



Dominion's End of Life Criteria

Transmission Replacement Processes Senior Task
Force

May 23, 2016

Agenda

- Overview of Dominion's End of Life Criteria
- Example #1 – Elmont to Cunningham
- Example #2 – Roslyn 69 kV UG cable

Introduction

- Dominion's Local Transmission Owner Criteria
 - Part of PJM's Reliability Planning Criteria driving baseline projects
 - PJM Manual 14B Attachment D
 - File annually on FERC 715 filing
 - Incorporated into Dominion's FAC-001 Facility Interconnection Requirements Document
 - Exhibit A

Introduction

- Dominion's End of Life Criteria
 - Within Exhibit A of FAC-001 Facility Interconnection Requirements Document
 - Specifically criteria C.2.8

<http://pjm.com/planning/planning-criteria/to-planning-criteria.aspx>



Overview of Dominion's End of Life Criteria

Overview - Intent

- Intent of the “End of Life Criteria”
 - All Transmission Infrastructure will ultimately reach a point where replacement is inevitable
 - Recognize and address in order to ensure continued reliability of the transmission grid
- Factors Influencing “End of Life”
 - Environmental conditions can shorten its life
 - Maintenance activities can lengthen its life
 - Condition of components

Overview - Intent

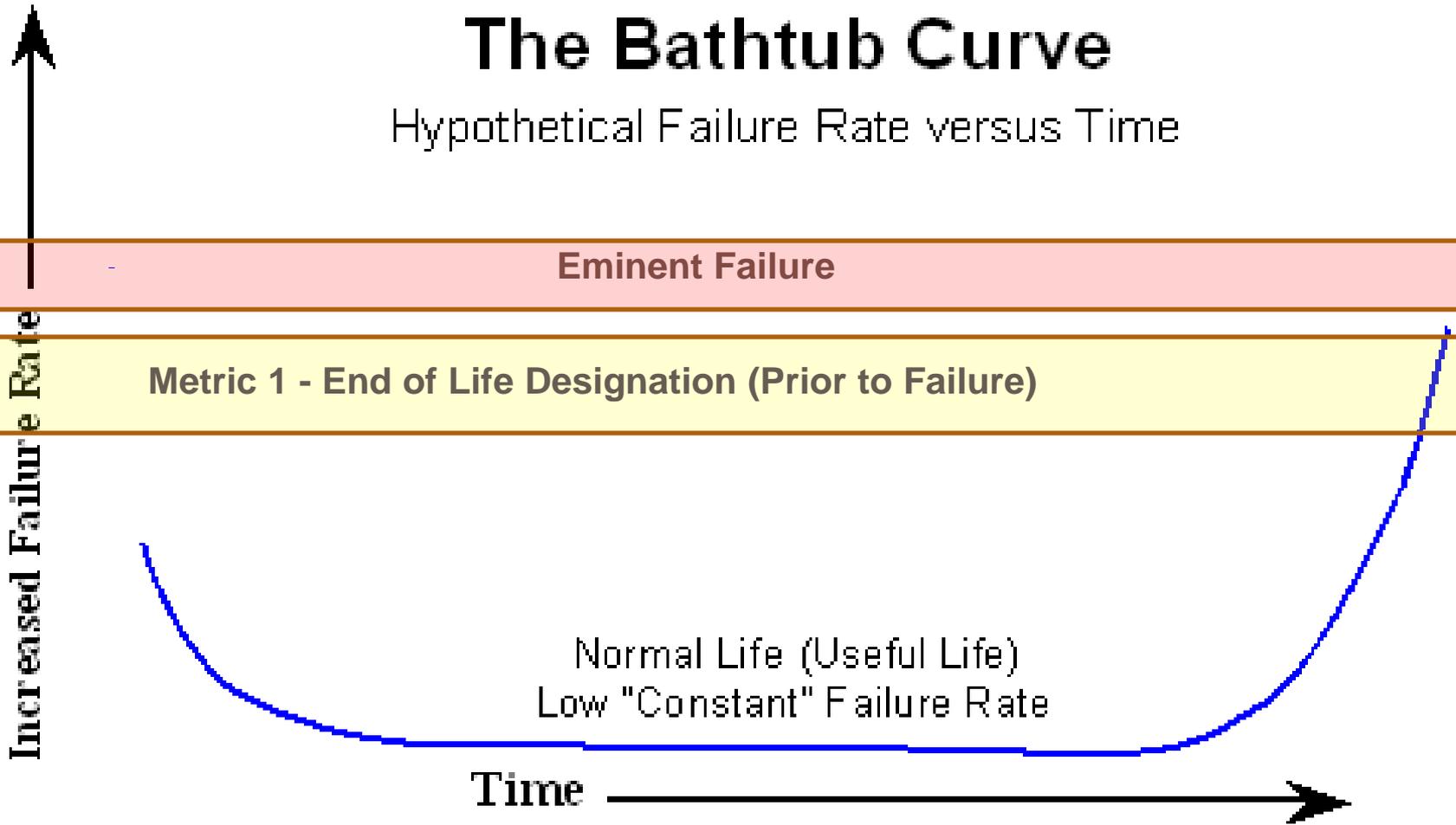
- “End of Life” Designation does not mean the facility must be removed from service
 - No way to predict actual point of failure
 - Only able to identify conditions which identify risk of failure
 - End of Life is to identify and address prior to “**ultimate failure**” of the facility
 - A systematic plan/program to address a large volume of aging assets

End of Life - Criteria Definition

“End of Life” is defined as the point at which infrastructure is at risk of failure, and continued maintenance and/or refurbishment of the infrastructure is no longer a valid option to extend the life of the facilities.

The Bathtub Curve

Hypothetical Failure Rate versus Time



End of Life Criteria Decision Points

- The decision point of this criterion is based on satisfying two metrics:
 - *Facility is nearing, or has already passed, its end of life, and*
 - *Continued operation risks negatively impacting reliability of the transmission system.*
- A violation of Dominion’s “End of Life” criteria is satisfied by meeting both decision point metrics



Exploring Each Decision Point Metric Separately

First Decision Point

Facility is nearing, or has already passed, its end of life

- Factors include, but are not limited to,
 - Manufacturer's recommendation on service life for the particular type of facility
 - The facility's performance history
 - Continued maintenance versus replacement
 - Third-party assessment

Aging Components

- Industry studies have reported an “expected” service life of various infrastructure components.
 - Steel structures 40 to 60 years
 - Conductors 60 years
 - Connectors 40 to 60 years
 - Insulators (Porcelain/Glass) 50 years+(Polymer) 30 years
 - Fiber 30 years
 - Wood 55 years with maintenance
- However, the actual service life is dependent upon many variables and ongoing inspection to evaluate condition is the best determinant of end of service life.

Major Concern

- COR-TEN Lattice Structures are Dominion's primary concern
 - Condition is directly tied to age
 - Members losing strength
 - Joint design and Tower design
 - NOT a lack of maintenance
- Also addressing other Facilities
 - Wood Poles
 - Other

Dominion's Aging System

- With 60% (3674 miles) of Dominion's system built prior to 1980 – we have a proactive plan for rebuilding lines to maintain system reliability
- Lines with following equipment currently targeted for End of Life:
 - 115kV COR-TEN Structures
 - 230kV COR-TEN Structures
 - 500kV COR-TEN Structures
 - Wood Structures
 - 3/8" Steel static wires
 - Fiber that is older than 30 years

COR-TEN on Dominion System

- “Original Loop” as referred to by Dominion are the 500kV transmission lines constructed in the mid to late 1960s that form ties between the Loudoun, Elmont, Doods, Mount Storm, and Doubs(First Energy) Substations.
 - Original loop is approximately 385 miles
 - 155 miles of loop have been rebuilt as baseline projects either by PJM criteria violation and/or End of Life designation (For example Mt Storm to Doubs)
 - Approximately 230 miles remaining on original 500kV Loop
- Approximately 975 miles of COR-TEN structures on 230kV and other 500kV lines (not original loop).
- Approximately 12 miles of COR-TEN structures on 115kV lines.

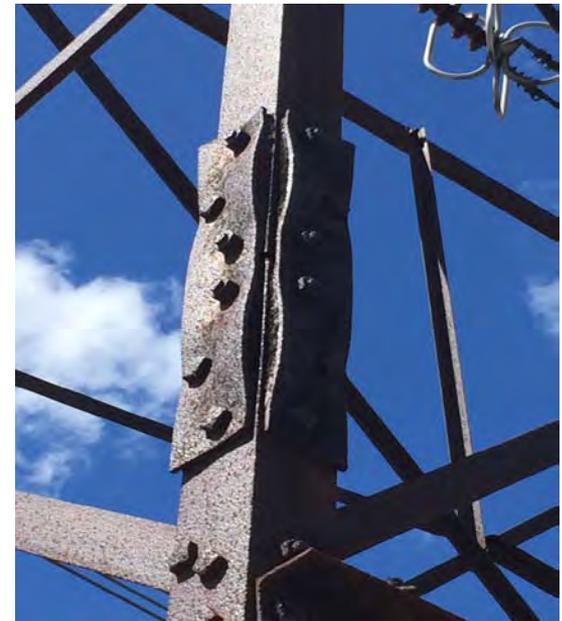
Concerns with COR-TEN Lattice Structures

- Patina is an iron-oxide layer that forms over the steel surface over time.

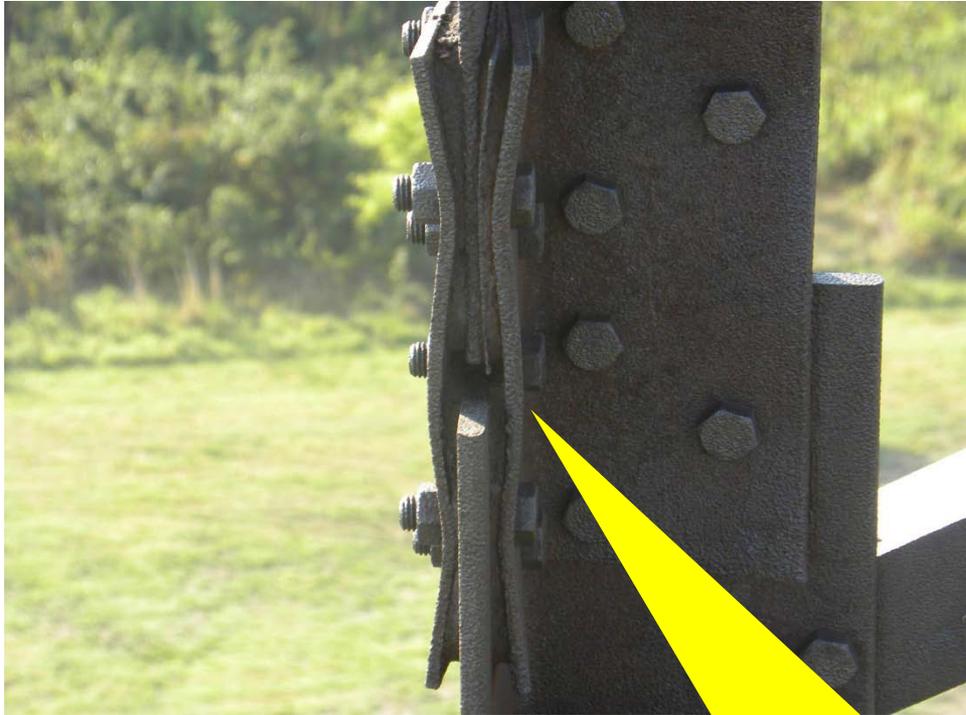
Ideally “seals” the steel and does not allow further oxidation to occur.

Patina layer not performing as expected.

- Joints collect moisture and develop large amounts of corrosion (pack out) build up over time and cause bolt failures and deformation of steel members.



Concerns with COR-TEN Lattice Structures



Pack Out

COR-TEN Refurbishment

- Maintenance of the COR-TEN 230kV and 500kV lines has been ongoing and continues today – life extension only.
- Performing climbing inspections and replacing components that are visibly broken, cracked or missing bolts to address immediate structural concerns. Adding additional members for tower support.
- Total spend on program to date approximately \$152M.

COR-TEN Refurbishment

- Summary of 230kV and 500kV towers inspected that were modified or repaired to date (This doesn't include the original loop)

Type	Vintage	Number Towers Inspected	% Modified or Repaired
F-Series (500kV)	Mid 60's	17	82%
V-Series (230kV)	Early 60's - 70	224	94.6%
X-Series (230kV)	Late 60's	72	86%
5-Series (500kV)	Early 70's-80's	1784	81.1%
N-Series (230kV)	Early 70's-80's	1494	36.3%

- Refurbishment doesn't address replacements of major bracing or legs. This would require extensive construction involving removing conductors and supporting structures with cranes.

COR-TEN - End of Life

- Original 500kV Loop COR-TEN Rebuild Projects Established
- Rebuild projects established for the 12 miles of 115kV structures
- Next Priority will be early generation COR-TEN (V, X & F Series Structures)
- With over 1200 miles of COR-TEN structures on our system we need a proactive plan to begin replacements
- Typical project will last four to five years from initial planning through construction and energization.

Wood Pole 115 kV Line Example

Maintain versus Replace

- Economically it is better to take a wholesale replacement approach to lines built with wood versus replacing component by component.
- Typical costs we have experienced for single component replacements:

Individual Component Replacements (per mile)	115kV Wood Pole Line
Structures	\$ 1,000,000
Static wire	\$ 250,000
Re-conductor	\$ 486,000
Insulator replacement	\$ 100,000
Total (per mile)	\$ 1,836,000

Complete 115 kV line replacement cost is typically \$1M per mile

Wood Pole 115 kV Line Example

Maintain versus Replace

- For this 115 kV Wood Pole line
 - Replace component by component
 - 20 miles times \$1.836 per mile = \$36.72 million
 - Wreck and Rebuild
 - 20 miles times \$1.000 per mile = \$20 million
- Simple example but seems obvious wreck and rebuild is least cost option
- This example makes sense economically when the entire line needs addressed versus only a small portion
- Access cost to site is a major contributor to higher costs by component as compared to wholesale replacement

Second Decision Point

Continued operation risks negatively impacting reliability of the transmission system

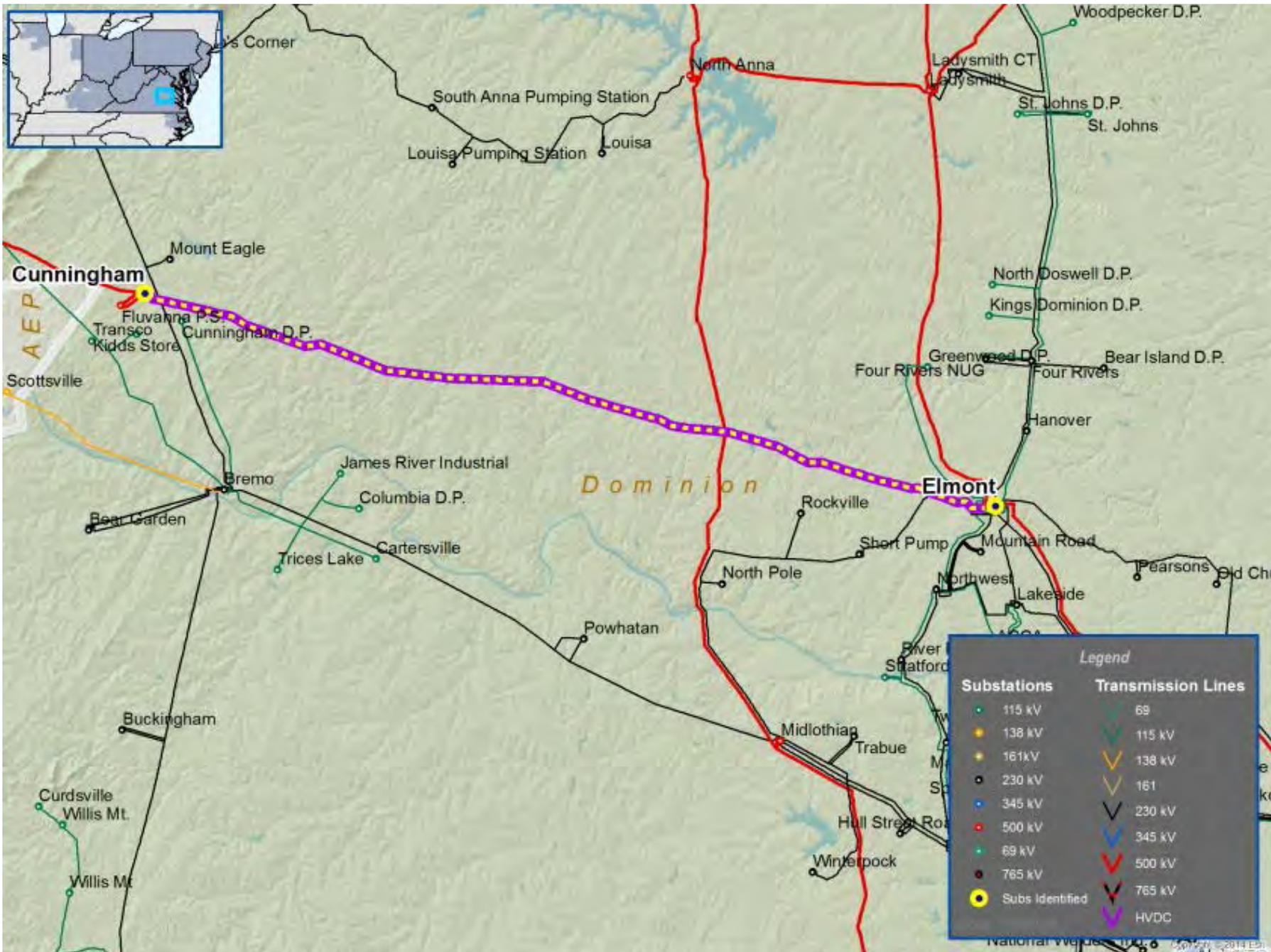
- A reliability impact assessment will be performed
- The existing system with the facility removed will become the base case system for which all reliability tests will be performed.
 - For example: The PJM RTEP 2021 case with the End of Life facility removed from service becomes the base system for all tests
- The primary four (4) reliability tests conducted:
 - NERC Reliability Standards
 - PJM Planning Criteria
 - Dominion's TO Criteria
 - Operational Performance

Example # 1

**ELMONT – CUNNINGHAM 500 KV
LINE**

Elmont – Cunningham 500 kV Line

- Part of Dominion's "Original Loop" of 500 kV lines
- 1965 construction
- Approximately 51 miles in length
- Consists of 409 COR-TEN[®] steel towers



Legend

Substations	Transmission Lines
● 115 kV	— 69
● 138 kV	— 115 kV
● 161kV	— 138 kV
● 230 kV	— 161
● 345 kV	— 230 kV
● 500 kV	— 345 kV
● 69 kV	— 500 kV
● 765 kV	— 765 kV
● Subs Identified	— HVDC

Metric #1 - First Decision Point

Facility is nearing, or has already passed, its end of life

- Hired a 3rd party to evaluate the entire 500 kV original loop
- 3rd party Scope of Work
 - Data Gather records of inspections, component failures, refurbishments/repairs, tower loading studies, COR-TEN corrosion studies and other relevant information
 - Perform field sampling and inspection
 - Perform analysis to determine condition of individual lines and a ranking to support remediation
 - Validate the “End of Life” and prioritize the work

Example of 3rd Party Review

- Evaluated actual measurements of steel members from 1984 to 1998
- Difference in measurements indicate rate of deterioration

Table 3-1. Tower measurements, 1984 and 1998

Line	Structure	Plate Size (in.)	1985 Measurement (in.)	1998 Measurement (in.)	Difference (in.)	Difference
549	81	0.1875	0.201	0.185	0.016	8%
549	81	0.25	0.247	0.226	0.021	9%
550	205	0.1875	0.198	0.188	0.010	5%
550	205	0.25	0.255	0.243	0.012	5%
550	210	0.1875	0.206	0.145	0.061	30%
550	210	0.25	0.254	0.207	0.047	19%
552	183	0.1875	0.197	0.171	0.026	13%
552	183	0.25	0.255	0.229	0.026	10%
552	185	0.1875	0.202	0.190	0.012	6%
552	185	0.25	0.248	0.230	0.018	7%
553	484	0.1875	0.206	0.189	0.017	8%
553	484	0.25	0.258	0.234	0.024	9%
553	485	0.1875	0.207	0.189	0.018	9%
553	485	0.25	0.252	0.239	0.013	5%

Example of 3rd Party Review

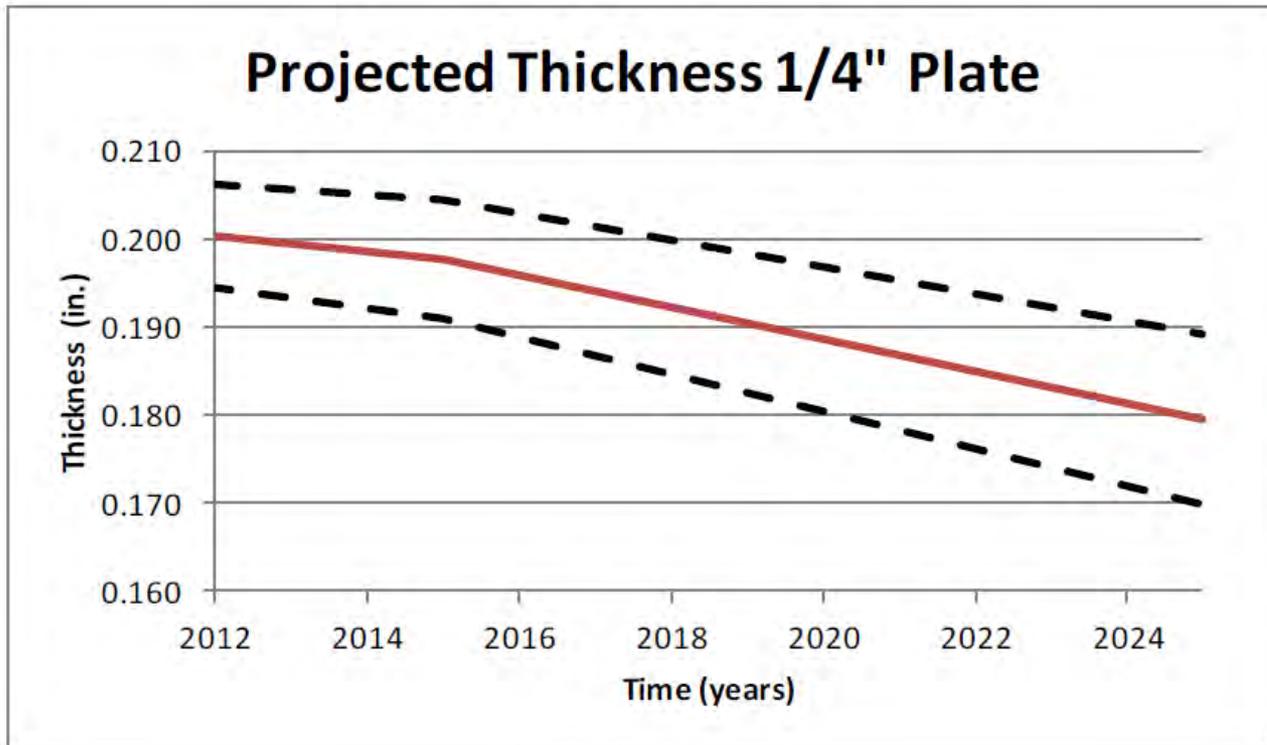
- Evaluated refurbishment/repair records of towers

Table 3-2. Number of Towers that have been modified by a refurbishment package

Year in Service	Line No.	Total Structure	Modified	% Modified
1964	549	84	53	63.1%
1964	550	263	218	82.9%
1965	553	409	286	69.9%
1966	551	458	347	75.8%
1966	552	181	113	62.4%
1966	555	185	86	46.5%
1966	558	75	7	9.3%
1966	566	35	28	80.0%
1966	574	123	80	65.0%
1966	569	115	81	70.4%
TOTALS		1928	1299	67.4%

3rd Party Findings

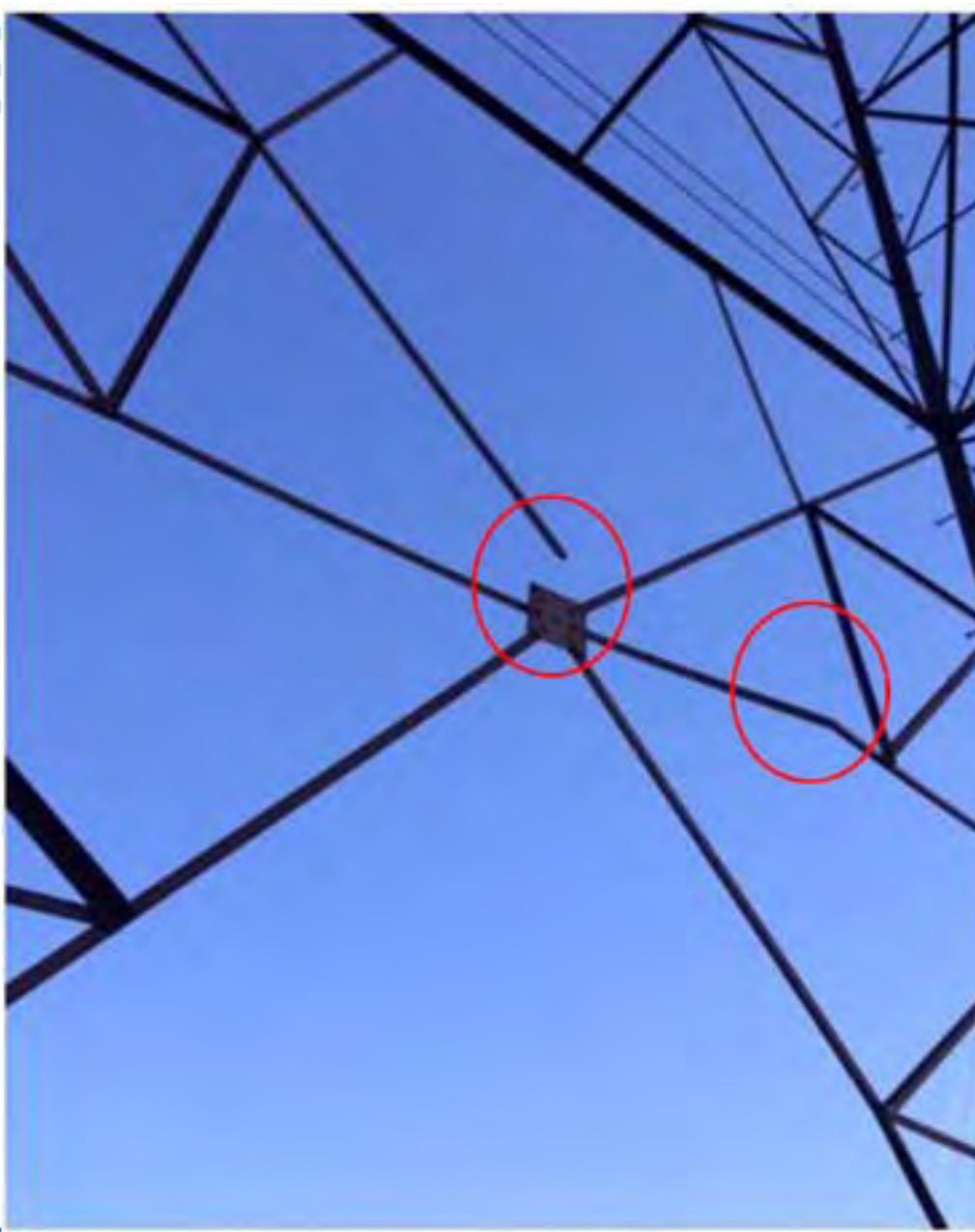
Figure 5-1. Projected plate thickness





Wind Event

**Failed members caused by
deterioration of Plate Thickness**



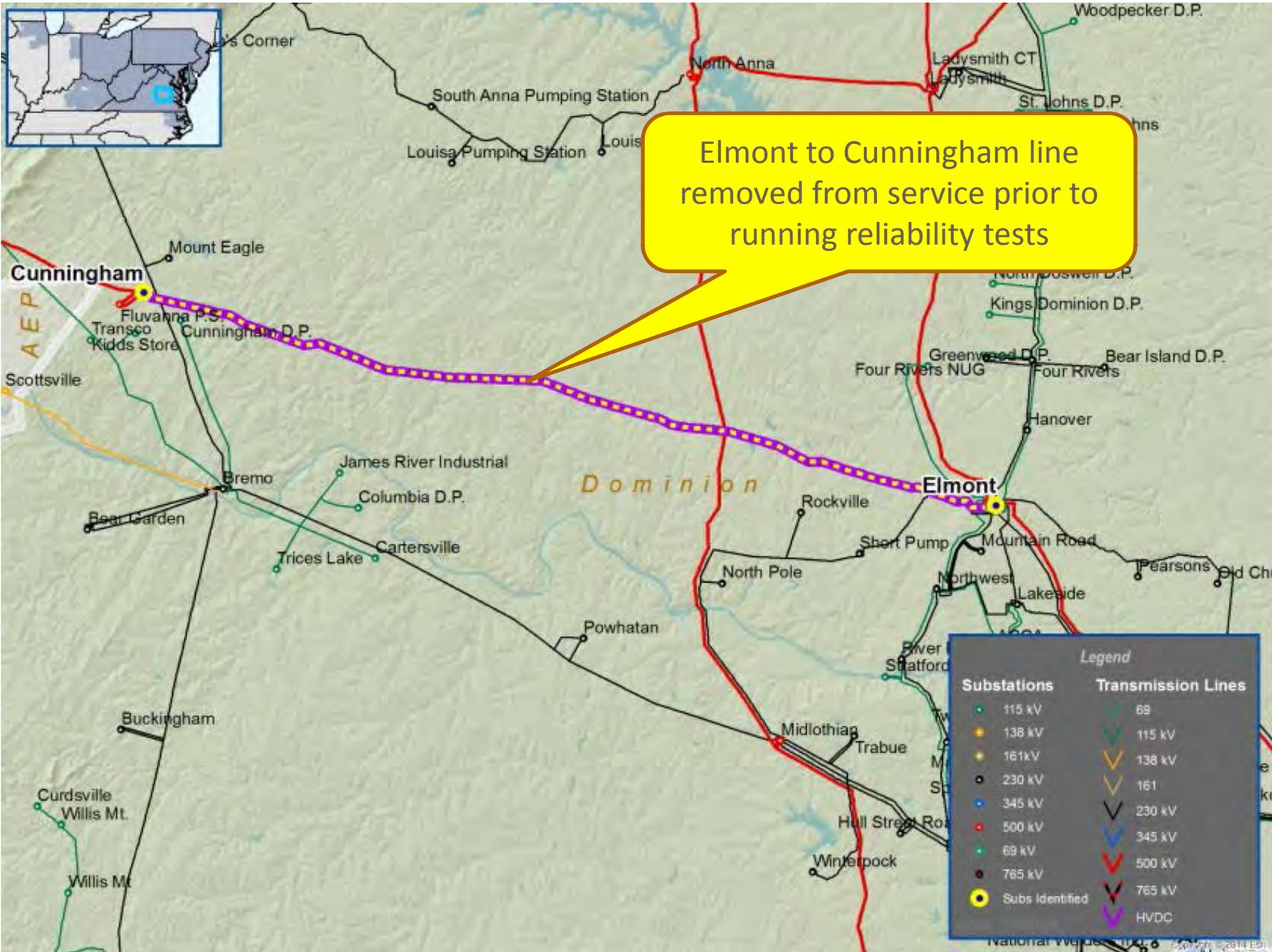
3rd Party Findings

- **Report validated Metric #1 of “End of Life” criteria for the Elmont to Cunningham line**
- Found that over 70% of the towers had some sort of rehabilitation package applied
- Found individual member strength has deteriorated and will continue
- Performed tower loading studies which indicated that stress on the tower legs is increasing as members continue to lose strength
- Supported the need to begin wholesale line replacement of the Elmont - Cunningham line with a target date of June 2018.
- Study also identified the priority of the remaining 500 kV original loop lines with a total projected completion of by 2023.

Metric #2 - Second Decision Point

Continued operation risks negatively impacting reliability of the transmission system

- Used the PJM 2019 RTEP Basecase
- Removed Elmont – Cunningham line from power flow cases
- Conducted the various reliability tests to determine risk of not having Elmont to Cunningham line available



Reliability Test Findings

- Multiple category B criteria violations
- Multiple category C criteria violations
- Violations also included voltage and thermal issues on 230 kV and 138 kV systems
- Costs for other solutions to resolve violations far exceeded replacement option

Conclusion

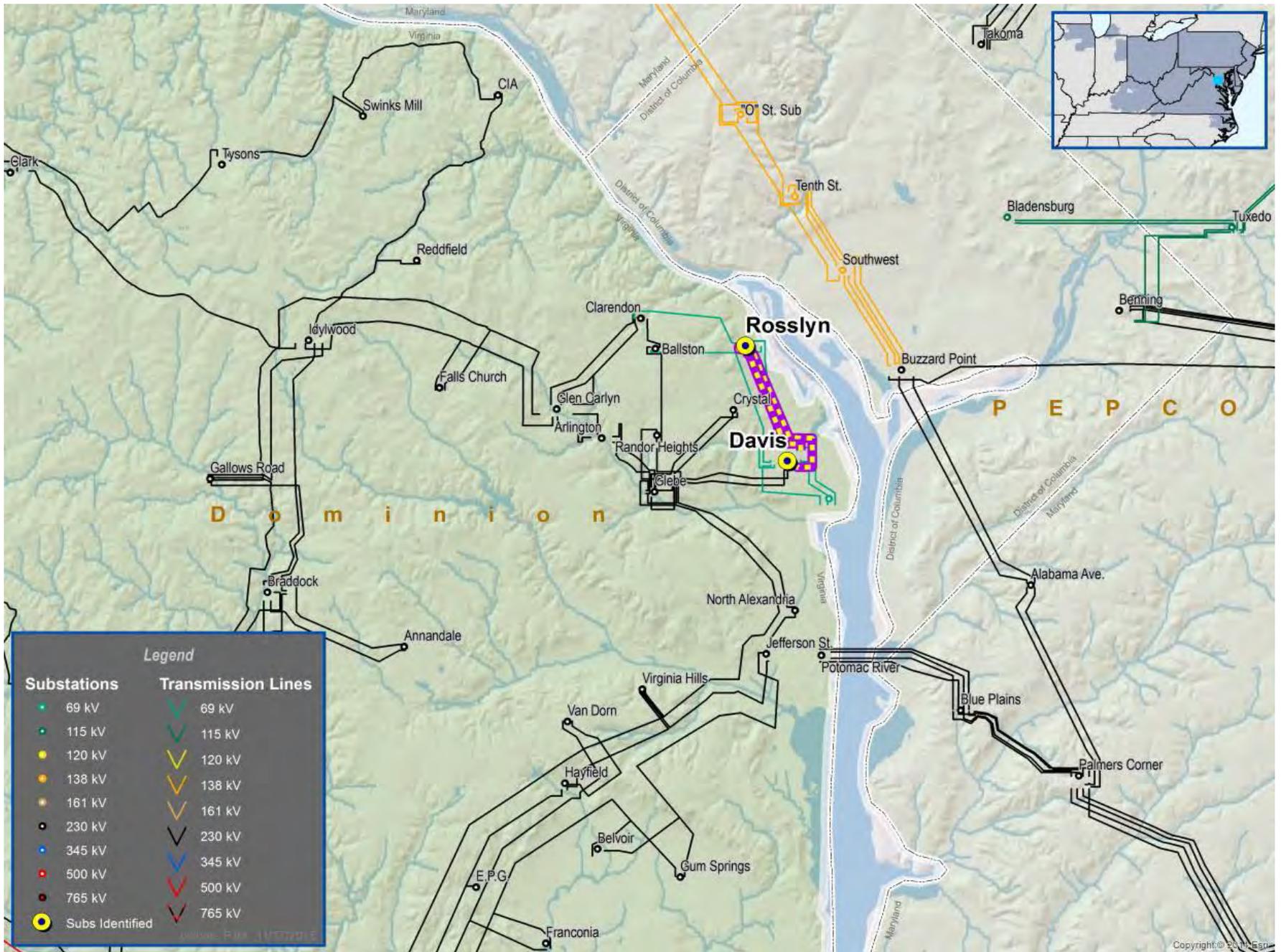
- Violation of Dominion's End of Life criteria
 - Both Metric #1 and Metric #2 violated
- PJM reviewed and validated both Metrics
- Solution recommended and approved is to rebuild the Elmont to Cunningham 500 kV line as a PJM baseline upgrade
- Estimated Project Cost: \$106.1 M
- Project currently under construction

Example # 2

ROSSLYN 69 KV UG CABLE

Rosslyn 69 kV UG Cable

- Two Underground network 69 kV lines
Davis Substation and Rosslyn Substation
- These are Medium Fluid Field Lines (Oil)
- Installed in the 1971 to 1973 timeframe



Metric #1 - First Decision Point

Facility is nearing, or has already passed, its end of life

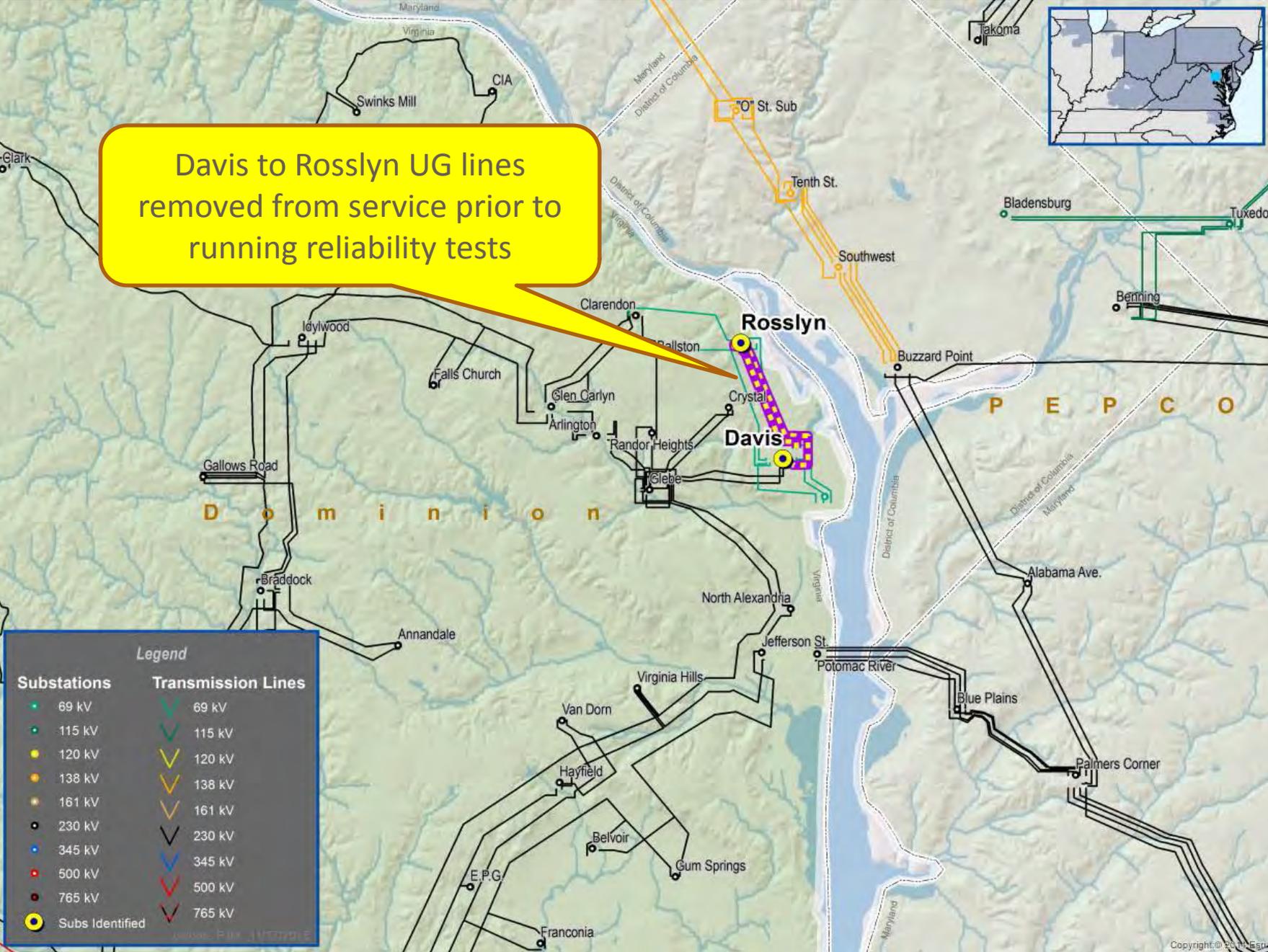
- Dominion's 69 kV Medium Pressure Fluid-Filled (MPFF) Lines #179 and #180 between Davis Substation and Rosslyn Substation were installed in the early 1970's (approx.1971-1973)
- Have exceeded their 30-35 year service life
- These self-contained cable installations have seen an increase in mechanical joint failures that has resulted in the loss of insulating fluid into the manholes
- Increased cost of maintenance and the lack of readily available spare parts are making the continued safe operation of these lines prohibitive

Metric #2 - Second Decision Point

Continued operation risks negatively impacting reliability of the transmission system

- Used the PJM 2020 RTEP Basecase
- Lines #179 and #180 between Davis Substation and Rosslyn Substation were removed from service in the power flow model
- Conducted the various reliability tests to determine risk of not having lines #179 and #180 available

Davis to Rosslyn UG lines removed from service prior to running reliability tests



Legend	
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● 69 kV	— 69 kV
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● Sub Identified	

Reliability Tests Findings

- System studies did not identify any issues that would result in a reduction of reliability for this area
 - No NERC, PJM, or Dominion criteria violations identified

Conclusion

- Violation of only Metric #1 of Dominion's End of Life criteria
- Since no reliability impact identified, Metric #2 was not met
- PJM reviewed and validated findings
- Solution is to de-energize and permanently retire lines #179 and #180
- Estimated Project Cost: \$2.5 M

Questions and Comments?