Electric Transmission:

A Changing Landscape

Dominion®

Agenda

Dominion Overview

Culture of Reliability Excellence

Electric Transmission Near Term Challenges

Electric Transmission Long Term Challenges

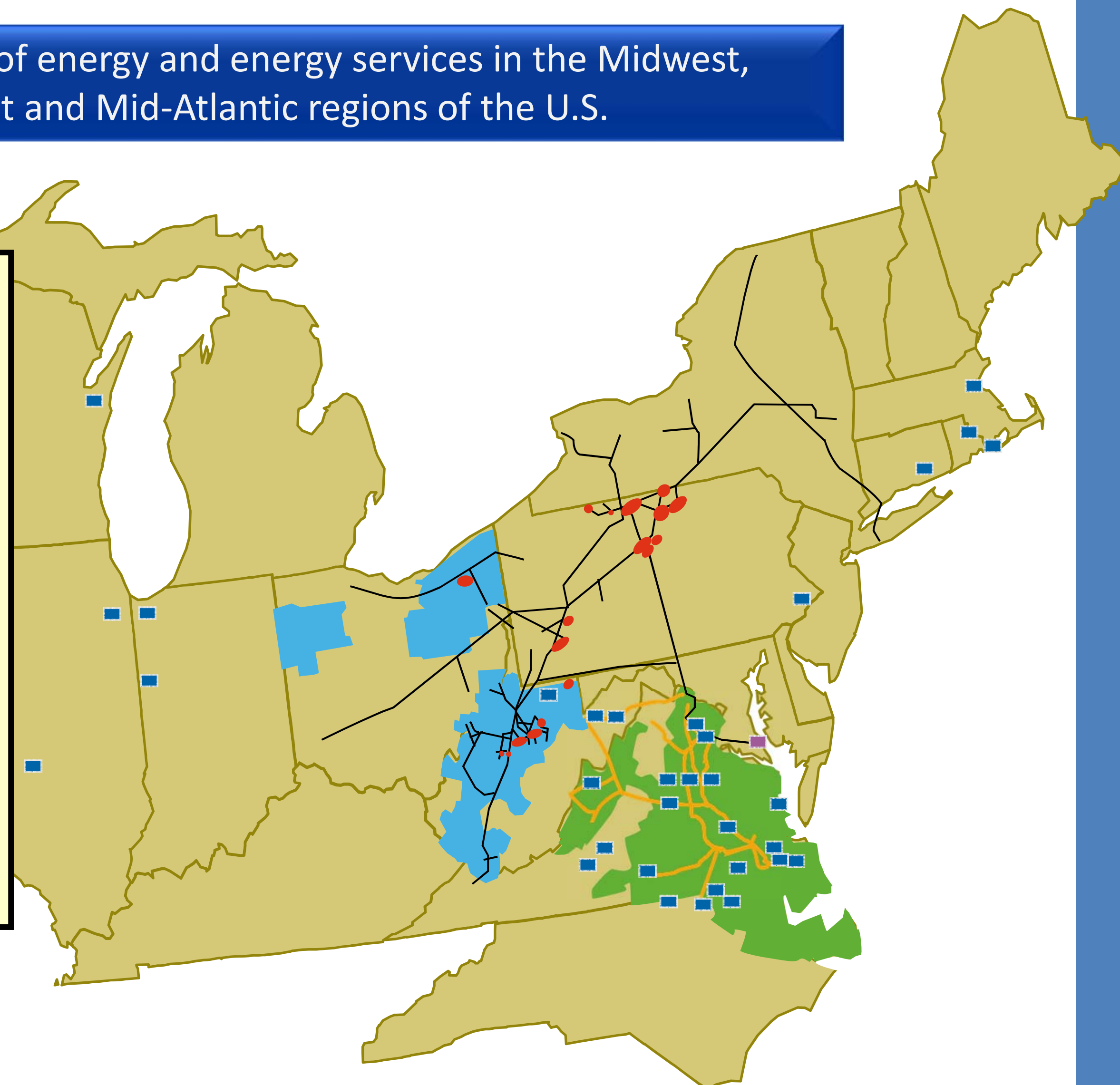
Engineers are Critical to Our Future Success

Dominion Profile

Leading provider of energy and energy services in the Midwest, Northeast and Mid-Atlantic regions of the U.S.

- ~27,600 MW of electric generation
- 6,000+ miles of electric transmission
- 12,000 miles of natural gas transmission, gathering and storage pipeline
- 942 billion cubic feet of natural gas storage operated
- Cove Point LNG Facility
- 2.4 million electric customers in VA and NC
- 1.3 million natural gas customers in OH & WV

2.1 million non-regulated retail customers in 13 states

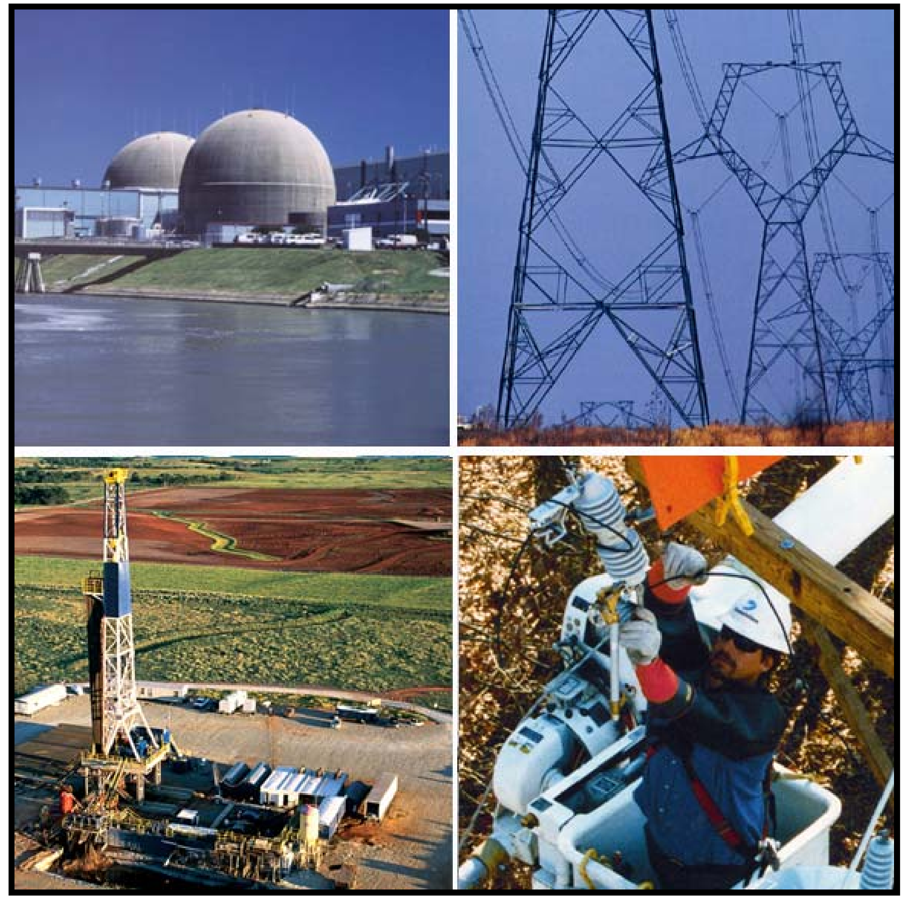


Our Integrated Business Model

Dominion Virginia Power
- Electric Distribution
- Electric Transmission
- Unregulated Retail

Dominion Generation
- Regulated Generation
- Merchant Generation

Dominion Energy
- Gas Transmission
- Gas Distribution
- Producer Services



Culture:
Reliability Excellence

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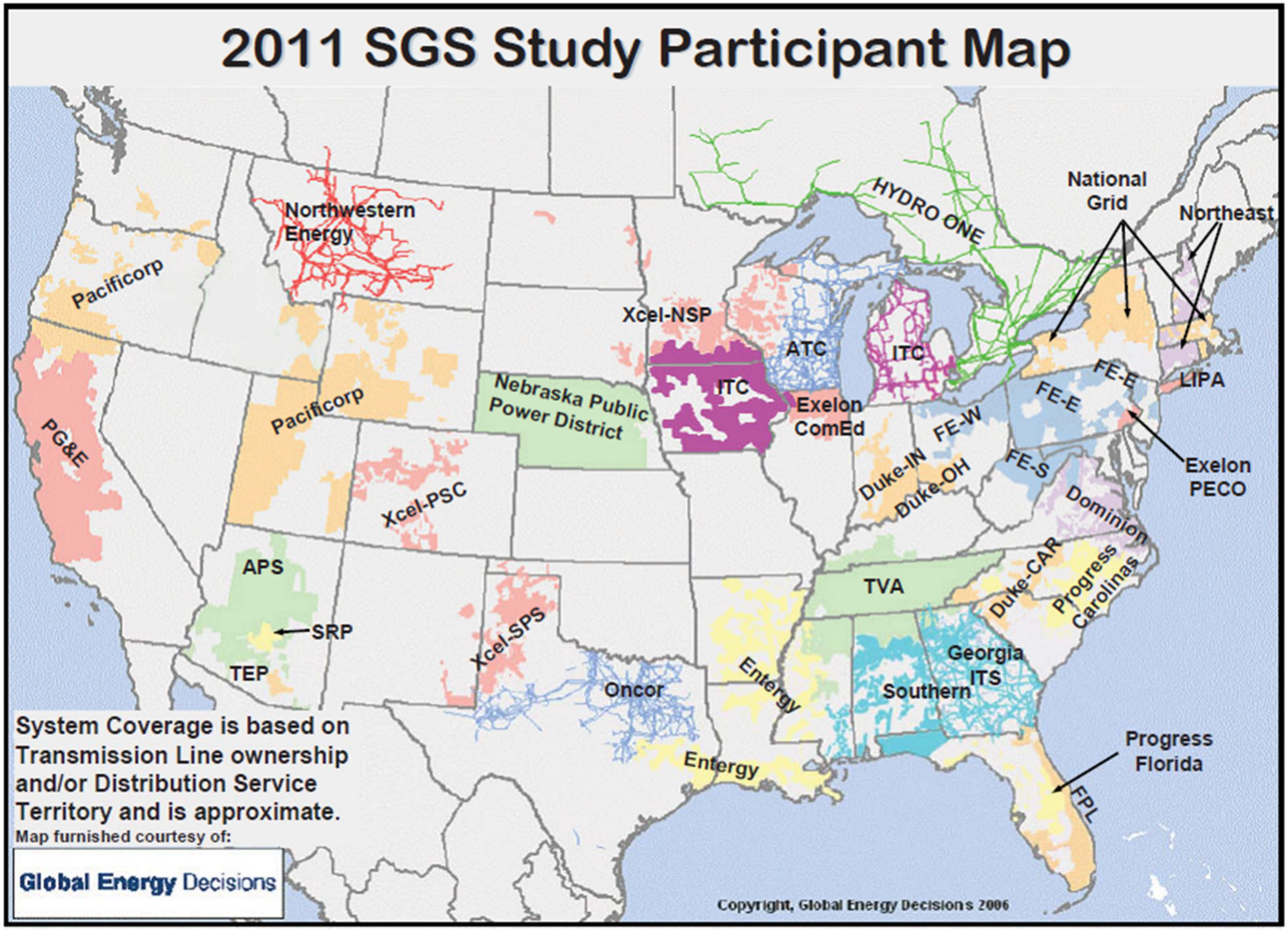
Reliability



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SGS FOHMY-S

(Forced Outages per 100 miles – Sustained)

- No.1 ranking – Last 5 yrs (All voltage classes combined)
- No.2 ranking - 115/138kV & 230kV voltage class (No.1 within peer group)
- 0 outages in 2010 for 500kV voltage class – Best FOHMY-S score for this voltage class

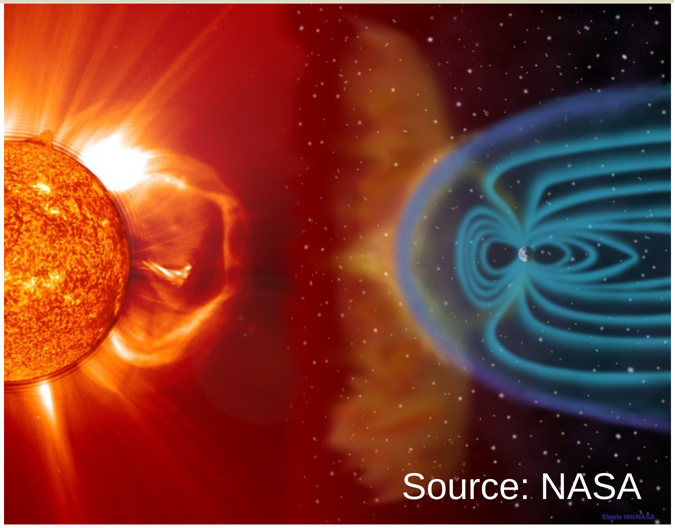
Electric Transmission:
Near Term Challenges

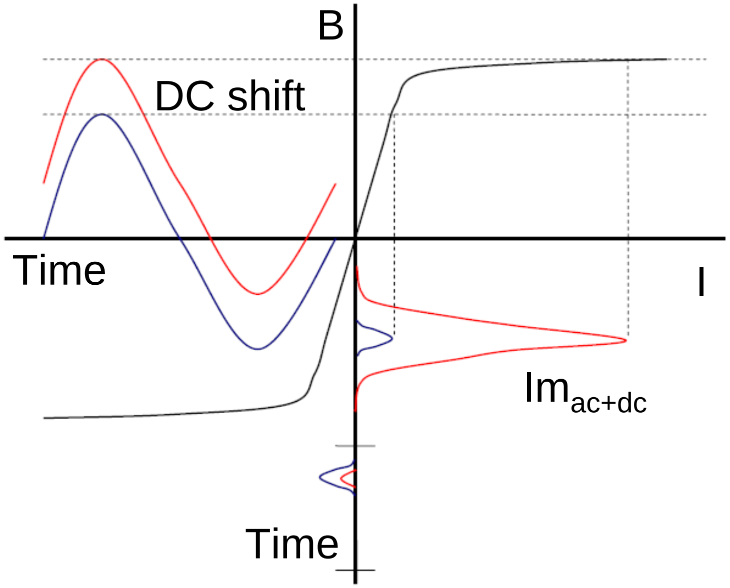
Near Term Challenges (2013 – 2015)

- Potential of solar activity during this time period
- Retirement of significant generation in a short time horizon
- New generation remote from load centers and retired generation
- Increased stability concerns with loss of generation in network
- Increased voltage swings during varying load profiles
- Rapid deployment of FACTS devices
  - electric systems more dependent on proper models
  - Devices depend on proper control algorithms for various conditions
- Transmission System components are approaching end of life and require replacement

Geomagnetic Disturbances (GMD)

- Solar activity approaching the maximum currently predicted for 2013
- Challenges: Geomagnetically Induced Current (GIC)
  - Potential for transformer hot-spots
  - Potential for voltage stability problems
  - System harmonics could increase
- FERC/NERC drafting a new Reliability Standard for GMD





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Geomagnetic Disturbances (GMD): Mitigation

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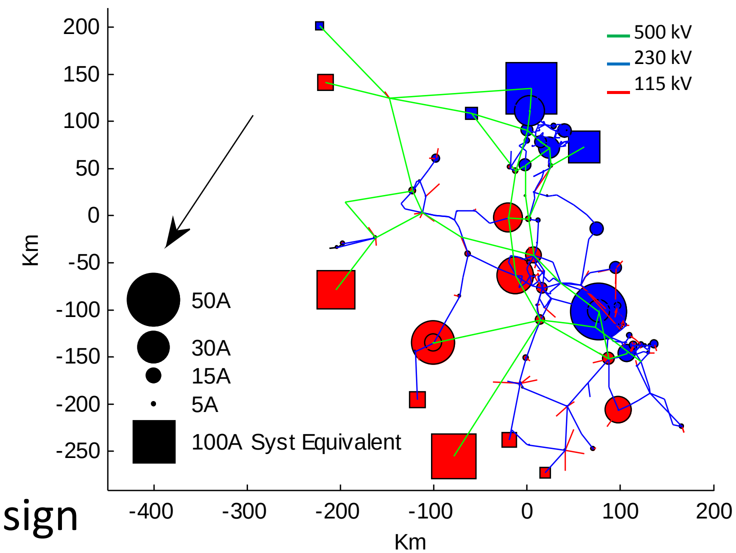
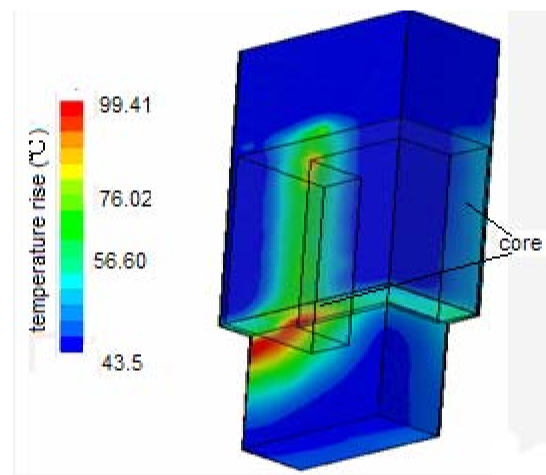
- Mitigation: the right balance of equipment hardening and operational procedures
  - System-wide GIC flow simulations
  - Understanding critical locations
  - Operational procedures:
    - Situational awareness (*GICnet*) (advance notifications, operator tools)
    - Reactive power reserves
    - Contingency simulations
  - Equipment Hardening: Incorporated in design specifications
    - Transformer hot-spot simulations and design improvements
    - Protection system philosophy: contemplate unbalance and harmonics
    - Capacitor bank and SVCs design
    - GIC blocking devices (not utilized in Dominion)



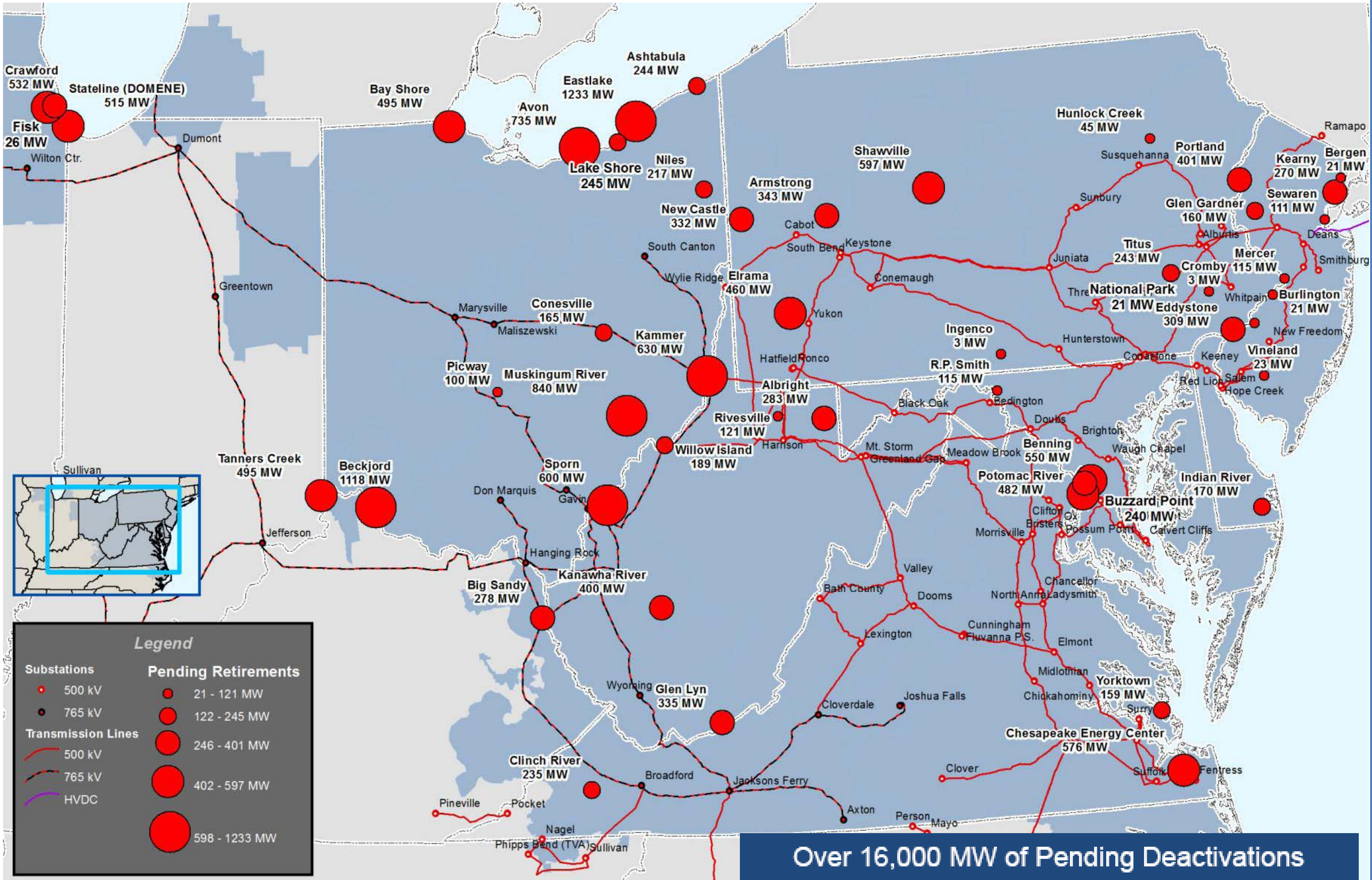


Generation Retirements in PJM

- Over 16,000 MW pending
- 13,500 MW since 11/2011
- Mostly retiring in order to meet stringent EPA standards
- Dominion Units Retiring

Unit	Capacity (MW)	Retirement Date
Chesapeake 1	111	12/31/2014
Chesapeake 2	111	12/31/2014
Yorktown 1	159	12/31/2014
Chesapeake 3	147	12/31/2015
Chesapeake 4	207	12/31/2015

Retirements Across PJM



Over 16,000 MW of Pending Deactivations
(~13,500 MW since 11/2011)

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Flexible AC Transmission System (FACTS)

Facts devices required for normal operation, not just contingencies

- Voltage Control - Load Located Remote From New Generation
  - Static Var Compensator's (SVC), Wide area control of Cap Banks and Reactors
- Congestion- Maximize Low Cost Generation Transfer
  - HV DC, SVC's , Thyristor Controlled Series Cap Banks
- Stability- Maximize Line Loading and Prevent Generator Contingencies
  - SVC's , Series Cap Banks
- Thermal Capability- Prevent Transmission Line Overloads
  - SVC's , Series Cap Banks

Additional SVC's Contemplated

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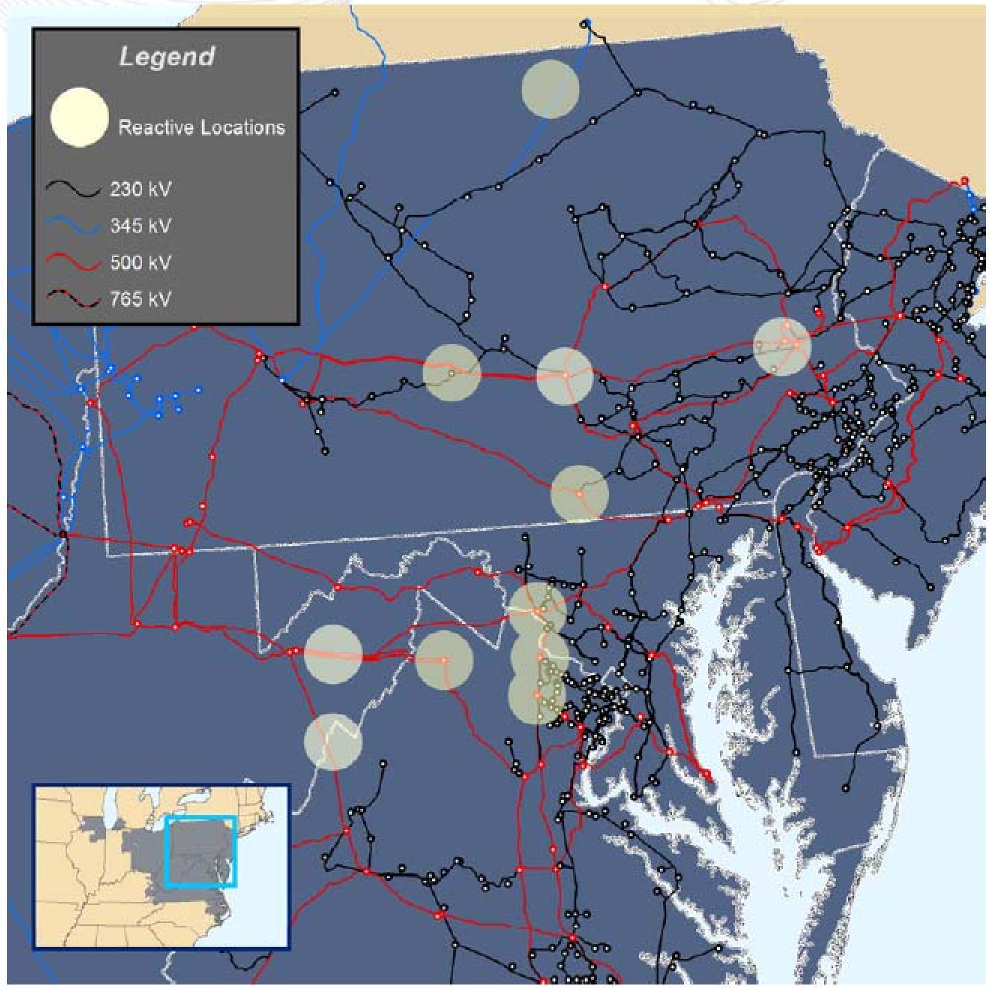
pjm

Reactive Upgrade Locations Evaluated

- Alburtis 500 kV
- Altoona 230 kV
- Doubs 500 kV
- Hunterstown 500 kV
- Juniata 500 kV
- Loudoun 500 kV
- Mansfield 345 kV
- Meadow Brook 500 kV
- Mt Storm – Valley 500 kV
- Pleasant View 500 kV
- T157 500 kV



SVC Drivers

- Performance of the SVC superior to
  - Fast Switched Shunts or
  - Static Capacitors
- Steady state analysis shows how the reactive output of the SVC would automatically change post contingency
- Dynamic analysis shows the benefits of SVC to recover voltages post contingency
- Ability of SVC to absorb reactive power will help to improve system voltage profile during light load periods
  - Shunt reactors used in some locations
- SVC will help to improve dynamic stability
- SVC will help to replace dynamic reactive capability lost due to generation deactivations

Static VAR Compensator (SVC)

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Valley Substation Fixed Series Capacitors

Redundant Fiber Optic Columns on Platform

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Variable Reactor

Yadkin Substation

Hamilton Substation
with sound enclosure

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Electric Transmission: Longer Term Challenges

Long Term Challenges

- Transmission line siting will continue to be harder to attain
- Upgrade and update of utility Data historian and data management required to handle increased volume of information
- Renewable generation will further complicate system designs
- SF6 management and development of new insulating fluids will be needed due to increased environmental concerns
- Increased transmission construction is challenging circuit breaker interrupting capability technically available today
- Mitigate and reduce harmonic components being proliferated on transmission system by electronic controlled load
- Improved asset management to determine end of life
- Multi-nodal HVDC will be required in the future
  - protection systems will have to be developed
  - protective components will be required

Nuclear Energy

- Concerns about rising electricity demand and clean air are among the factors driving interest in new nuclear plants
- Nuclear energy remains the best option for generating baseload electricity
- Fukushima and Virginia earthquakes have prompted action to make nuclear facilities even safer
- Maintaining nuclear energy's current 20 percent share of generation would require building 20 to 25 new units by 2035, based on DOE forecasts
- NRC recently approved licenses for 2 new reactors in Georgia. The first permits in 30 years
- Large portion of the original nuclear reactor fleet will be decommissioned in the coming years

Renewable Generation

- Comparatively cost prohibitive – Presently requires government subsidies/credit to encourage development
- Generating cycle does not coincide with load profiles
- Lack of proven storage cell solutions
- Generating sites remote from load centers
- Requires transmission lines to connect to load – likely HVDC

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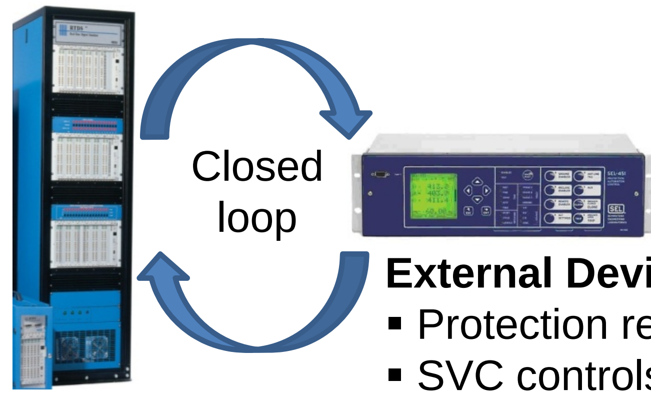
Dominion Equipment Monitoring System

- Drivers for the Dominion Equipment Monitoring System
  - Aging assets
  - Compliance
  - Equipment condition awareness
  - Reliability enhancement
  - More efficient equipment maintenance processes
- Goals for the Dominion Equipment Monitoring System
  - Centralized platform that congregates the data and enables a flexible analytics engine
  - Early detection to reduce forced outages and minimize catastrophic failures
  - Assess effective age and performance of critical assets
  - Optimize maintenance and extend asset life, i.e. convert from time-based to analytics-based maintenance and replacement
  - Provide data for post-failure analysis
  - Provide fact-based recommendations for identifying equipment replacement priorities and planning future investments

Advance Power System Simulations

- ❑ Real Time Digital Simulator (RTDS)
  - – Closed-loop simulations.
- ❑ RTDS studies in Dominion:
  - – “Aurora Vulnerability”.
  - – Photovoltaic (PV) farms.
  - – Static Var Compensator (SVC) controls.
  - – Open phase detection.
  - – Harmonic interaction investigation.
  - – Black-start procedure.
  - – PMUs: operator training.
  - – Smart Grid: voltage reduction (EDGE)

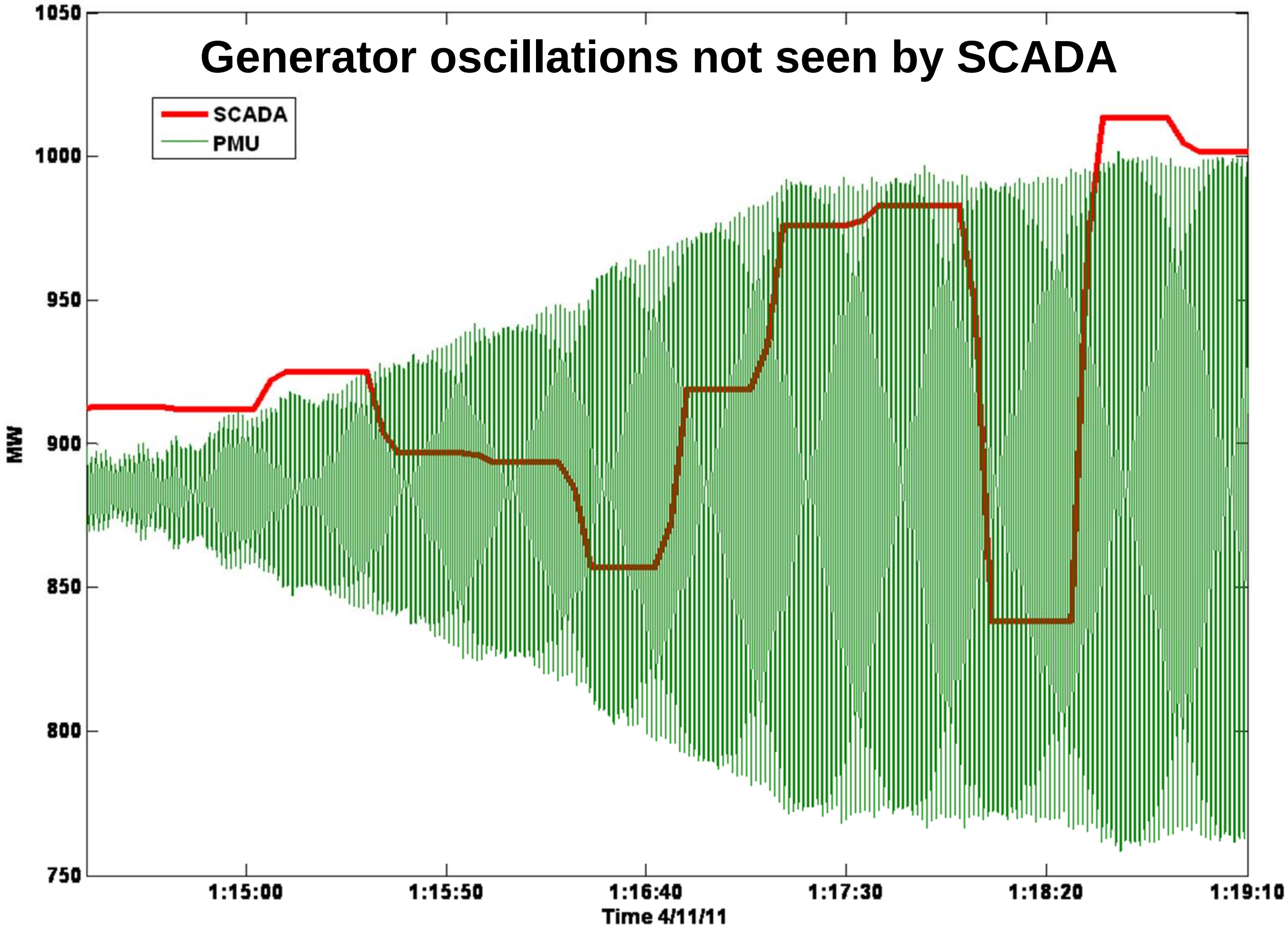


External Device:
- Protection relays
- SVC controls
- Solar PV-inverters
- Smart grid controls

Synchrophasor

- Synchrophasors are precisely time-synchronized, high resolution measurements of the electrical waves, on the electric grid
- Load models are the least accurate component of the power system model
- Having synchrophasor data will help better characterize and represent loads in system studies
- Baselining studies of phasor angles are required for understanding system behavior
- Increasing phasor angle across grid is an indicator of increasing system stress
- For true situation awareness we need to know:
  - Where the edge is
  - How close to the edge we can safely (reliably) operate

High-resolution synchronized measurements allow for visibility of emerging transmission phenomena



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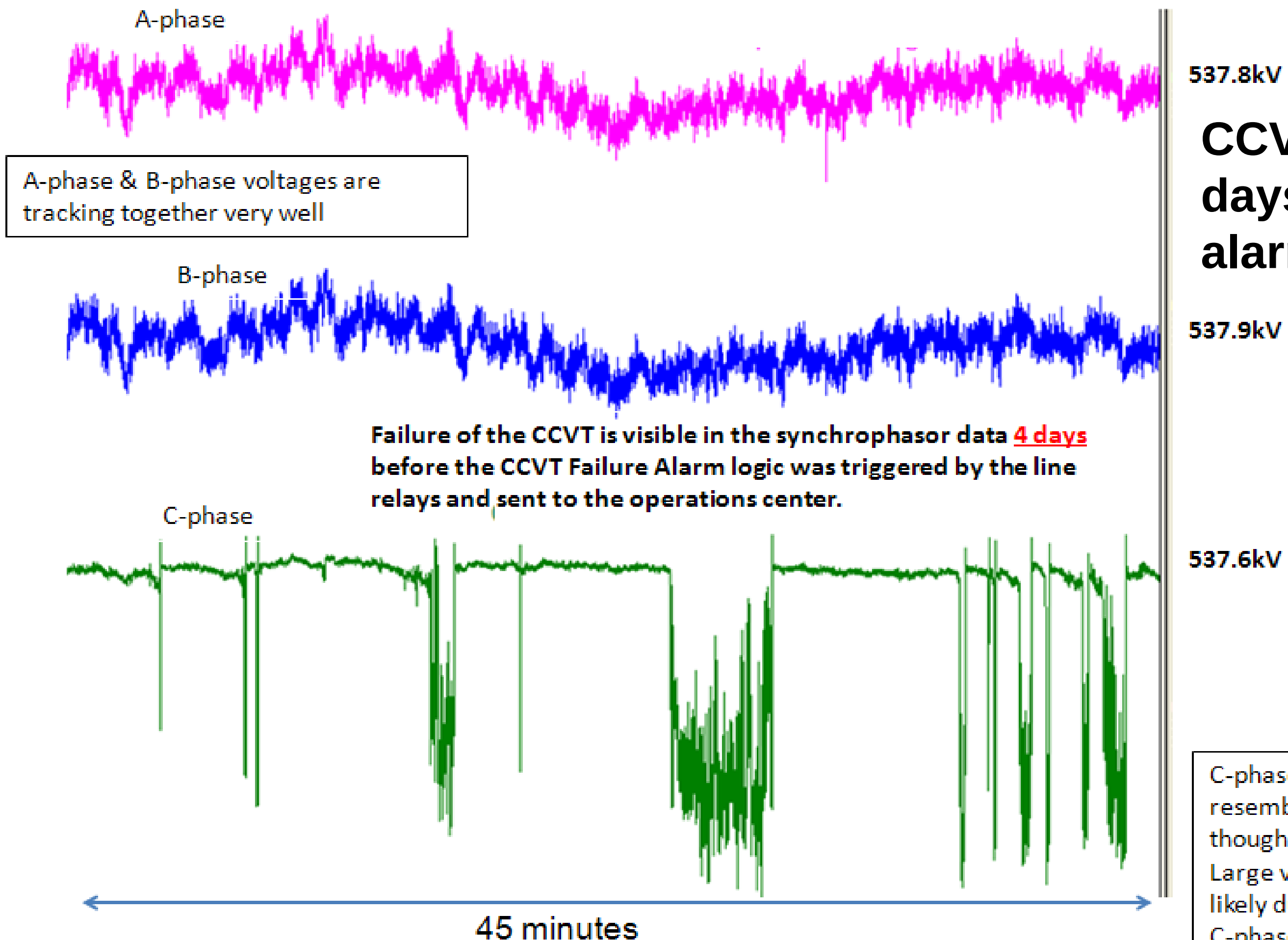
High-resolution synchronized measurements allow for visibility of emerging transmission phenomena

Synchrophasor Voltage Magnitudes at an Eastern Interconnection 500kV Line terminal, showing a C-phase CCVT failure



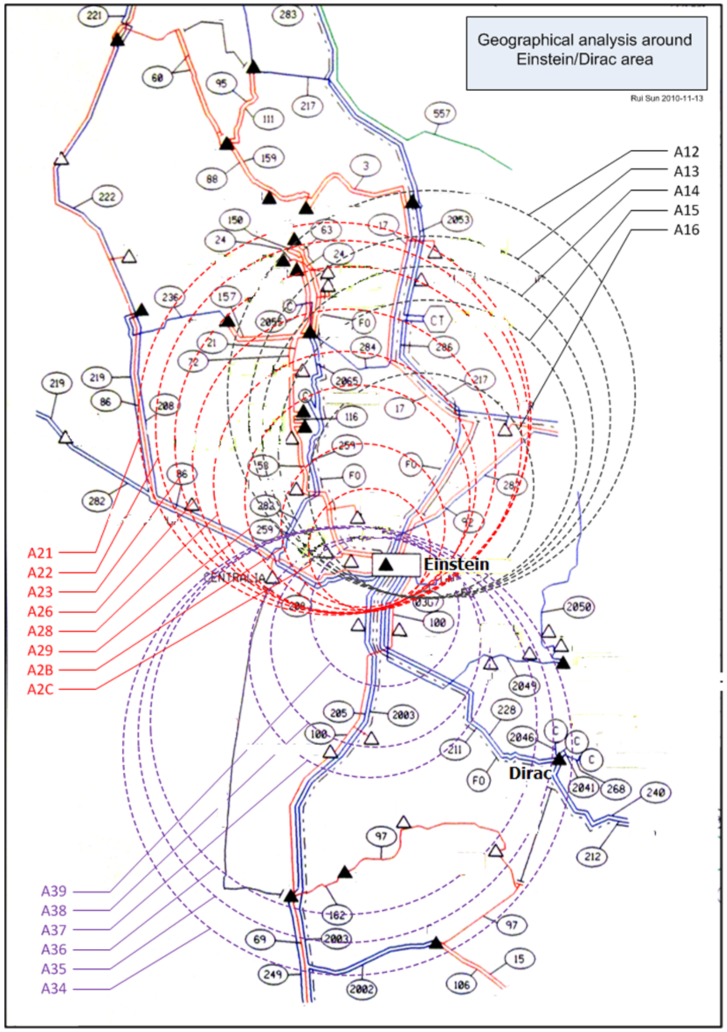
CCVT Failure – 4 days before failure alarm

C-phase voltage does not at all resemble A-phase & B-phase, even though the magnitude is normal. Large voltage swings shown are likely due to arcing inside the bad C-phase CCVT.

High-resolution synchronized measurements allow for visibility of emerging transmission phenomena

- Abnormal system stresses can create system islands
- Islands are virtually impossible to detect without PMU data
- Undetected islands often collapse – possible cascading can result from collapse
- In 2008, Entergy detected an island during Hurricane Gustav. PMUs were essential for highlighting remedial actions necessary for managing the island. The island was sustained for 33 hours and eventually re-synchronized keeping the lights on for 250,000 customers.

System Islanding Detection



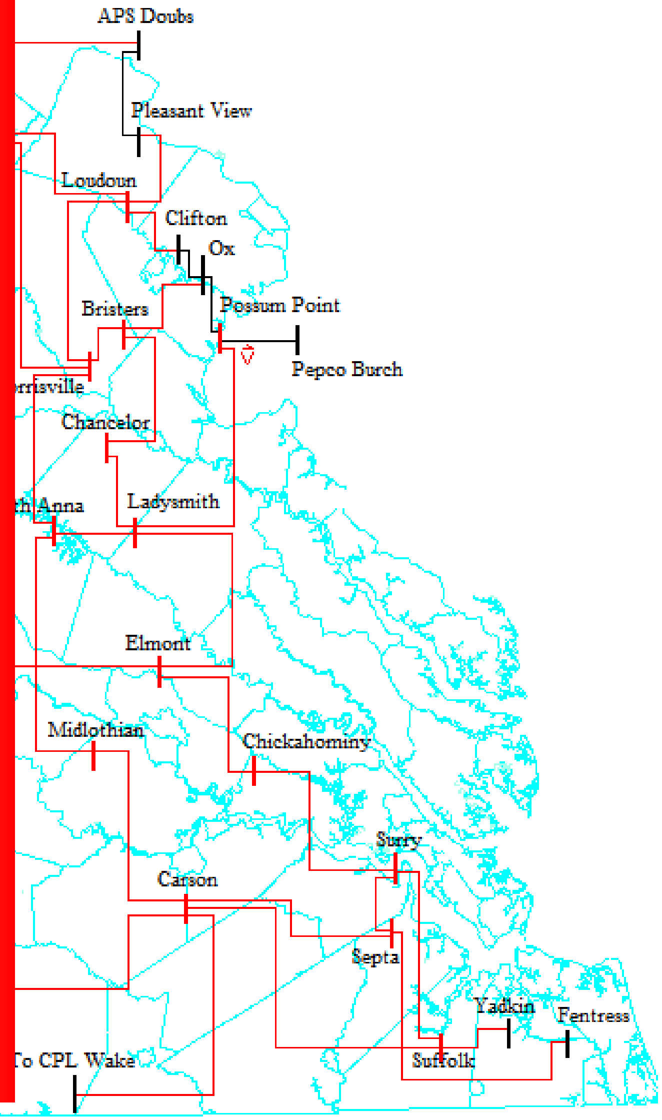
Dominion's Synchrophasor Technology Goals

Near Term

- Three-phase tracking state estimator
  (Synchrophasor observability of entire EHV)
- Transducer Calibration
  (Early detection of drifting/failing equipment)
- Three-phase observations allow for system balance monitoring
  (Better understand generation heating and constraints)
- System islanding observability
- <u>Basic tools for engineers and operators to interface with synchrophasor data</u>

Long Term

- Transmission pathway & congestion management
- Detection of imminent disturbance cascading
- Wide area protection & control



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Engineers:
Critical to Our Future

Challenges Ahead

- Communications
  - Synchrophasor measurements typically taken continuously and output 30 to 60 times per second
  - Conventional technology measurements taken about once every 4 seconds
  - Higher bandwidth communications obviated
- Data Volume
  - No commercially available and standardized data mining tools
  - Processing and concentration tools still developing
- Standards
  - IEEE and IEC standards not unified or stable
  - NIST standards still developing
  - NERC compliance (CIP and other developing standards)
- User Training and Familiarity
  - Industry has only scratched the surface of operator training
  - Synchrophasor tool space for engineers quickly expanding by not yet mature and standardized.

Changing Landscape

- ❑ Increased consumption of electricity
- ❑ Increasing dependence on electricity
- ❑ Critical to other infrastructures
  - Cellular coverage
  - Internet access
  - Traffic control
- ❑ Demands for renewable energy have implications
- ❑ Increasing dependence on power electronics to maximize power transfer capabilities
- ❑ Increased need to harden designs as distribution and transmission assets are replaced or added for natural disasters.

Engineers Required

- ❑ Complex modeling capabilities
- ❑ Balance of practical experience and electrical theories
- ❑ Fully engaged with engineering associations (IEEE, CIGRE, EPRI, etc…)
- ❑ Sensitive to regulatory requirements to contribute and influence industries standards
- ❑ Leadership to guide equipment manufacturers and technical consultants
- ❑ Development and retention of engineering talent at the utility level
- ❑ Understand and use human factors in design to insure successful use of designs – keep it simple
  - People not Engineers operate our electric grid
- ❑ Replacing aging workforce of power engineers

Questions?

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