



Reliability Analysis Update

Transmission Expansion Advisory
Committee

May 4, 2017





2016 RTEP Load Deliverability Study “As Left” CETL

- 2016 RTEP Load Deliverability Study Assumptions
 - 2020 Summer Peak model created from 2021 Summer Peak RTEP base case
 - Same model used for 2020/21 RPM planning parameter development
 - Updated PJM loads based on January 2017 PJM Load Forecast Report
 - Updated transmission based on upgrades approved by PJM Board through December 2016
 - Update generation model through December 2016
 - Deactivations
 - Interconnection Projects
 - Update transmission service through December 2016

- Limiting facilities identified for LDAs with less than 150% margin or those that are to be modelled in the 2020/21 RPM auction



2016 RTEP Load Deliverability Study of Summer 2020

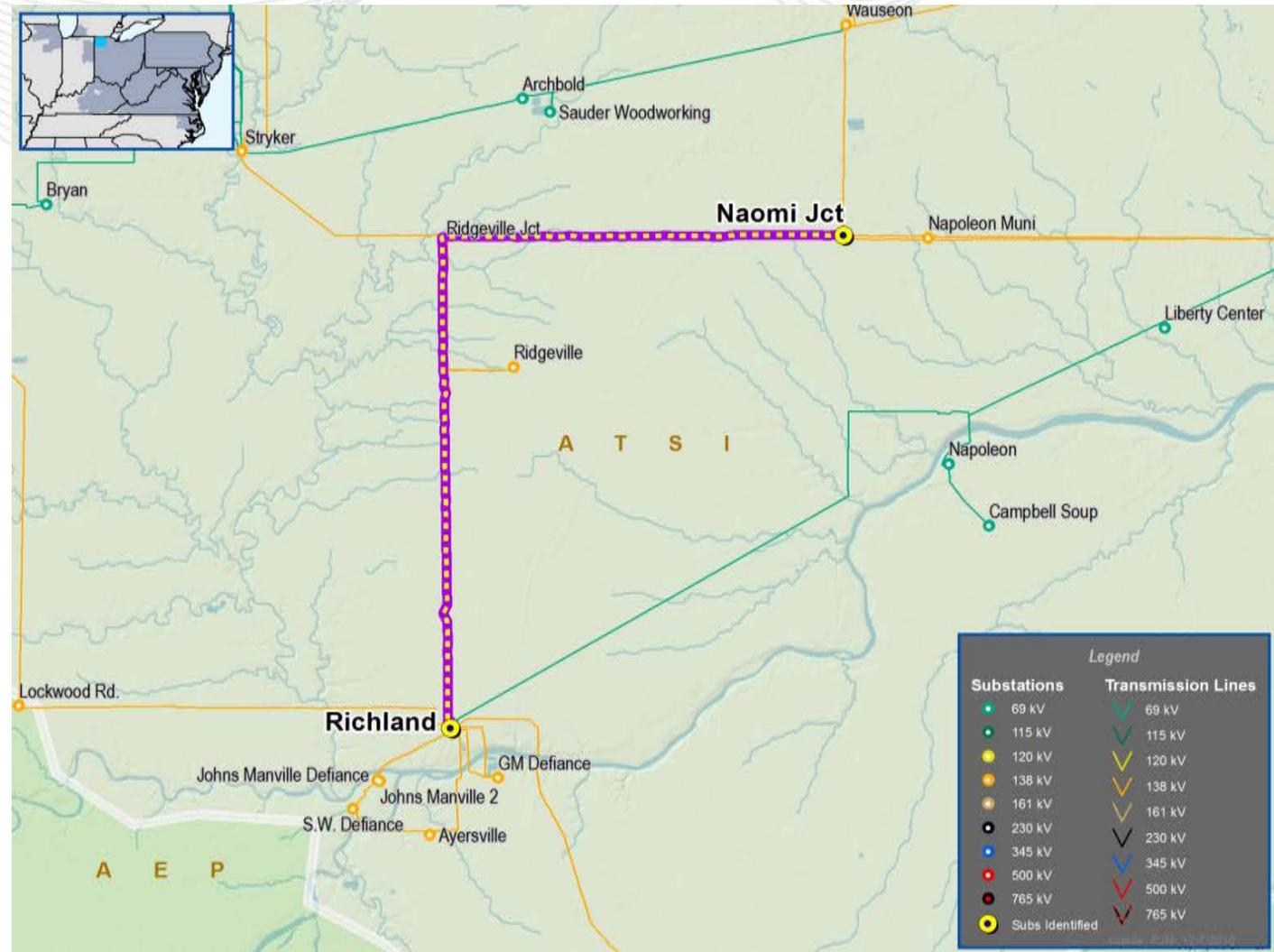
Area	MW CETO	MW 2020/21 CETL	2020/2021 Margin	Limiting Facility	Violation Type
AE	1140	>1793	>150%		None
AEP	-170	>0	*		None
APS	2020	>3463	>150%		None
ATSI	4660	9889	212%	South Canton-Harmon 345 kV line for the loss of the Hanna-Canton Central 345 kV line	Thermal
BGE	4410	6244	142%	Howard-Pumphrey 230 kV line pre-contingency (Base Case)	Thermal
CLEV	3540	5605	158%	Low Voltage at Hayes for the loss of the Hayes-Davis Besse 345 kV line	Voltage
COMED	640	4063.7	635%	Eugene-Dequin 345 kV line for the loss of the Greentown-Jefferson 765 kV line	Thermal
DAYTON	2550	3401	133%	Sugar Creek - OHH 138 kV line for loss of OHH - College Corner 138 kV	Thermal
DEOK	3650	5072	139%	Tanner-Miami Fort 345 kV line for the loss of the Terminal-South Bend 345 kV line	Thermal
DLCO	1530	>2554	>150%		None
DPL	910	>1808	>150%		None
DPL SOUTH	1230	1872	152%	Red Lion-Cedar Creek 230 kV for the loss of Cartanza-Milford 230 kV	Thermal
EKPC	560	>840	>150%		None
EMAAC	3650	8800	241%	Low Voltage at Cochranville 230 kV for loss of Keeney - Rock Springs 500 kV; low voltage at Hotpacong & Roseland 500 kV for loss of Branchburg - Hopatcong 500 kV	Voltage
JCPL	3430	> 5145	> 150%		None
MAAC	-7000	4218	*	Sandy Spring "2334" - High Ridge 230 kV for loss of Sandy Spring "2314" - Burtonville 230 kV	Thermal
METED	770	> 2167	> 150%		None
PECO	2690	>4035	>150%		None
PENELEC	-210	>383	*		None
PEPCO	1540	7625	495%	Voltage drop at High Ridge 230 kV station for the loss of Burches Hill-Possum Point 500 kV line	Voltage
PJM WEST	2350	>3525	>150%		None
PLGRP	-1010	7084	*	Wescosville 500/138 kV transformer pre-contingency (Base Case)	Thermal
PSEG	5900	8001	136%	Roseland-Cedar Grove 230 kV for loss of Roseland-Williams Pipeline 230 kV/low voltage at Hotpacong & Roseland 500 kV for loss of Branchburg - Hopatcong 500 kV	Thermal/Voltage
PSEG NORTH	2620	4264	163%	Roseland-Cedar Grove 230 kV for loss of Roseland-Williams Pipeline 230 kV/low voltage at Hotpacong & Roseland 500 kV for loss of Branchburg - Hopatcong 500 kV	Thermal/Voltage
SWMAAC	2900	9802	338%	Graceton-Bagley 230 kV CKT #1 and #2 for the loss of the one or the other	Thermal
VAP	-3010	>-928	*		None
WMAAC	-10140	>-5070	*		None

* LDA has adequate internal resources to meet the reliability criterion.

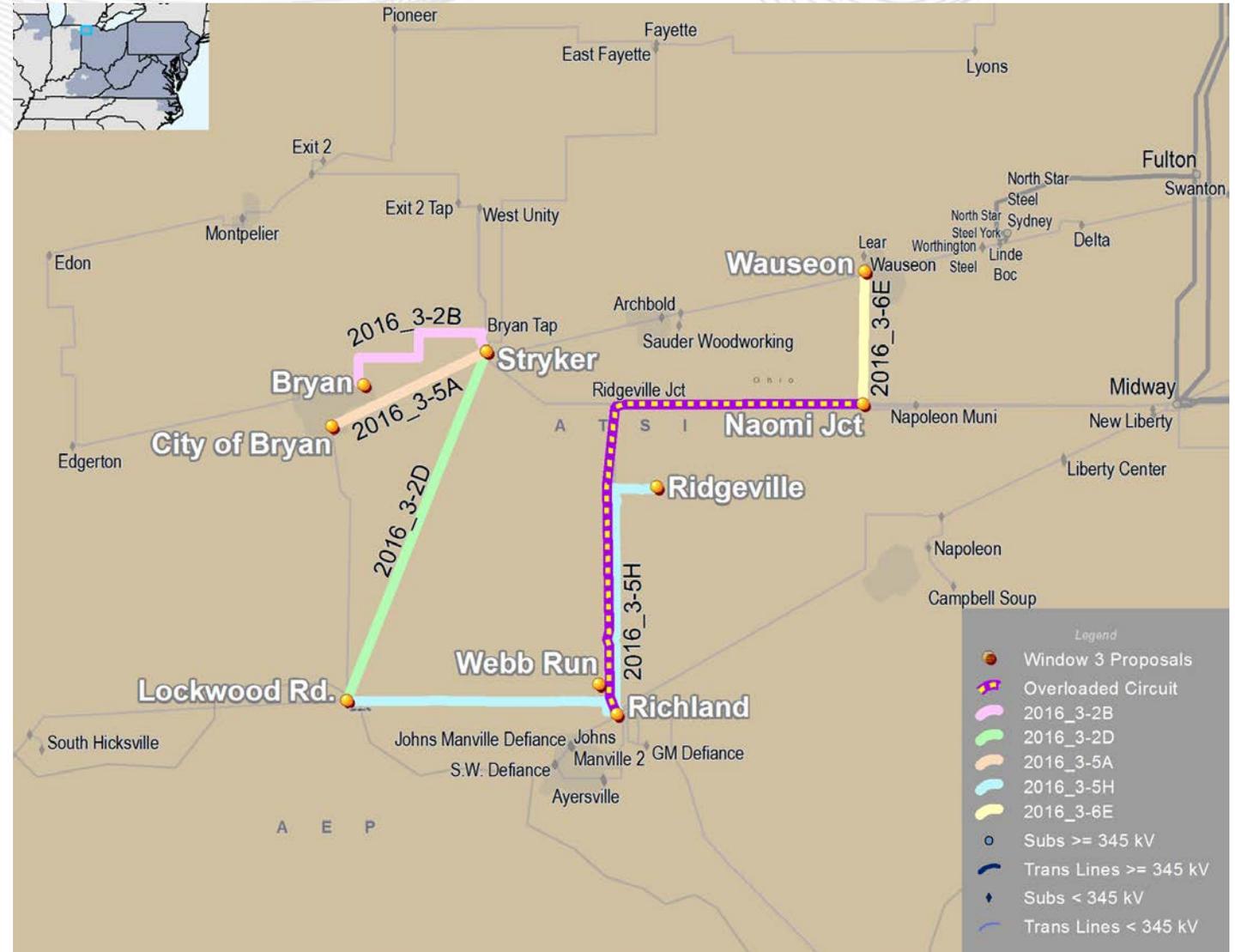


2016 RTEP Proposal Window 3

- 2016 RTEP Proposal Window #3
- Common Mode Outage Violations (FG# 1, 2, and 3):
- Richland to Naomi Junction 138 kV circuit is overloaded for multiple bus and line fault stuck breaker contingencies.
- Continued on the next slide...



- Continued from the previous slide...
- Alternatives considered:**
 - 2016_3-2B (\$ 8.3 M)
 - 2016_3-2D (\$ 17.2 M)
 - 2016_3-5A (\$ 8.5 M)
 - 2016_3-5H (\$ 6.1 M)
 - 2016_3-6E (\$ 9.1 M)



Summary of Project Alternatives

Project ID	Project Description	Proposing Entity	Cost Estimate (\$M)	Advantages	Disadvantages
2016_3-2B	Construct a new single circuit 138 kV line between Bryan Station and Stryker Station.	Transource (Greenfield)	8.3	Solves all identified flowgates	Requires a new ROW (~7 miles); relative high cost
2016_3-2D	Construct approximately 14 miles of new 138 kV line establishing a Lockwood Road – Stryker 138 kV Circuit.	Transource (Greenfield)	17.2	Solves all identified flowgates	Requires a new ROW (~14 miles); relative very high cost
2016_3-5A	Build a 138 kV line from the existing 138 kV City of Bryan substation to the existing 138 kV Stryker substation	NTD (Greenfield)	8.5	Solves all identified flowgates	Requires a new ROW (~7 miles); relative high cost
2016_3-5H	Build a 138 kV switching station ("Webb Run") interconnecting the Richland to Lockwood Road 138 kV line and the Richland LJ to Ridgeville 138 kV line	NTD (Greenfield)	6.1	Solves all identified flowgates	Building a new sub next to the existing substation to achieve the "reconfiguration of an existing substation"; Risk of substation site: if the location needs to move farther away from Richland substation it will probably increase the length of the 4 138kV lines ;
2016_3-6E	Eliminate three terminal line at Naomi Junction by constructing a double circuit line towards Wauseon substation. Wauseon substation will need to incorporate a new 138kV line exit by adding a 138kV breaker and relaying.	First Energy (Upgrade)	9.1	Solves all identified flowgates; Creates a third resource into Wauseon 69KV area where a potential reliability concern exists and eliminate the need for the pre-contingency switching of the Wauseon 138/69kV transformer under certain N-1 contingencies; Eliminate the three terminal lines and improve system protection and coordination.	Small margin (95.8% loading); relative high cost
PJM Solution	Relocate the Richland to Ridgeville 138KV line from Richland J bus to K, extend the K bus and install a new breaker.	PJM (Upgrade)	1.7	Solves all identified flowgates; lowest estimated cost	None

* PJM reviewed the proposed cost estimates and found the estimates were reasonable (within \$1~2M difference)

* The 2016_3-2D project cost allocation would be to both AEP and ATSI; the remaining proposals would be 100% allocated to ATSI

Recommended Solution:

PJM Proposed Solution: Transmission Owner Upgrade to Relocate the Richland to Ridgeville 138KV line from Richland J bus to K, extend the K bus and install a new breaker. (B2875)

Designated Entity: FirstEnergy (ATSI)

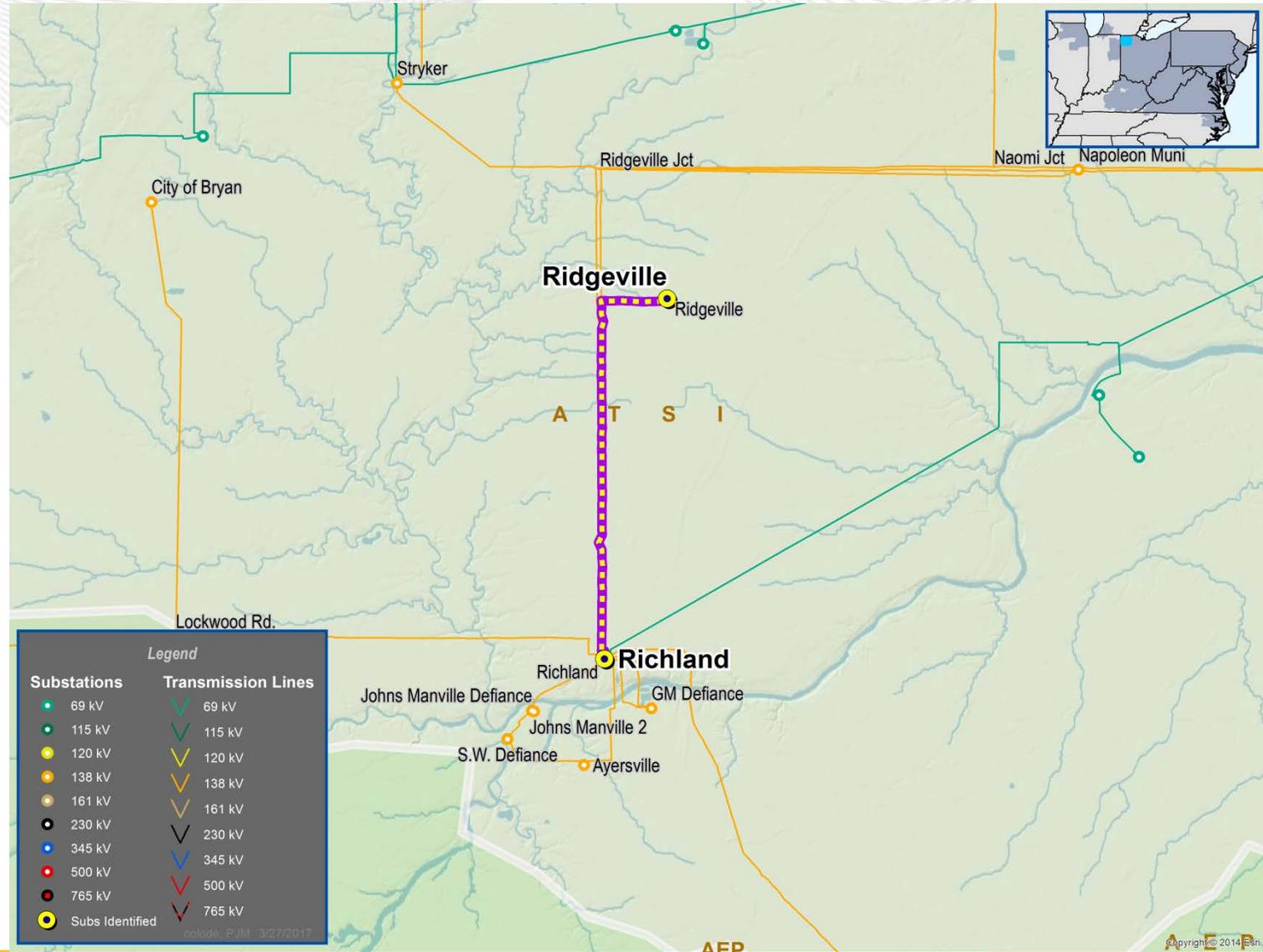
Estimated Project Cost: \$1.7M

Required IS Date: 6/1/2019

Cancel B2558: Close normally open switch A 13404 to create a Richland J Bus - Richland K Bus 138 kV line.

Estimated Cost: \$0.02M

Required IS Date: 6/1/2019



Dominion Reliability Analysis Update

Problem Statement: DOM “End of Life Criteria”

Date Project Last Presented: 4/13/2017 TEAC

- Line #247 Swamp to Suffolk 230kV is constructed primarily on wood H frames in 1968 (~49 years).
- This line needs to be rebuilt to current standards based on Dominion’s “End of Life” criteria.
 - Wood structure life is 35-55 years
 - Conductor & connectors are 40-60 years
 - Porcelain insulators are 50 years
- Permanent MW load loss for removal of this line is 21 MW.

Proposed Solution:

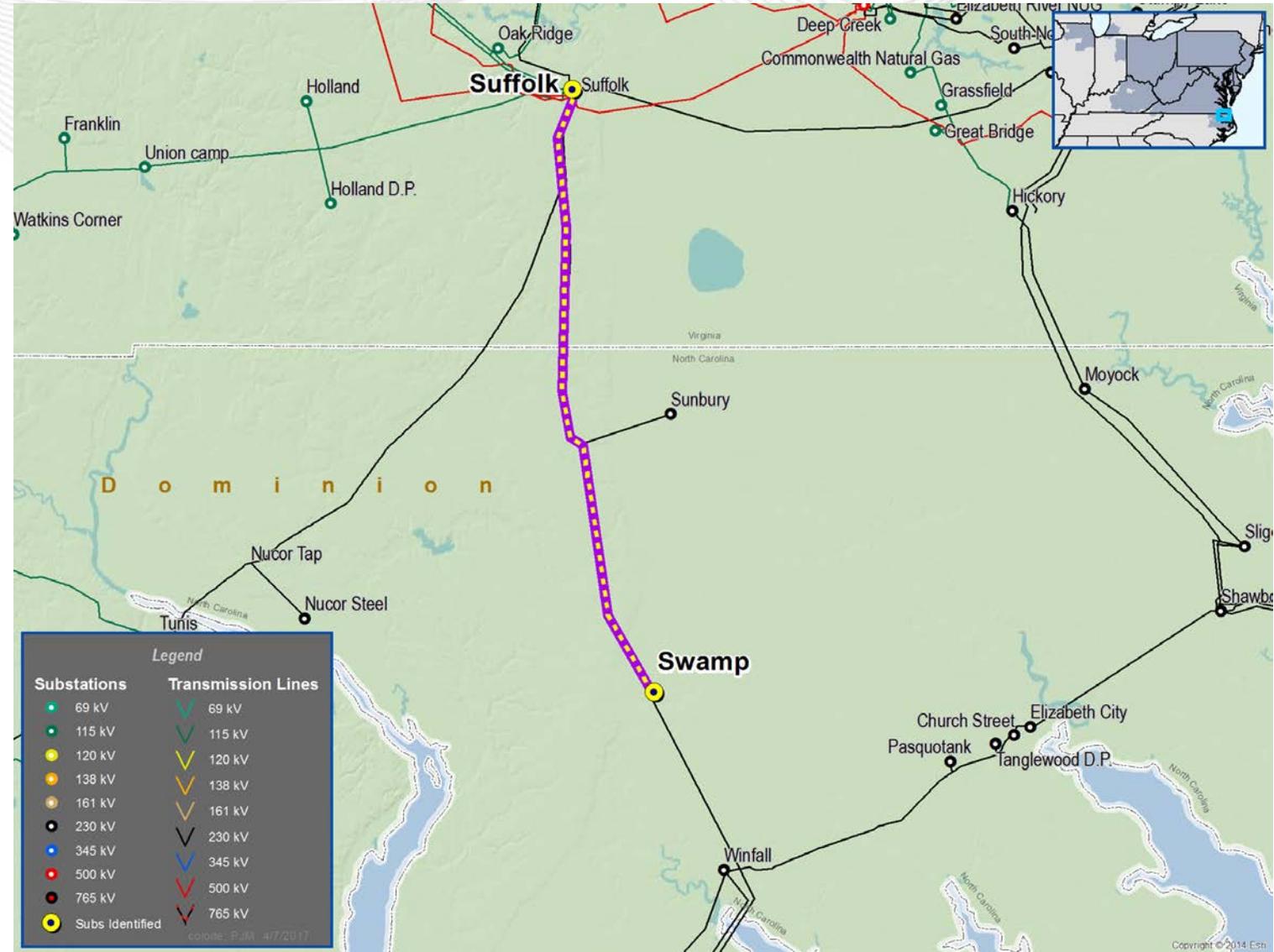
- Rebuild 230kV line #247 from Swamp to Suffolk (31 miles) to current standards with a summer emergency rating of 1047 MVA at 230kV. **(b2871)**

Alternatives: None

Estimated Project Cost: \$31 M

Projected IS Date: 12/30/2022

Project Status: Conceptual



Short Circuit

Short Circuit Violation

Problem Statement:

The South Canton 138 kV breakers 'M' and 'M2' are overstressed for a fault at South Canton 138 kV.

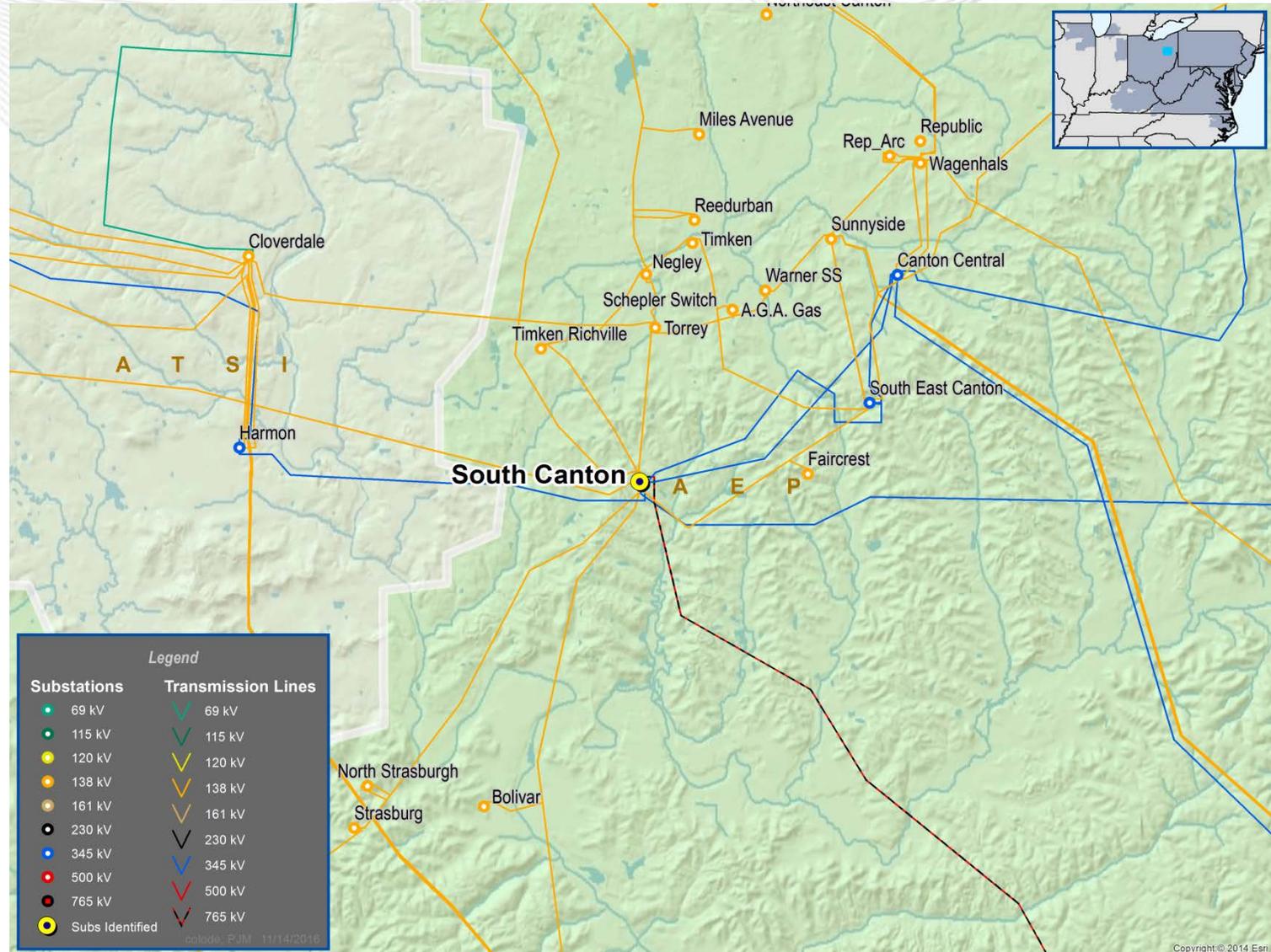
Proposed Solution:

Replace the South Canton 138 kV breakers 'M' and 'M2' with 80 kA breakers

Estimated Project Cost: \$600 K (per breaker)

Required IS Date: 6/1/2022

*Exempt from Proposal Window process per Operating Agreement, Schedule 6,1.5.8 (n).



Supplemental Projects

Supplemental Project: Amos - 345kV CB J2 Replacement

Previously Presented at 4/13/2017 TEAC

Problem Statement/Driver:

The Amos J2 345KV breaker is a 1970's air blast, PK type breaker. Air breakers are being replaced across the AEP system due to safety concerns regarding their catastrophic and violent failures. Air blast breakers tend to expel sharp pieces of porcelain from their bushings with failures which are a safety hazard. Additionally most of the PK's are near or at their life expectancy. Given they are being replaced across AEP, spare parts are becoming more difficult to find for break and fix scenarios. Breaker J2 has also suffered 17 fault operations that exceeds the manufacturer life expectancy on this category (10 operations).

Recommended Solution:

Replace Amos 345KV circuit breaker J2, 50kA CB with new 63 kA CB to match the rest of the breakers. (S1275)

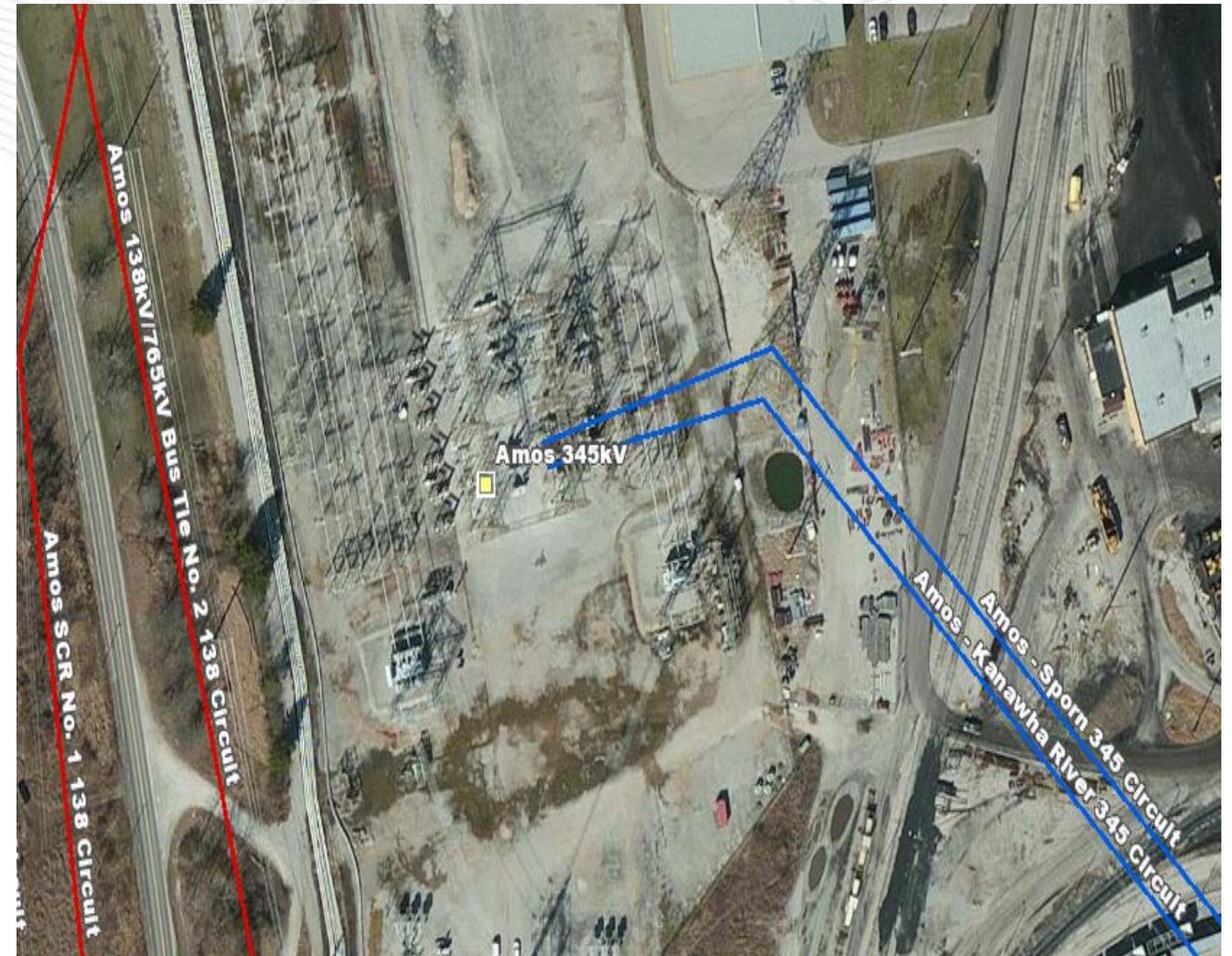
Alternatives:

No cost effective alternatives were identified.

Cost Estimate: \$0.83M

Projected IS date: 3/31/2017

Status: Under Construction





Supplemental Project: Hayden – 345 kV CB C1 and C2 Replacement

Previously Presented at 4/13/2017 TEAC

Problem Statement/Driver:

Breakers in this project to be replaced are all I.T.E. SF6 breakers that were both manufactured in 1974. AEP has been replacing this breaker type for several years now due to multiple bushing failures. There are only 7 breakers of this type left in the entire AEP system, including these. Breakers C1 and C2 have the following documented conditions: age and spare parts availability.

Recommended Solution:

Replace 345 kV 40 kA circuit breakers C1 and C2 with new 63 kA units at Hayden station to match the other breaker ratings at the Hayden 345kV station. (S1276)

Alternatives:

No cost effective alternatives were identified.

Cost Estimate: \$2.255M

Projected IS date: 8/31/2017

Status: Under Construction





Supplemental Project: Hyatt Breaker Replacements

Previously Presented at 4/13/2017 TEAC

Problem Statement/Driver:

Breakers in this project to be replaced are all I.T.E. SF6 breakers that were manufactured in 1974. AEP has been replacing this breaker type for several years now due to multiple bushing failures. There are only 7 breakers of this type left in the entire AEP system, including these. Breakers 302N, 302C and 302S have the following documented conditions: age and repair parts availability.

Recommended Solution:

Replace Hyatt 345 kV 50 kA circuit breakers 302N, 302C and 302S with new 5000 A 63 kA units (S1277)

Alternatives:

No cost effective alternatives were identified.

Cost Estimate: \$3.13M

Projected IS date: 11/22/2017

Status: Under Construction



Supplemental Project: Dumont 765/345kV Transformer Replacement

Previously Presented at 4/13/2017 TEAC

Problem Statement/Driver:

Dumont 765/345kV transformer T1 was manufactured in 1977. It has the following documented conditions: age, bushing maintenance issues, dielectric breakdown, oil quality, partial discharge readings and insulation breakdown. To avoid neutral current imbalances, all three single phase transformers will be replaced.

Recommended Solution:

At Dumont station, replace the existing 765/345kV 500MVA transformer T1 with new 765/345kV/34.5 750MVA transformer T3 and a spare T3SP 765/345kV/34.5 750MVA transformer along with associated equipment and protection. (S1278)

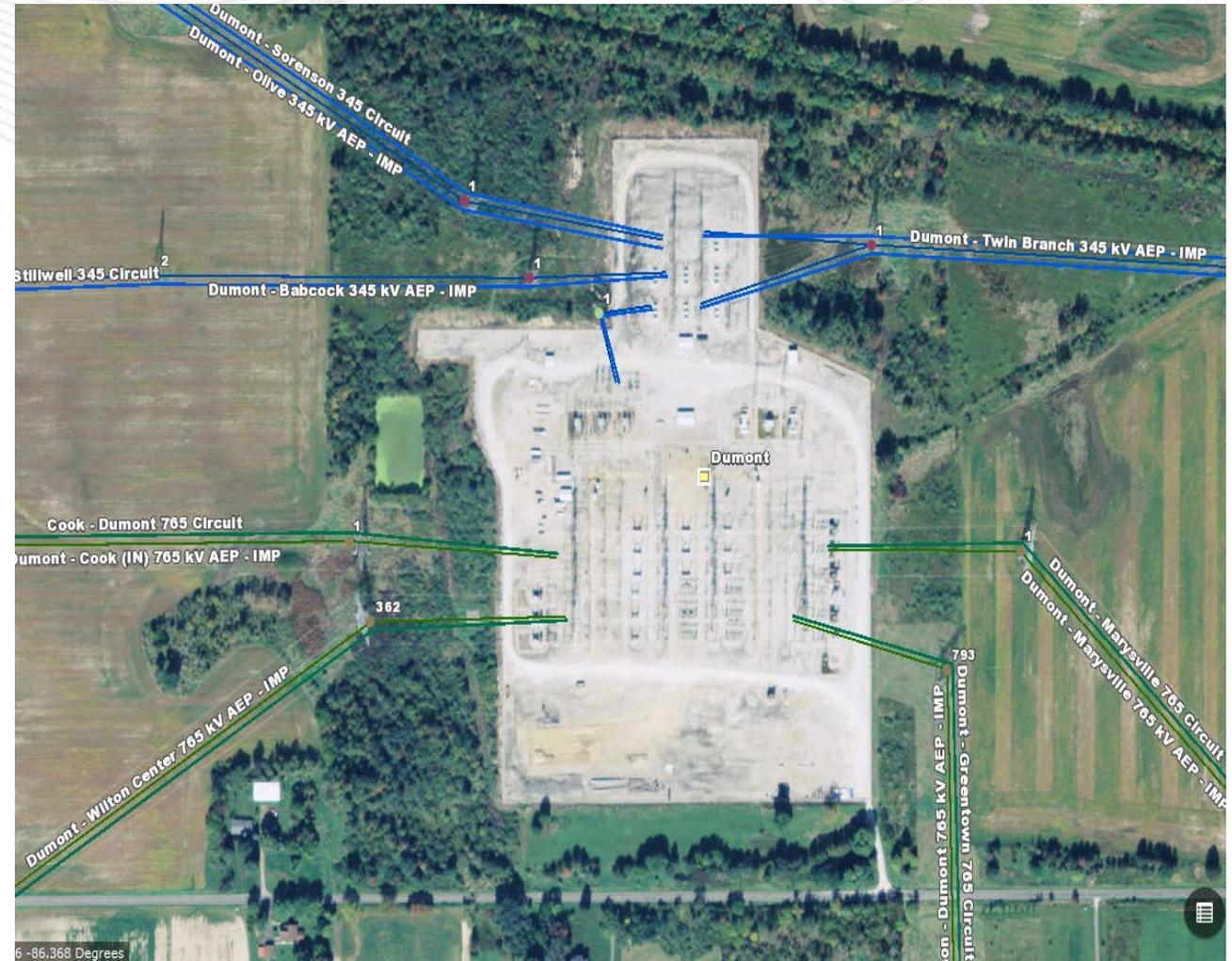
Alternatives:

No additional cost effective alternatives were identified.

Cost Estimate: \$43.743M

Projected IS date: 12/29/2017

Status: Engineering



**Supplemental Project: Olive-Bosserman 138 kV
Previously Presented at 4/13/2017 TEAC and 4/21/2017
Western SRTEAC**

Problem Statement/Driver:

The LaPorte Junction - New Carlisle 34.5 kV circuit has a vintage from 1930s and is wood pole construction. Between 2010-2015, ~2 million customer minutes of interruption (CMI) were recorded at Silver Lakes station. There are 183 open conditions, 95 of which are category A conditions on the ~20 mile long line.

Indiana and Michigan Power Company has requested to convert Silver Lake and Springville to 138 kV operation.

This project would also resolve congestion on the Olive-Bosserman 138 kV identified during MISO-PJM JOA market efficiency studies in addition to addressing the a potential overload identified on this facility during the PJM 2021 RTEP. It was submitted (without the new distribution station additions) to the PJM reliability and market efficiency windows.

Recommended Solution:

Construct two 138/12 kV distribution stations, Bootjack and Marquette, to replace Silver Lake 34.5 kV and Springville 69 kV stations. (S1279.1)

Cut the existing Olive – Bosserman line into New Carlisle station. (S1279.2)

Rebuild sections of the LaPorte Junction-New Carlisle/New Buffalo 34.5 kV line to 138 kV to establish Bootjack-Olive 138 kV circuit. (S1279.3)

Install a three way phase over phase switch, called Kuchar, near Liquid Carbonics station and construct a new 138 kV line between Bootjack and Kuchar. (S1279.4)

Construct a 138 kV extension to Marquette station by tapping the Bosserman-Liquid Carbonics 138 kV line. (S1279.5)

Alternatives:

Rebuild ~20 mile long New Carlisle – LaPorte Junction 34.5 kV utilizing existing line ROW corridor. This alternative was not selected because it did not provide the operational flexibility & efficiency and customer service benefits provided by the preferred option. Estimated cost: ~\$32M

Cost Estimate: \$36.786M

Projected IS date: 12/1/2019

Status: Conceptual





Supplemental Project: Olive Station Breaker Replacement

Problem Statement/Driver:

The Circuit Breaker E2 at Olive Station is an SF6, FX-22 type manufactured by GE. There are only 11 of this type in the entire AEP system. Additionally, physical space limitations do not allow ground switches to be installed on the existing breaker. This breaker has had 48 fault operations, exceeding the manufacturer's recommended limit of 3.

Potential Solution:

Replace existing 345kV 50 kA CB E2 at Olive station with a 5000A 63kA circuit breaker along with associated equipment and protection.

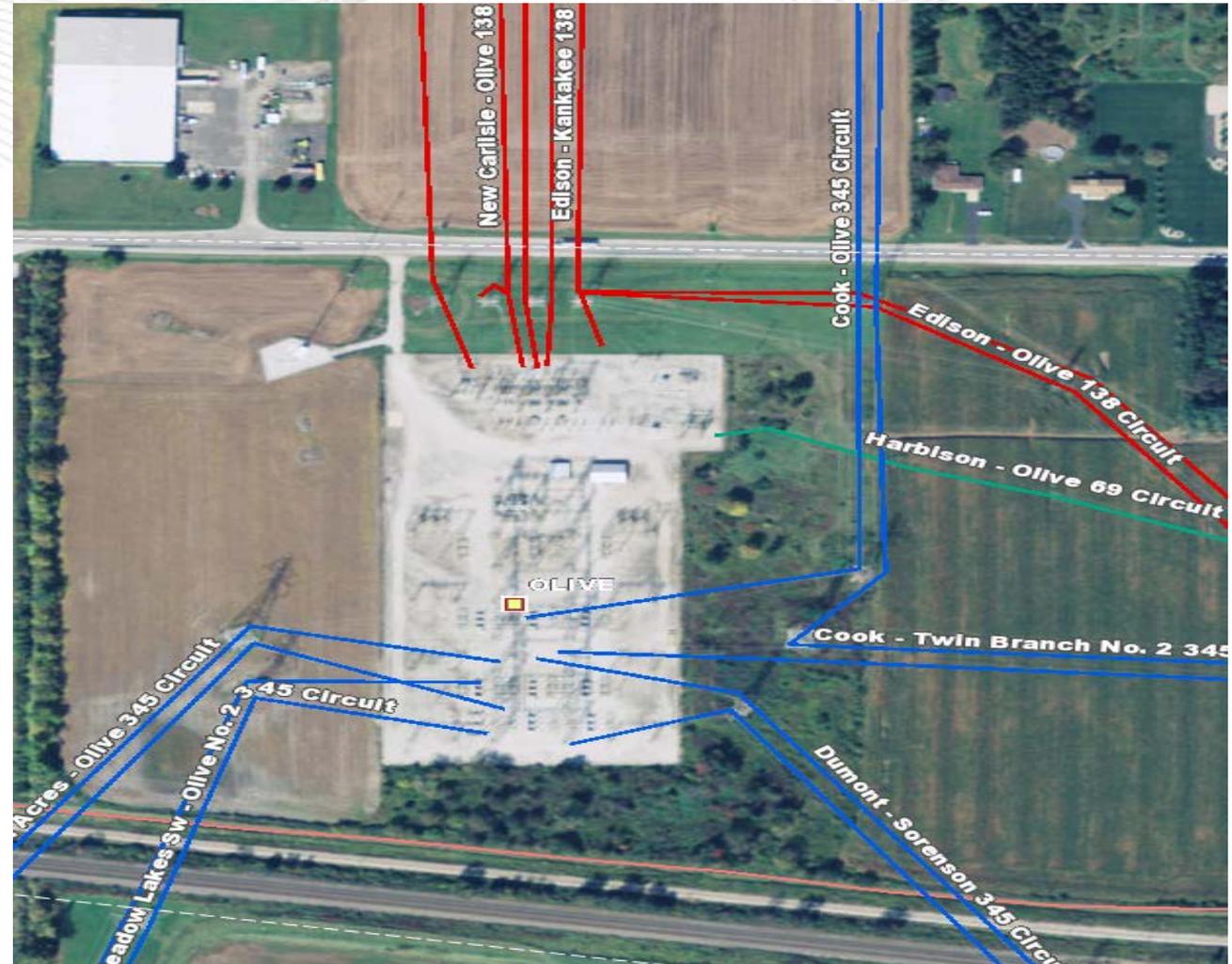
Alternatives:

No additional cost effective alternatives were identified.

Cost Estimate: \$1.077M

Projected IS date: 5/19/2017

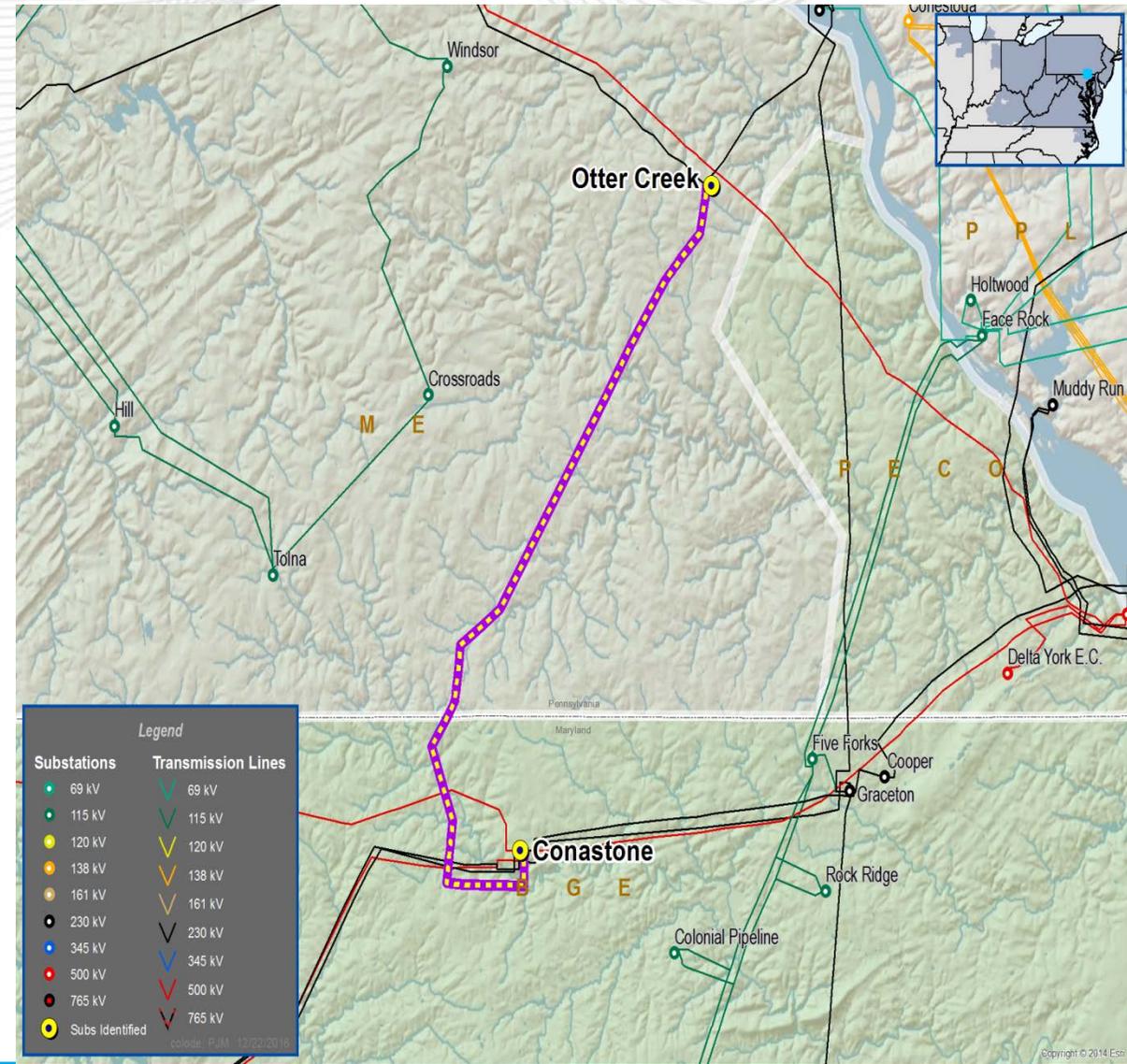
Status: Engineering



**Supplemental Upgrade:
Conastone to Otter Creek #2302 230 kV Line Rebuild and Protection and
Communications Upgrade**
Previously presented: January 5, 2017

Problem Statement:

- Line #2302 is a 230 kV tie line between the BGE Conastone substation and the PPL Otter Creek Substation. The line is 85 years old.
- The line uses a power line carrier blocking relay scheme that is currently less reliable and a frequent contributor to misoperation(s). BGE standards call for dual pilot channels on 230 kV circuits. BGE has retired all internal PLC blocking schemes within the BGE zone and on all BGE tie lines with PEPCO in an effort to modernize the communication and protection systems.
- PPL identified this line to be rebuilt as part of supplemental project S0233 due to significant aging infrastructure concerns in their zone. To resolve this, PPL is rebuilding 12 miles of its portion of the line to 1590 ACSR, installing OPGW and upgrading relaying as part of PPL supplemental project S0233. This supplemental project was completed in February 2017.
- The line segment is only 7 towers long and there are routine maintenance issues regarding buried foundations, rusted steel at the foundation, and bent tower steel that are being managed. Maintenance inspections on a recently replaced BGE circuit similar (same age and structure configuration) to #2302 revealed the following problems:
 - Degraded phase conductors due to core wire corrosion, and aluminum annealing.
 - Temporary clearance mitigations previously installed need permanent resolutions
 - Steel corrosion at the foundation interface due to recurring soil cover
 - All the insulators need replacement due to pin/cap corrosion as well as degraded porcelain due to years of lightning exposure. The attachment hardware and attachment plates are worn and need to be replaced
- BGE needs to address its portion of the tie line





BGE Transmission Zone

Supplemental Upgrade: Conastone to Otter Creek #2302 230 kV Line Rebuild and Protection and Communications Upgrade

Previously presented: January 5, 2017

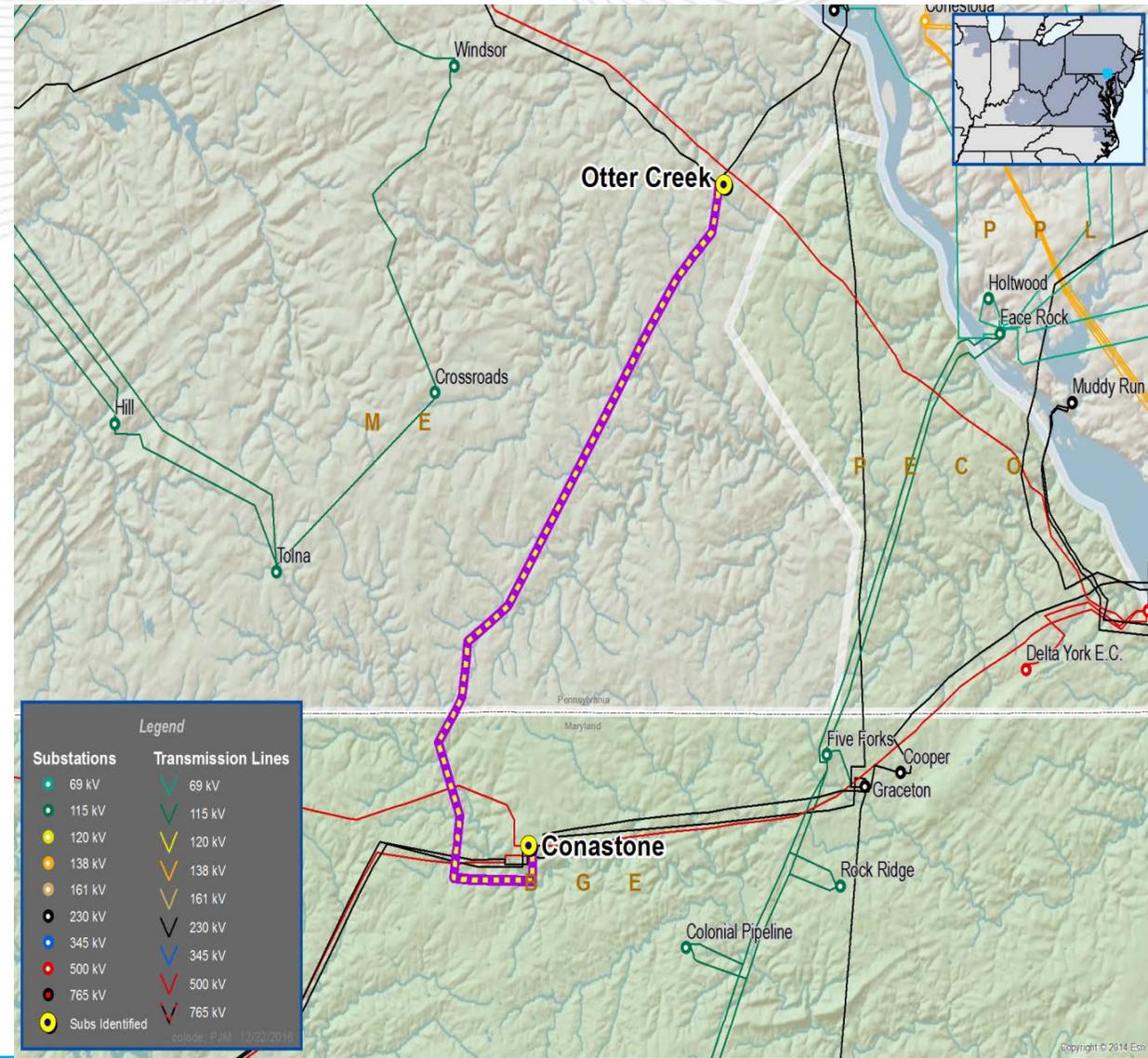
Proposed Solution:

- Rebuild 1.6 miles of the #2302 transmission circuit with 1590 ACSR, remove existing wave trap, replace static wire with OPGW, and install new communications and upgrade protective relaying equipment thereby matching PPL's construction.

Estimated Project Cost: \$ 4.08 M

Projected IS Date: 06/01/2018

Project Status: Engineering and Construction





DEOK Transmission Zone

Supplemental Project: - Remove Beckjord U6 Feeder

Previously Presented at 4/13/2017 TEAC

Problem Statement/Driver:

Beckjord Unit 6 was retired October 2014. The GSU has been removed. The connecting 345kV feeder from the GSU to Pierce substation is no longer in use and crosses over a state highway. The single support tower and the feeder are over fifty years old and in declining condition. Need to remove the risk of the feeder falling onto the highway.

Recommended Solution:

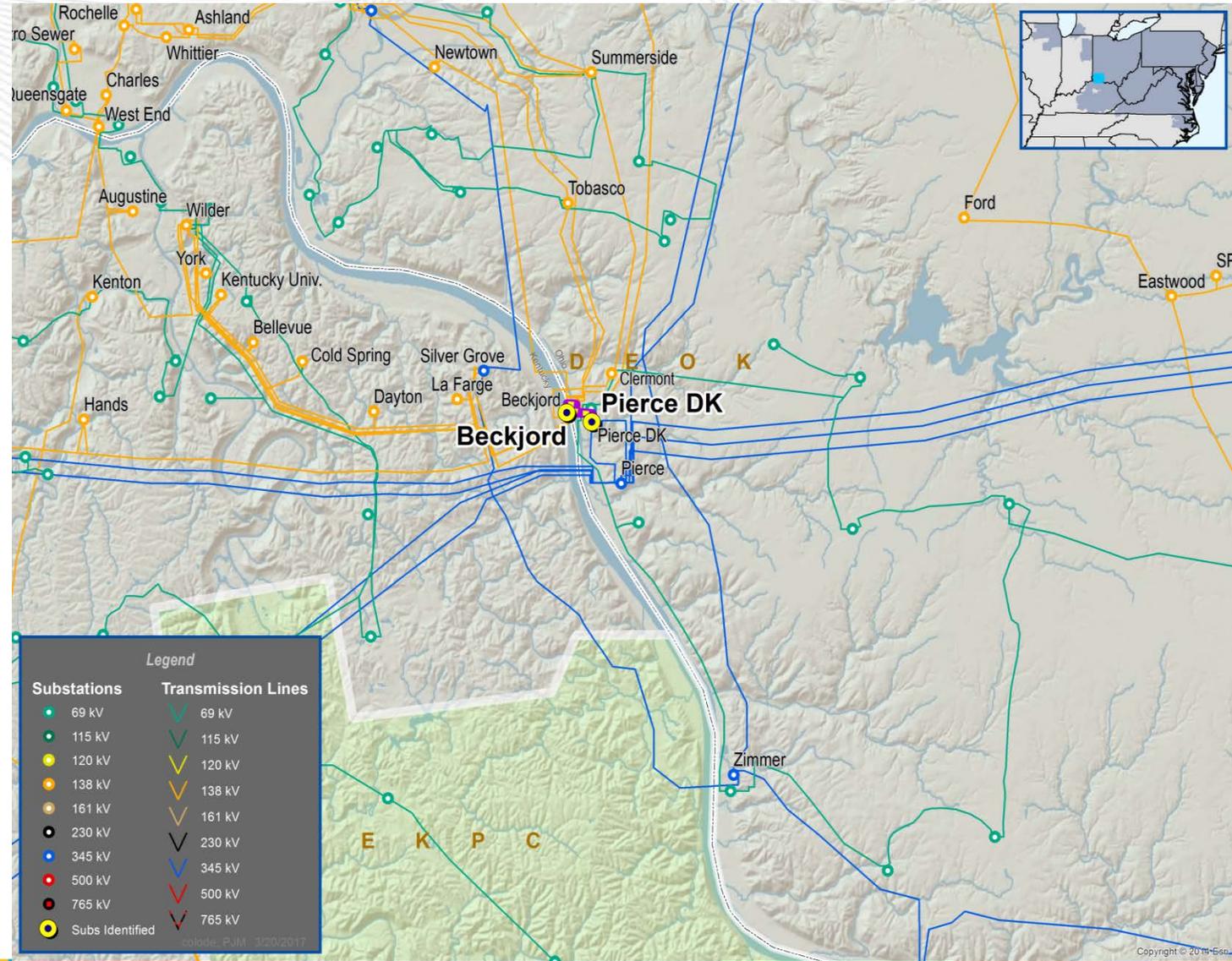
Remove Beckjord 345kV from the GSU to Pierce substation feeder and support tower. (S1274)

Alternatives: No cost effective alternatives identified

Cost Estimate: \$0.121M

Projected IS date: 12/31/2017

Status: Engineering





Dominion Transmission Area

Supplemental Project: Poolesville Station
Date Project Last Presented: 4/13/2017 TEAC
Problem Statement: Operational Performance

- On Jan 26, 2017 a ground fault occurred when closing the 21416 switch at Poolesville substation to energize the Poolesville to Winchester section of the 214 Line.
- In depth field inspection found the switch to be in good working condition.
- On February 11, 2017, while returning the 21416 switch to service, a large arc formed across the switch contacts. Had weather events been different (ex: stronger wind), another fault could have occurred. See photo at bottom of slide.
- Initial engineering studies and analyses indicate that heavy mutual coupling from other transmission lines is the root cause. Heavy mutual coupling results in an increased voltage difference between the open contacts of the switches, greater than the capability of the switches

Proposed Solution:

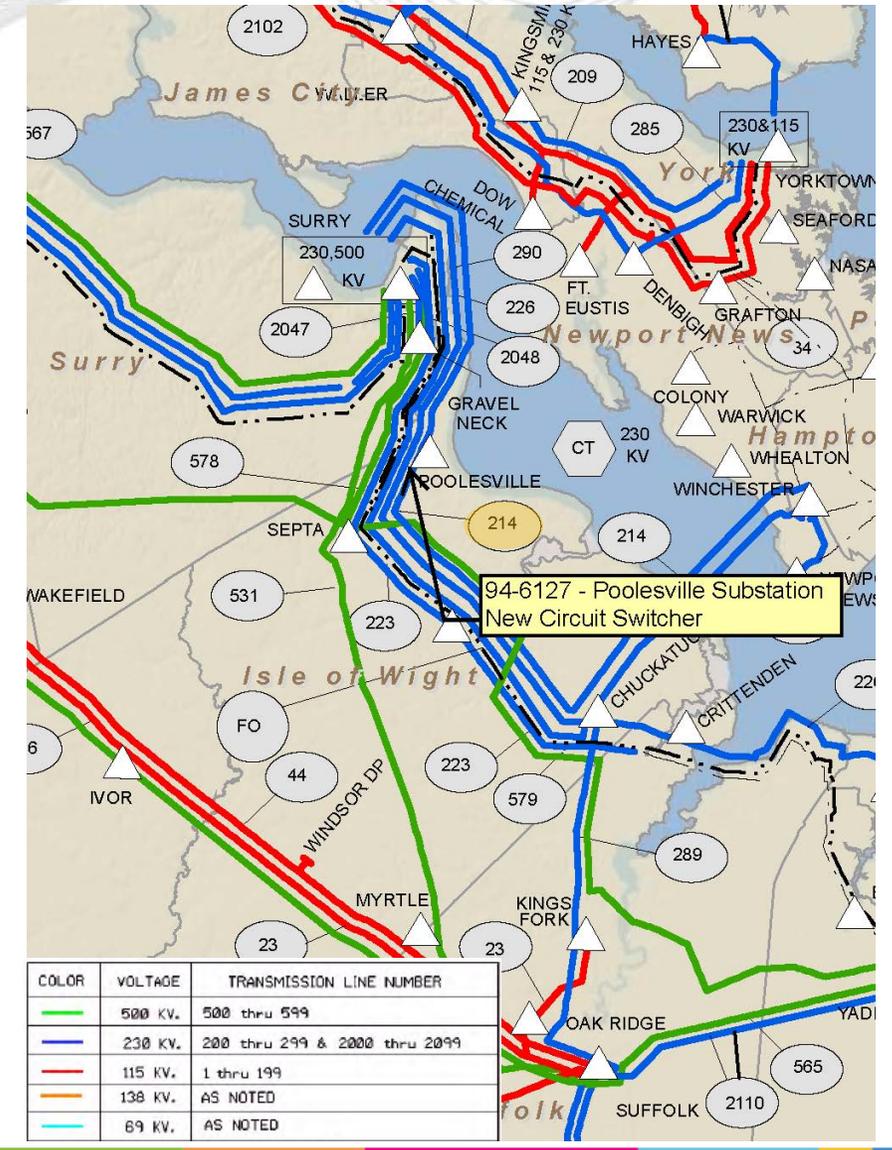
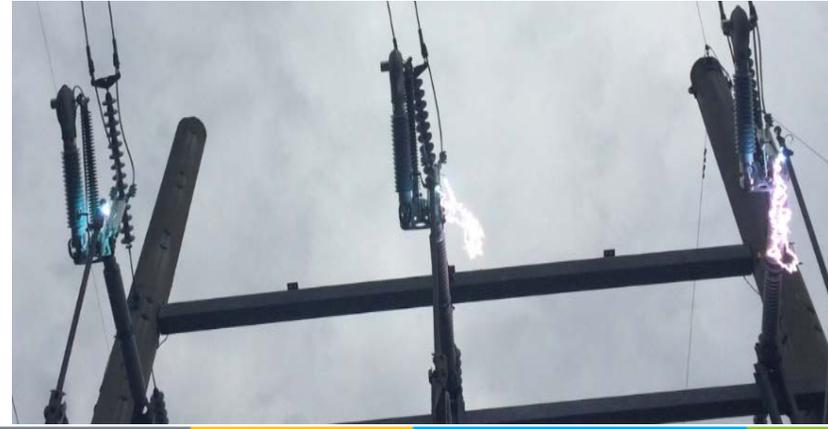
- Install a Circuit Switcher in series with line switch 21416 at Poolesville to enable line switching and address this operational performance problem. **(s1270)**

Alternatives: No cost effective alternatives identified

Estimated Project Cost: \$410 K

Projected IS Date: 04/13/2017

Project Status: Under Construction





Dominion Transmission Area

Supplemental Project: Reeves Ave Station

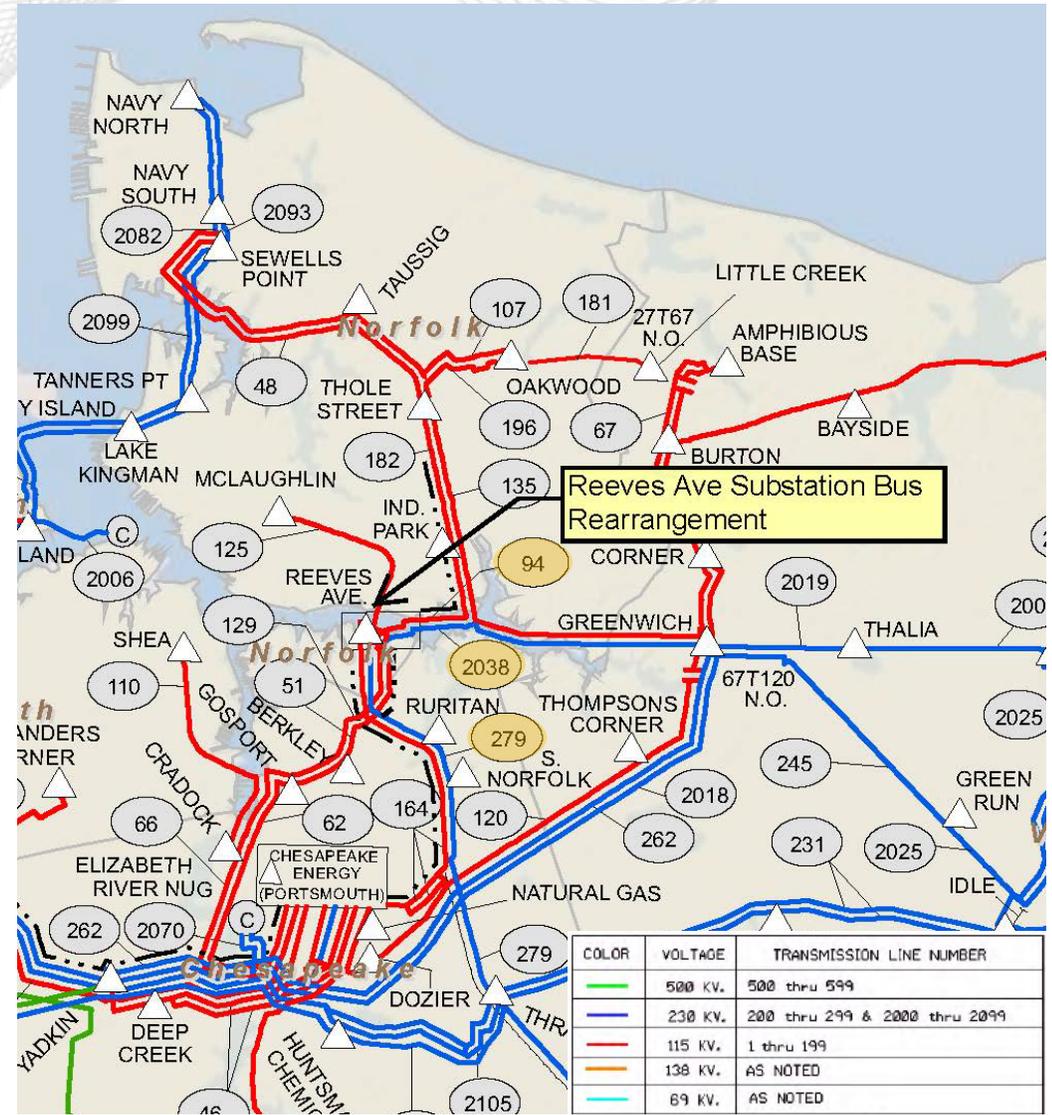
Date Project Last Presented: 4/13/2017 TEAC

Problem Statement: Operational Performance

- Reeves Ave 230kV configuration: 230/115kV transformers #4 and #5 are hung off 230kV Line #279 from Reeves Ave to Thrasher and Line #2038 from Reeves Ave to Greenwich respectively with sectionalizing schemes
 - Fault on the 230kV lines remove network transformer, and fault on transformers trip corresponding line, interrupting the network and any tapped load.
 - Breaker maintenance on the 230kV tie breaker opens the 230kV network.

- Reeves Ave 115kV configuration: 115/34.5kV transformer #6 is hung off 115kV Line #94 from Reeves Ave to Industrial Park with sectionalizing scheme, 115/34.5kV transformer #2 and #3 connect to 115kV bus #2 and #1 respectively with sectionalizing schemes, multiple 115kV lines connect to corresponding bus with breakers.
 - Fault on line #94 removes transformer #6 affecting about 3000 customers, fault on transformer #6 trips Line #94, interrupting the network.
 - Fault on transformer #2 or #3 trips all 115kV lines associated with corresponding bus, interrupting the network.

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Dominion Transmission Area

Supplemental Project: Reeves Ave Station

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Proposed Solution:

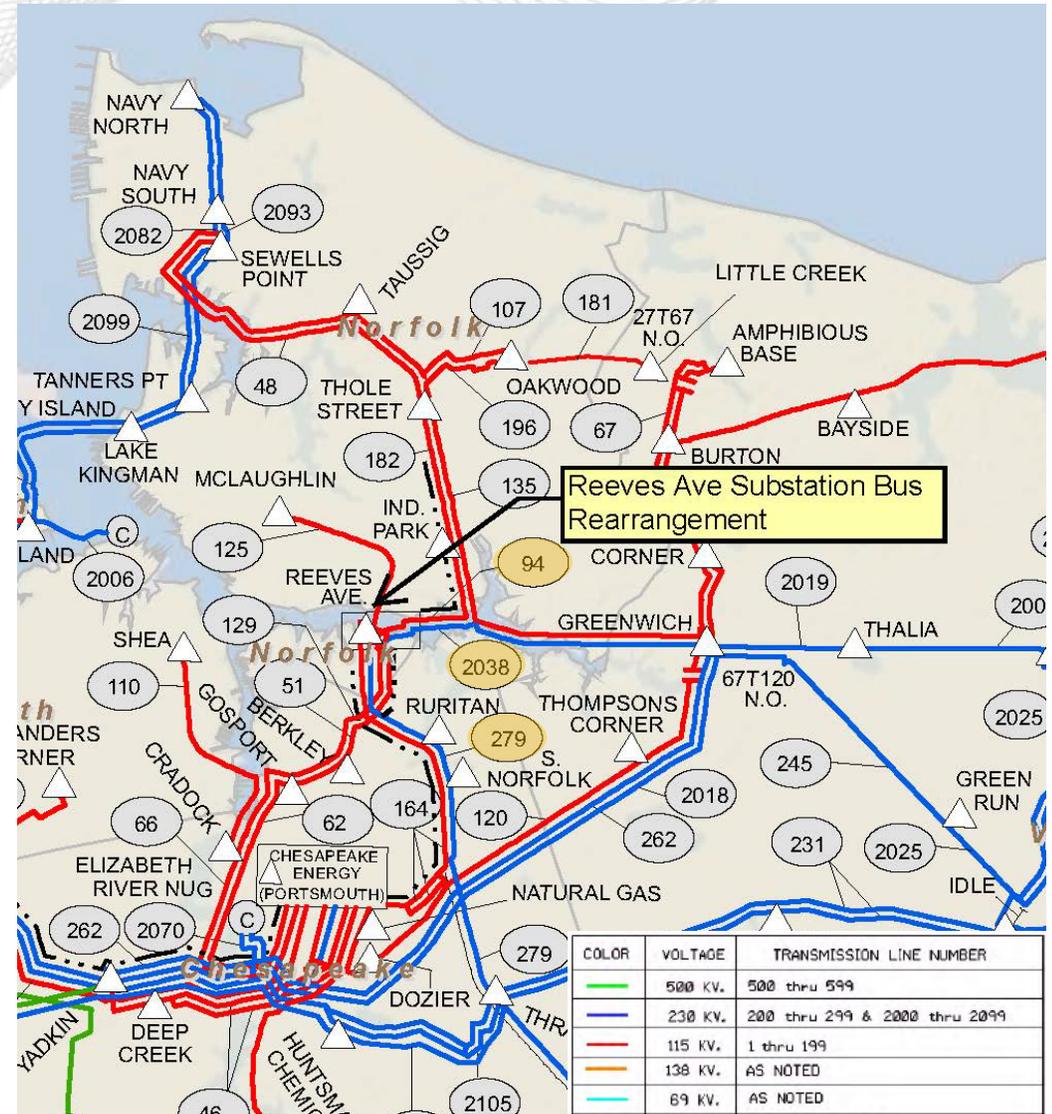
- New Reeves Ave 230kV configuration: Install three 230kV breakers to form a 4-breaker ring bus. **(s1271.1)**
 - A fault operation on 230kV lines maintains network flow through both transformer #4 and #5. A transformer #4 or #5 fault operation will no longer trip the associated line, maintaining the integrity of the grid and service to the tapped load.
 - Breaker maintenance on any 230kV breaker in the ring does not effect network flows.
- 115kV configuration: Install 115kV breakers on high side of transformer #2, #3, and #6. **(s1271.2)**
 - A fault operation on the Line #94 does not affect the transformer #6 load.
 - A transformer #2, #3 or #6 fault operation will no longer trip the associated line or bus, maintaining the integrity of the grid and service to the network and tapped load.

Alternatives: None

Estimated Project Cost: \$5.2 M

Projected IS Date: 12/15/2018

Project Status: Engineering





Dominion Transmission Area

Supplemental Project: Reeves Ave Transformer

Date Project Last Presented: 4/13/2017 TEAC

Problem Statement:

- Reeves Ave TX#4 (230-115-13.2 kV 224 MVA, installed 1988) and TX#5 (230-115-13.2 kV 168 MVA, installed 1984) need to be replaced due to age and increased maintenance
- Dominion Transformer Health Assessment “THA” identified need

Proposed Solution:

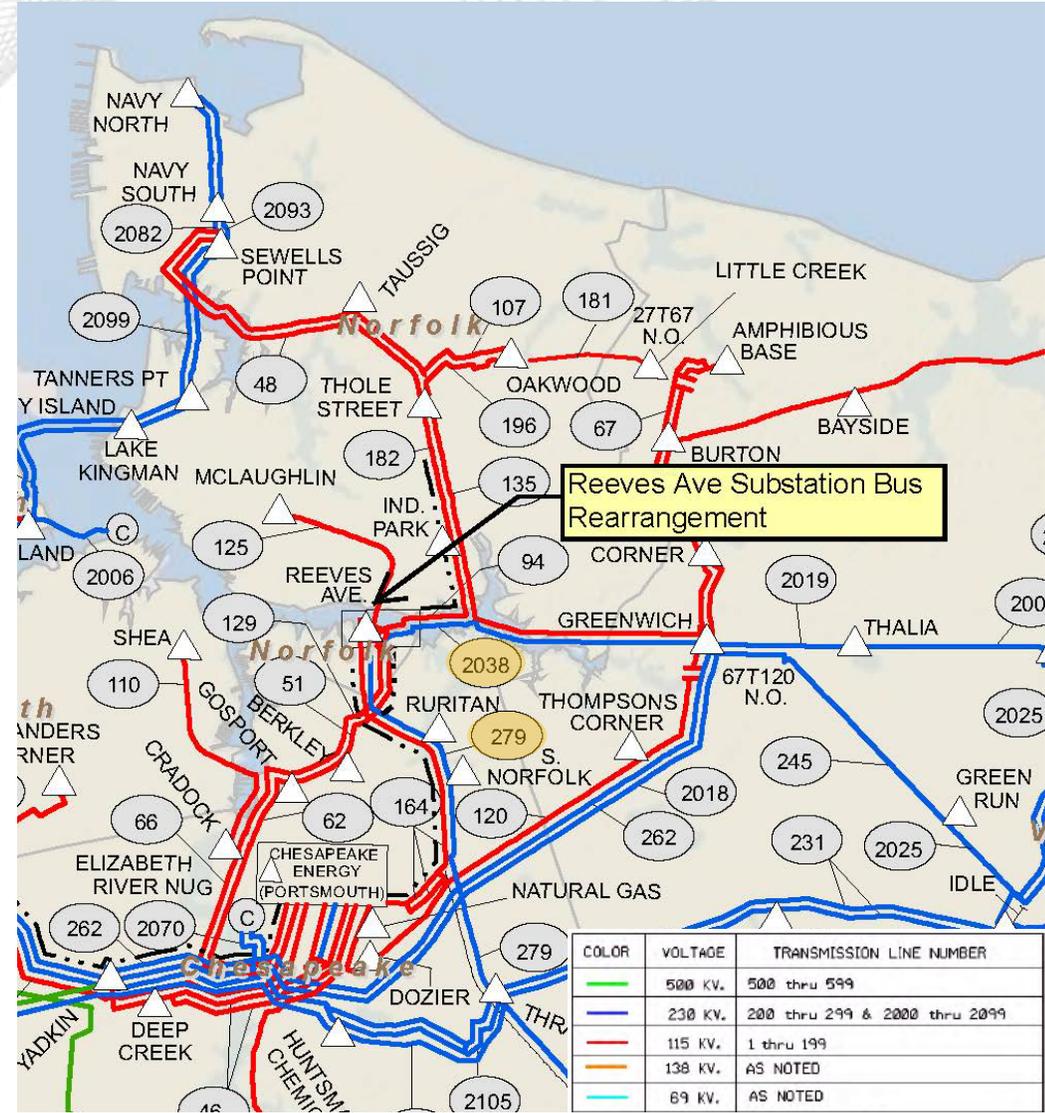
- Replace TX#4 and TX#5 with new 168MVA (nameplate rating) transformers. **(s1272)**
- A study has been performed to verify the ratings are sufficient.

Alternatives: None

Estimated Project Cost: \$8.7M

Projected IS Date: 01/31/2018

Project Status: Engineering



2017 RTEP Next Steps

- Preliminary 2022 Summer results posted
 - Baseline N-1 Thermal
 - Generation Deliverability - Thermal
- Anticipated next Steps for Summer (N-1-1 Thermal and Voltage as well as Load Deliverability and Baseline N-1 Voltage)
- Finalize Light Load case Model
- Finalize Winter case Model
 - Begin Light Load and Winter analysis

Questions?

Email: RTEP@pjm.com

- Revision History
 - V1 – 5/1/2017 – Original Version Posted to PJM.com