors to manufacture.

• Quick emergency delivery by having steel core available to conductor manufacturers
• Flexibility to use one core wire in two different conductor applications
Single Point Failure

Problem:
Protection System single point of failure that causes an adverse impact to the BES

Elements to consider include:

• DC Control Circuitry
• Station DC Supply
• Protective Relays (including auxiliary relays)
• Communication Systems
• AC Current & Voltage Inputs

Response:

• 2007 – IEEE PSRC developed white paper on Redundancy Considerations for Protective Relay Systems
• 2009 – NERC System Protection and Controls Subcommittee released a white paper on Protection System reliability
• 2012 – FERC Order 754 data request required the industry to provide statics for single point of failure vulnerability for Protection Systems.
• 2016 – TPL-001-4 clarified evaluation and mitigation for non-redundant relay failure.
• 2017 – Proposed TPL-001-5 includes Single Points of Failure for non-redundant components of Protection Systems including DC supply and control circuitry; NERC is currently reviewing responses received during comment period.
Single Point Failure

TVA Actions

• TVA has revised design standards to address redundancy inadequacy for…
  o Protection Systems
  o Non-redundant AC & voltage inputs
  o Non-redundant DC control circuitry
  o Two independent DC supplies

• TPL-001-5 high-level screening determined potential impacts of failures of non-redundant components of Protection System failures
  o Mitigation required for P5 events impacting facility’s assuming a single line to ground fault
  o Extreme events, 3-phase faults, require evaluation but not mitigation
  o TVA screening study process uses principles consistent with FERC Order 754 and proposed TPL-001-5
  o Preliminary screening showed need for potential projects to enhance redundancy

• TVA has made a significant effort in recent years to provide redundant Protection Systems on new installations and modifications to existing stations

Next Steps

• Awaiting NERC final approval of TPL-001-5
• Pending approval, finalize analysis and initiate projects as necessary
Workforce/Support

Problem:
The workforce required to respond safely, efficiently, and orderly to a major system interruption or natural disaster will come from various sources. The expertise and experience of internal resources, including safety professionals, will be called upon first to provide engineering, procurement, construction, and oversight services. After assessing and assigning internal resources, additional support may be required.

Response:
• Memorandum of understanding with labor
• Mutual aid and other agreements for support
• Assess and arrange for logistical needs (food, lodging, hygiene, security, traffic control, etc.)
• Fuel sustainability: gasoline, diesel, aviation and propane
• Heavy-haul agreements
• Material and transport
• Heavy equipment support

Low probability high consequence events may overwhelm resource availability.
Community Resiliency

Critical Load Examples

- Chemical
- Commercial facilities
- Communications
- Critical manufacturing
- Dams
- Defense industrial base
- Emergency services
- Energy
- Financial services
- Food & agriculture
- Government facilities
- Healthcare & public health
- Information technology
- Nuclear reactors, materials & waste
- Transportation systems
- Water & wastewater systems
Community Resiliency - LPC Data Sheet for Critical Loads

Criticality Level:
- C1 – Issues with an outage
- C2 – Can ride through 1 day outage
- C3 – Can ride through multi-day outage

<table>
<thead>
<tr>
<th>Criticality Level</th>
<th>Critical Load Name</th>
<th>TVA Delivery Point</th>
<th>Delivery Point Voltage</th>
<th>Critical Load (MW)</th>
<th>Type of Load*</th>
<th>Backup Generator Available?</th>
<th>Comments (Path from DP to Critical Load?)</th>
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</tbody>
</table>

*Motor starting, continuous/intermittent, chemical, communications, etc.
Critical Load Evaluation

Download the LPC Critical Load Evaluation form below. Complete the information and save to your computer using your LPC Name as a prefix to the file name.

Critical Load Evaluation Upload

Put your LPC Name at the beginning of your file
Browse for the file and Submit
Next Steps

- Continue enhancing TVA & State Emergency Services collaboration
- Working with local communities to support community resiliency planning
- Update Enterprise & Transmission Emergency Plans
- Incorporating National Incident Command System
- Grid resiliency activities are being factored into our Regional Strategy Plans connectivity, flexibility & capacity in the grid.

TVA is doing extensive grid planning to assure that we are providing the connectivity and flexibility to meet our mission and serve the 9 million residents of the Tennessee valley.

Resiliency considerations are being factored into our Regional Grid Planning Studies.
Questions?

Email isgrant@tva.gov