



Dominion Synchrophasor Projects

**North American SynchroPhasor Initiative
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Dominion's Roots Run Deep



Upper Appomattox Trustees
1781



Virginia Railway and Power Co.
1909



Virginia Electric and Power Co.
1925



VIRGINIA POWER



Dominion Resources
1983



Dominion
2000

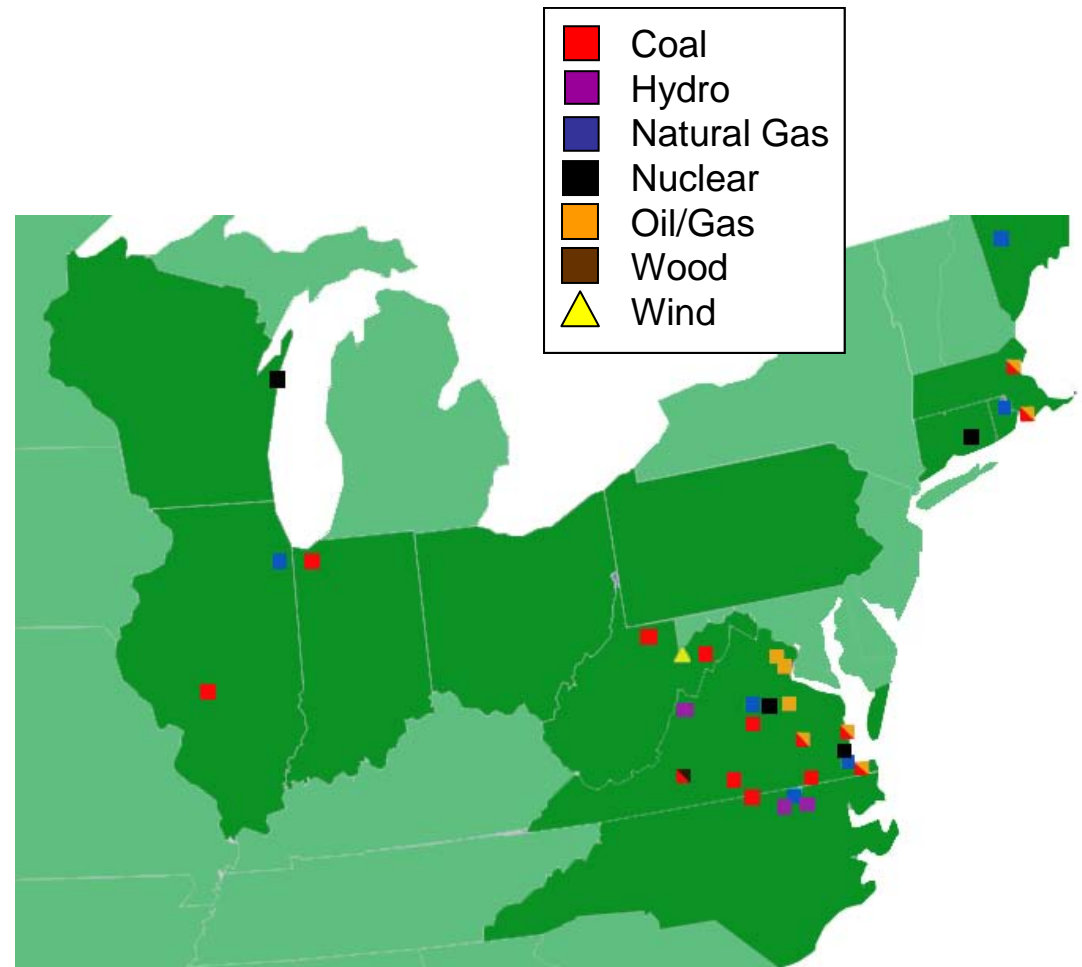


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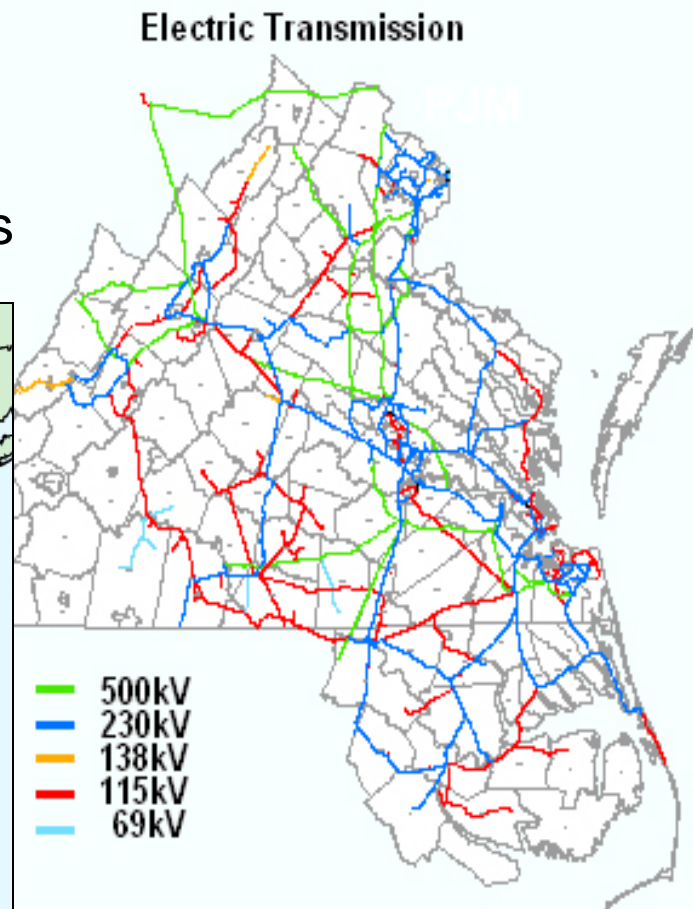
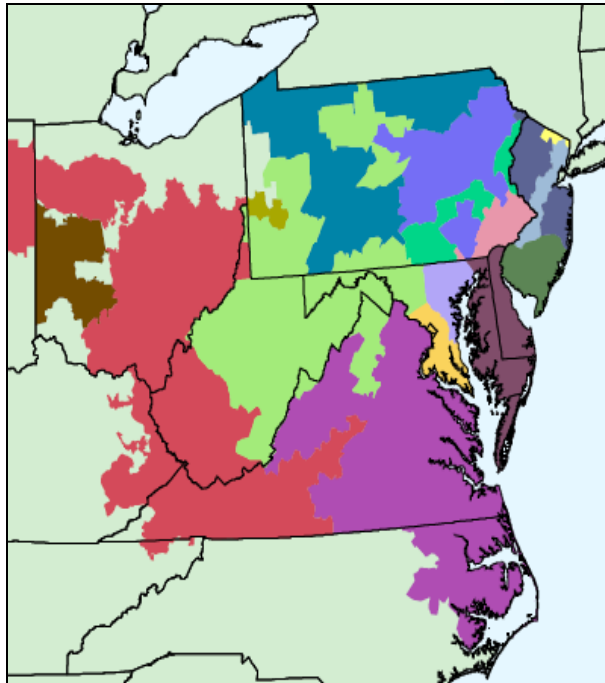
Dominion Generation

- 26,500 megawatts of capacity
- 6th largest producer in U.S.



T&D Business

- 6,000 miles of high-voltage transmission lines, up to 500KV
- 54,000 miles of distribution lines
- As high as 50,000+ new customers annually





PMU Applications:

- 3 Φ State Estimator.
 - Characterization and analysis of unbalanced conditions.
- Transducer Calibration.
- Optimum islanding strategies during catastrophic system events.
- Network topology configurator.
- Visualization tools for the 3-phase tracking state estimator.

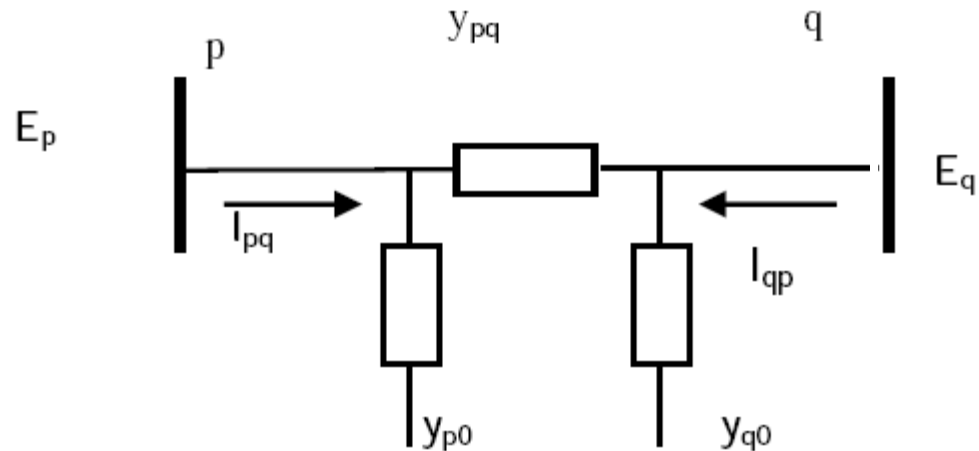


3-Phase Estate Estimator

- Linear state estimator based on PMUs.
- PMUs strategically located at 500 kV buses.
- Estimator is run every 1/30 sec.

$$\begin{bmatrix} E_p \\ E_q \\ I_{pq} \\ I_{qp} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ y_{pq} + y_{p0} & -y_{pq} \\ -y_{pq} & y_{pq} + y_{q0} \end{bmatrix} \begin{bmatrix} E_p \\ E_q \end{bmatrix}$$

$$z = \begin{bmatrix} II \\ y_A + y_s \end{bmatrix} E \longrightarrow \hat{x} = (B'W^{-1}B)^{-1}B'W^{-1}z$$





Bad Data Detection

- Analysis is based on residuals.

$$r_i^N = \frac{|r_i|}{\sqrt{\Omega_{ii}}}$$

Traditional State Estimator

$$x^{k+1} = x^k + (H'W^{-1}H)^{-1}H'W^{-1}(z - h)$$

Leverage points:

- Injection at buses with a large number of branches.
- Injection at buses whose branches impedance values are very different.
- Flow measurements on short lines.

Linear State Estimator

$$\hat{x} = (B'W^{-1}B)^{-1}B'W^{-1}z$$



PMU Testing

- Dual use PMUs: protection reliability assessment.
- Steady State PMU testing:
 - Phasor magnitude.
 - Phase angle.
 - Off-nominal frequency.
 - Unbalanced inputs.
- Data communication:
 - 24 hours of recorded data.

PMU and PDC Testing at Virginia Tech

Project Objectives:

Develop a NIST traceable PMU Testing System

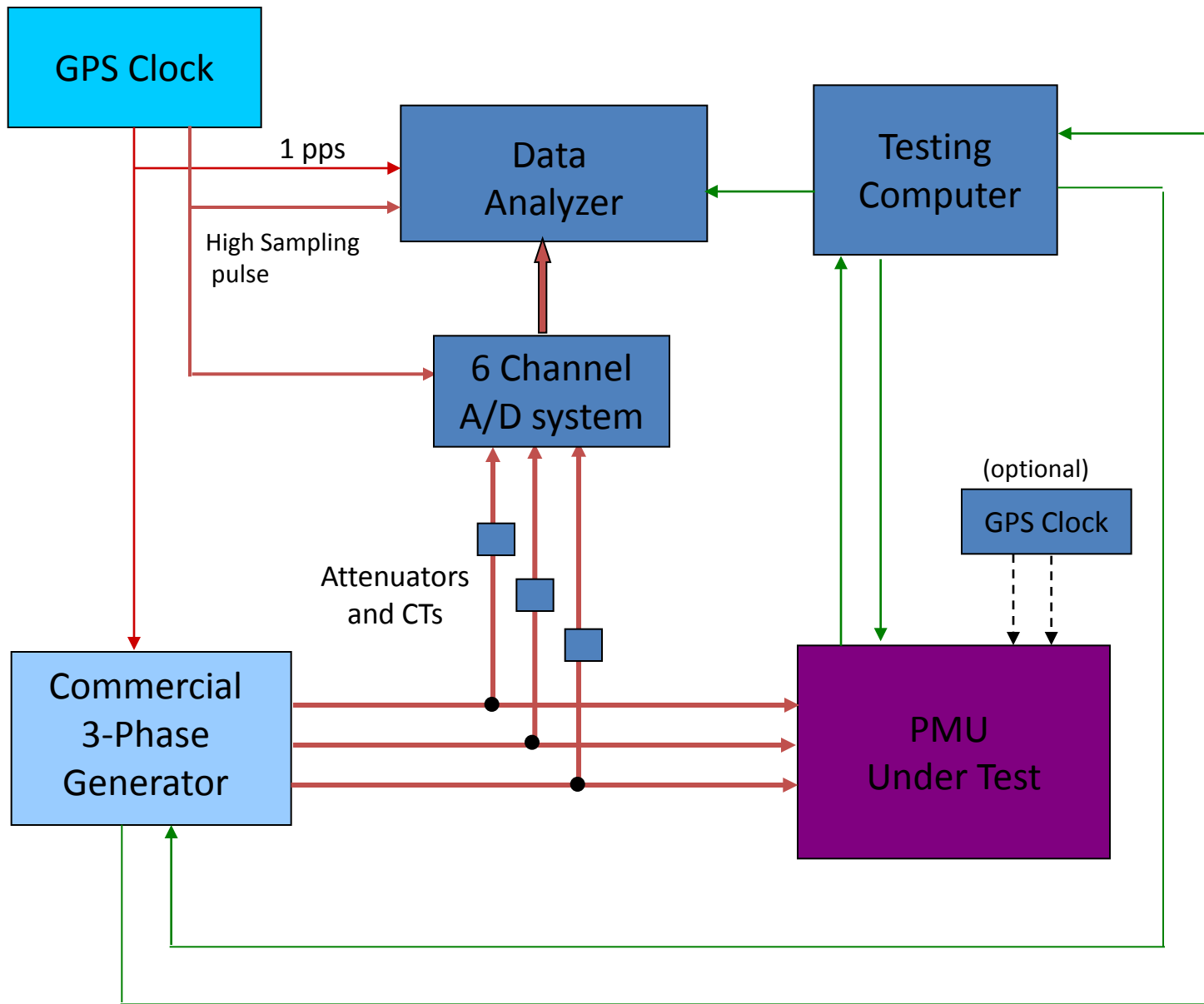
Develop procedures to test for conformance to the the IEEE C37.118 and new emerging PMU standard

Perform PMU testing in at most 30 PMUs

Develop a PDC testing system

Develop procedures for limited PDC testing based on emerging NASPI PDC requirements

Perform PDC testing in at most 12 PDCs



Functional Diagram of VT PMU Testing System based on NIST existing system

Tentative Schedule

Project aims for a maximum of:
 30 PMU test, and
 12 PDC test

(re-test counts as a separate test)

3 Weeks allocated for each PMU testing:
 Week 1: Steady State Tests
 Week 2: Dynamic Testing
 Week 3: Data analysis and report

Year 2010	Spring 2010		Summer 2010		Fall 2010	
					8-Nov	PMU-1
					29-Nov	PMU-2
Year 2011	Spring 2011		Summer 2011		Fall 2011	
	18-Jan	PMU-3	23-May	PMU-7	29-Aug	PMU-10
	7-Feb	PMU-4	13-Jun	PMU-8	12-Sep	PDC-4
	21-Feb	PDC-1	27-Jun	PDC-3	26-Sep	PMU-11
	14-Mar	PMU-5	11-Jul	PMU-9	17-Oct	PDC-5
	28-Mar	PDC-2			31-Oct	PMU-12
	11-Apr	PMU-6			28-Nov	PMU-13
Year 2012	Spring 2012		Summer 2012		Fall 2012	
	17-Jan	PMU-14	21-May	PMU-18	3-Sep	PMU-21
	30-Jan	PDC-6	11-Jun	PMU-19	17-Sep	PDC-9
	13-Feb	PMU-15	2-Jul	PDC-8	1-Oct	PMU-22
	27-Feb	PDC-7	23-Jul	PMU-20	22-Oct	PDC-10
	26-Mar	PMU-16			12-Oct	PMU-23
	17-Apr	PMU-17			3-Dec	PMU-24
Year 2013	Spring 2013		Summer 2013		Fall 2013	
	22-Jan	PMU-25	20-May	PMU-29		
	11-Feb	PMU-26	3-June	PMU-30		
	25-Feb	PDC-11				
	18-Mar	PMU-27				
	1-Apr	PDC-12				
	15-Apr	PMU-28				

Questions?



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