Reliability Analysis Update

Transmission Expansion Advisory Committee

November 9, 2017

2017 RTEP
Reliability Analysis Update

2017 RTEP Reliability Solutions Status

- 2017 RTEP Proposal Window #1
  - Remaining issues and corresponding solution alternatives

Supplemental Projects

AEP Transmission Zone: Supplemental Cloverdale Breaker Replacement

Supplemental Project

Problem Statement:

Equipment Material/Condition/Performance/Risk:

At Cloverdale station, 345 kV circuit breakers “P” and “P2” are 63 kA GEC, PK-4C type Air Blast breakers . Air blast breakers are being replaced across the AEP system due to reliability concerns, intensive maintenance, and their tendency to catastrophically fail. During failures, sharps pieces of porcelain from their bushings are typically expelled, which, can be a potential safety hazard to field personnel. In addition, the ability to get spare parts for these breakers is becoming increasingly difficult. The Manufacturers recommended number of fault operations is 10. Breaker “P” has experienced 25 fault operations.

Potential Solution:

At Cloverdale station, replace 2- 345 kV PK type breakers (“P” & “P2”) with new 345 kV, 5000 A, 63 kA breakers. Install new 345 kV 5000 A disconnect switches on both breakers. Install new 345 kV surge arresters on both 345 kV Busses (#1 & #2).

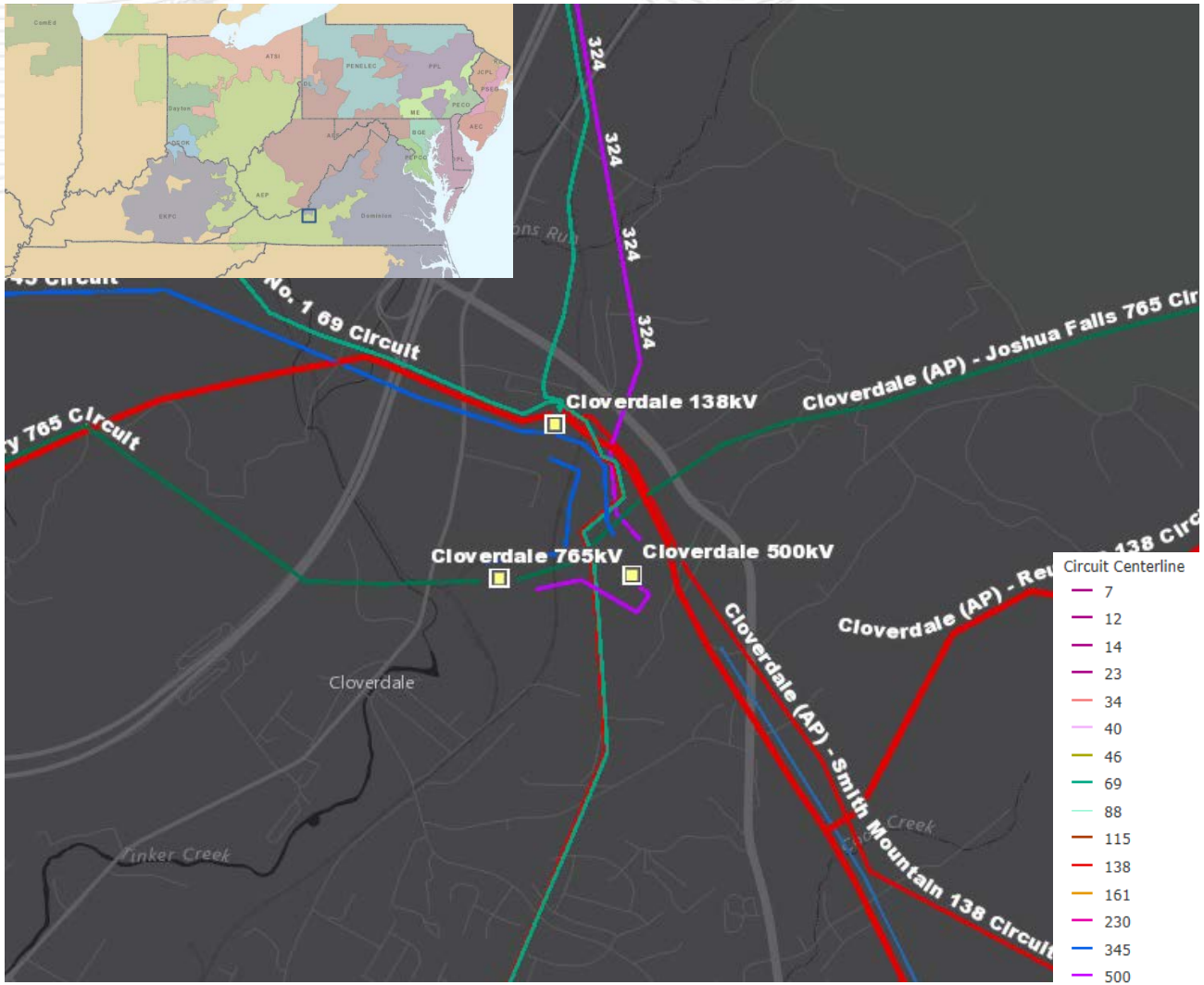
Estimated Transmission Cost: $4.7M

Alternatives:

- No viable cost-effective alternatives identified

Projected In-service: 11/29/2018

Project Status: Engineering



AEP Transmission Zone: Supplemental Kenzie Creek Breaker Addition

Supplemental Project
Problem Statement:

Operational Flexibility and Efficiency

Motor Operated Air Break Switches (MOABs) have been utilized in the past as a less costly alternate to Circuit Breakers. MOABs at Extra High Voltage (EVH) unnecessarily subject expensive equipment, such as Transformers, to grid events in order to isolate a faulted section of the grid. This not only reduces the life of such expensive equipment, but also results in misoperations. It is AEP's practice to not install MOABs for fault sectionalizing at EHV. In addition, AEP is proactively replacing all EHV MOABs at existing stations with circuit breakers.

Potential Solution:

At Kenzie Creek station, retire 345kV MOABS 'W' and 'Y'. Install 3 345kV 5000A 63kA breakers in a ring bus configuration. Set up station to allow for future 'B' and 'C' breaker strings.

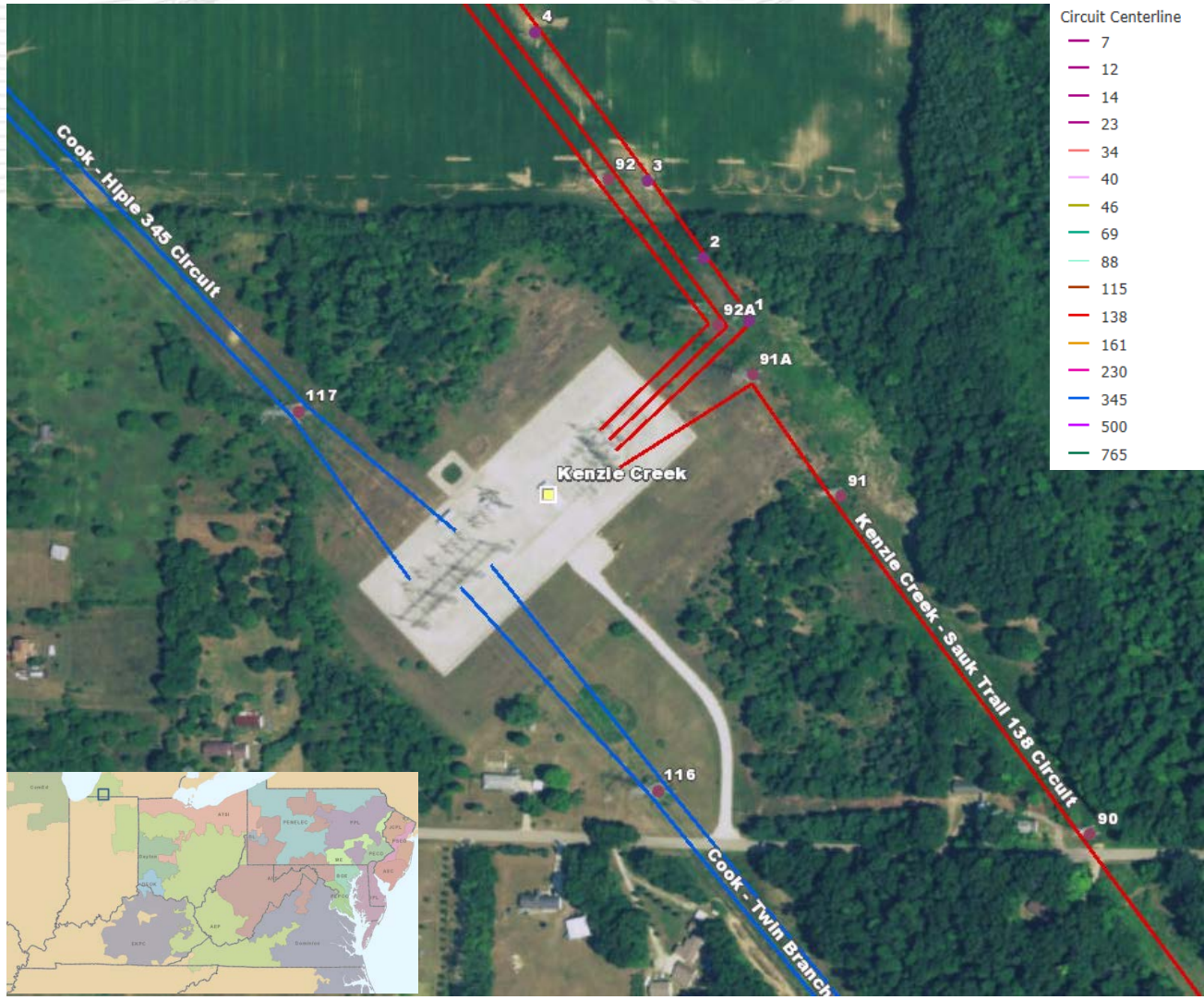
Estimated Transmission Cost: $7.4M

Alternatives:

- No viable cost-effective alternatives identified

Projected In-service: 12/31/2018

Project Status: Engineering



AEP Transmission Zone: Supplemental Tri-State Station Breaker Replacement

Supplemental Project

Problem Statement:

Equipment Material/Condition/Performance/Risk/Operational Flexibility:

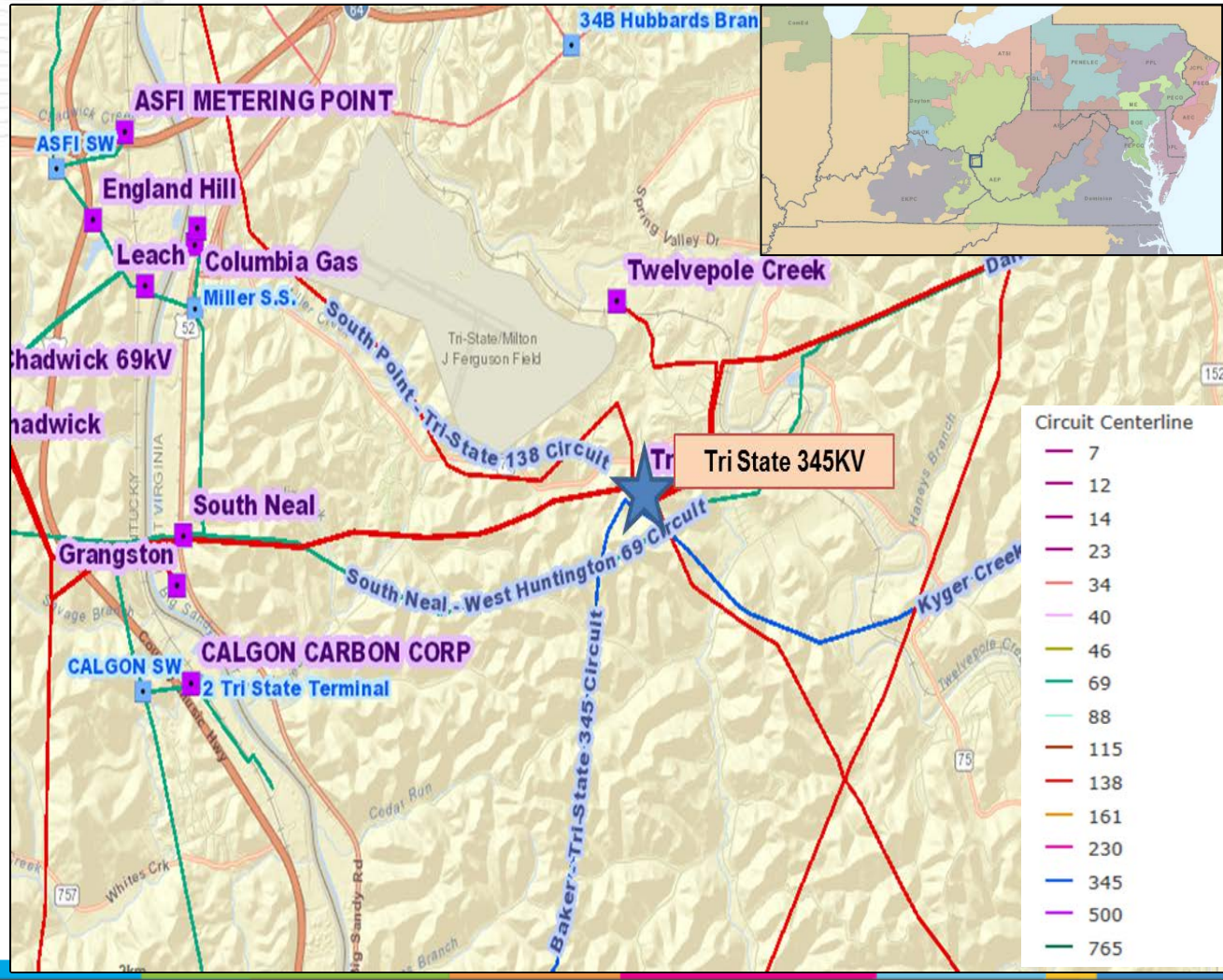
Breaker “H” at Tri-State is an Air Blast type breaker. Air blast breakers are being replaced across the AEP system due to reliability concerns, intensive maintenance, and their tendency to catastrophically fail. During failures, sharps pieces of porcelain from their bushings are typically expelled, which, can be a potential safety hazard to field personnel. In addition, the ability to get spare parts for these breakers is becoming increasingly difficult. CB “H” has experienced 32 fault operations compared to the manufacturer recommendation of 10.

The 345/138 kV transformer #1 (1965 vintage) is also being replaced due to dielectric breakdown (insulation), accessory damage (bushings/windings) and short circuit breakdown (due to amount of through faults).

The 345/138 kV transformer #2 is of the same age as Transformer #1, and the risk of failure of this unit will increase over the next few years due to its vintage and being a similar type as Transformer #1. In addition, there are elevated levels of ethane in the oil, some dielectric breakdown, and bushing damage.

Operational Flexibility and Efficiency:

The additional breakers being installed to create string G and the addition of one breaker on string H are being added break up dissimilar zones of protection (bus, line, and transformers), which could cause misoperations. In addition, this current lack of sectionalizing also makes it difficult for any maintenance work.



AEP Transmission Zone: Supplemental Tri-State Station Breaker Replacement

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Potential Solution:

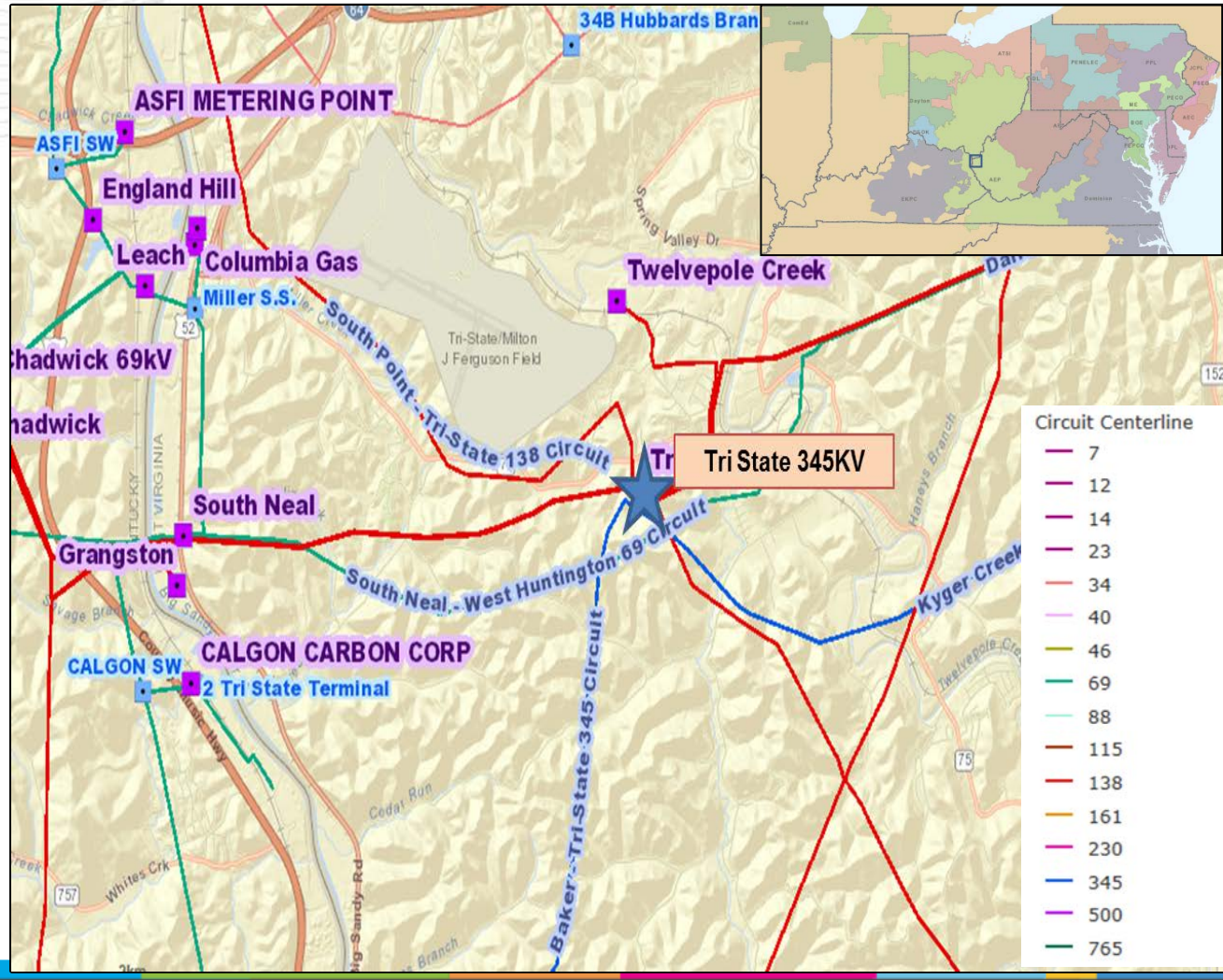
At Tri State station, replace circuit breaker “H” with a 345 kV 63kA breaker. Install 4 new 345 kV 63kA breakers in a new breaker and a half string configuration.
Replace transformers 1 & 2 with 345-138 450 MVA units.
Estimated Transmission Cost $9M

Alternative

- No viable cost-effective alternatives identified

Projected In-service: 12/1/2018

Project Status: Engineering



AEP Transmission Zone: Supplemental Desoto Breaker Replacement

Supplemental Project

Problem Statement:

Equipment Material/Condition/Performance/Risk:
At Desoto station, breaker C is an FX22A 3000A 50 kA Hydraulic breaker from 1985. Although only 32 years old, this breaker has experienced 124 fault operations which is significantly higher than the manufacturer recommendation of 3. In addition to this, there has been a rising trend of gas pressure on this breaker. Due to these identified issues, AEP recommends replacement of this breaker.

Potential Solution:

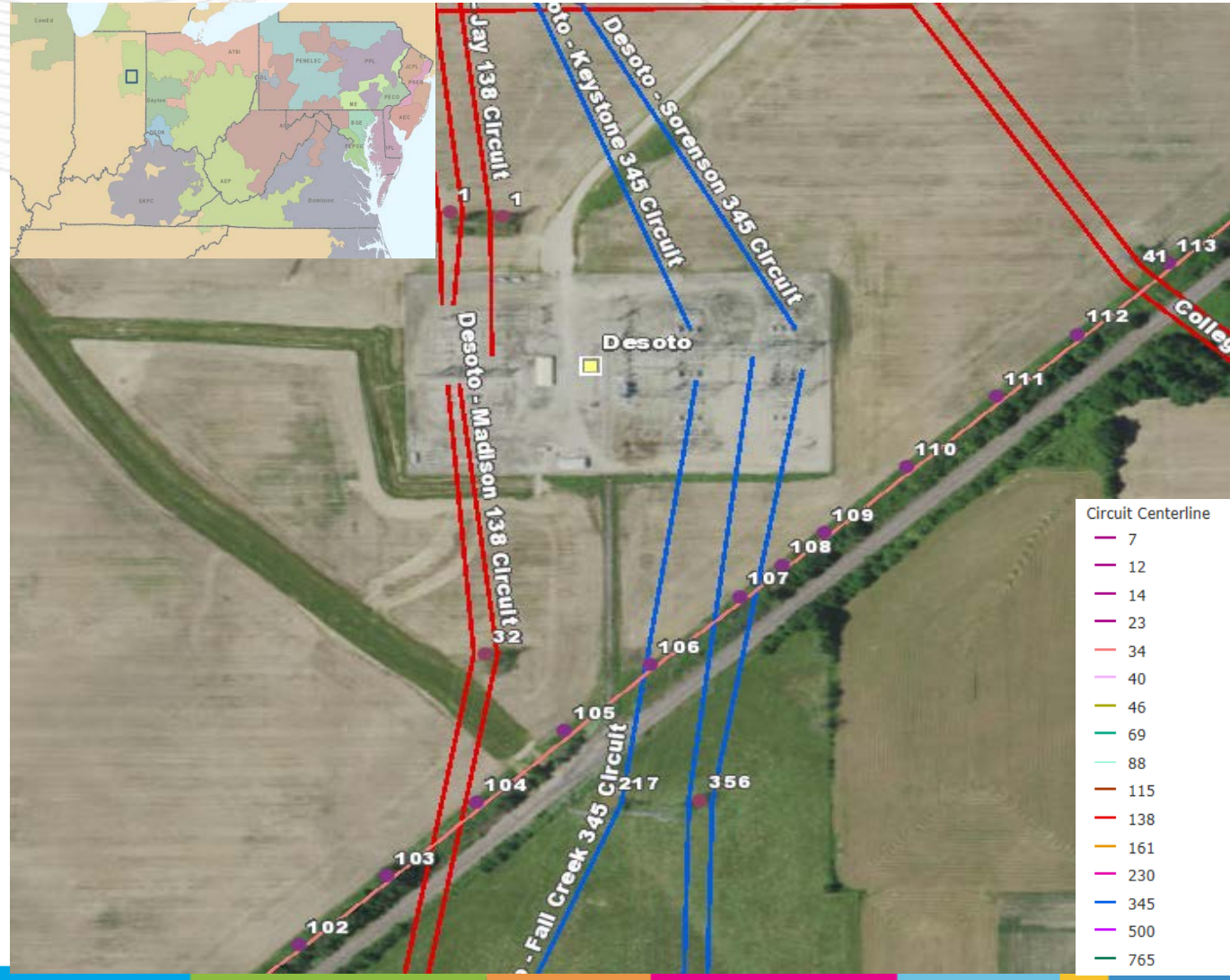
Replace 345kV breaker C with a GE Alstom 5000A 63kA 345kV breaker
Estimated Transmission Cost: $1.0M

Alternatives:

- No viable cost-effective alternatives identified

Projected In-service: 12/29/2017

Project Status: Construction



AEP Transmission Zone: Supplemental
Tidd 345 – 138 kV Transformer B Replacement

Supplemental Project

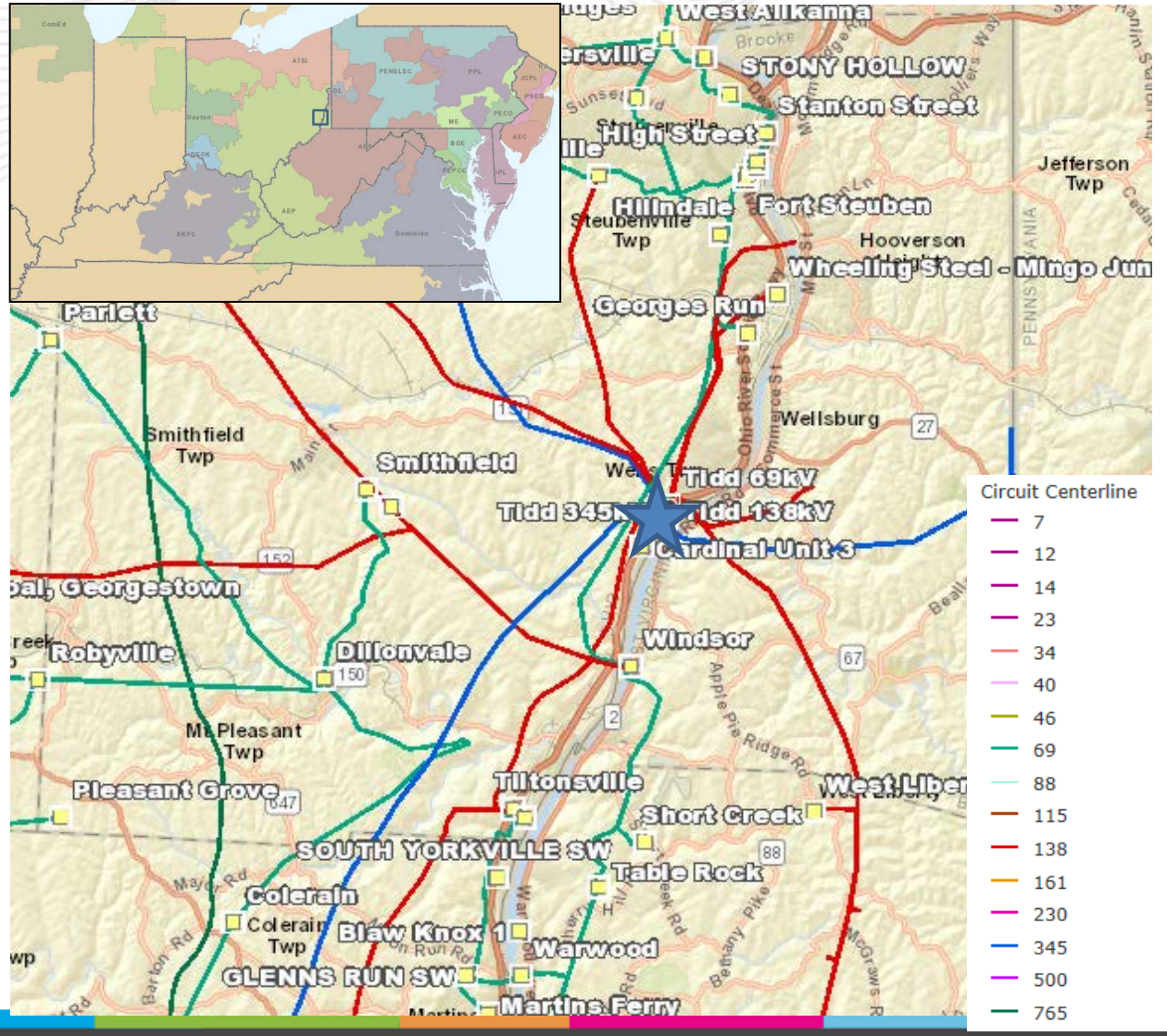
Problem Statement:

Equipment Material/Condition/Performance/Risk:

The Tidd 345-138kV transformer has failed, due to extreme levels of combustible gases (ethylene, ethane, methane). Asset Health Data required this unit to be removed from service for safety concerns in March 2017. The unit was made in 1957 and is 150 MVA. In its place a 450 MVA transformer will be installed, for additional system support. To limit the fault duty in the 138kV yard, series reactors will be installed (2%) on the low side of the transformer. This setup will mirror the parallel Tidd 345-138kV transformer C (450 MVA XFMR with 2% series reactor). This upgrade will serve to benefit the area's heavily-networked 138kV system.

Operational Flexibility and Efficiency:

Currently the two Tidd 345-138kV transformers are tapped directly off of the 345kV buses without high-side protection. For a transformer fault, or for scheduled transformer maintenance, 4- 345kV breakers must be isolated, which is a concern for operations and field personnel. This also requires an overly complex protection scheme for the 345kV buses and transformers. In addition, for a bus fault or scheduled bus maintenance, either transformer B or C is automatically taken out of service today. To resolve this reliability concern, a 345kV 3-breaker string will be installed on the high side of the two 345-138kV transformers.



AEP Transmission Zone: Supplemental
Tidd 345 – 138 kV Transformer B Replacement

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Potential Solution:

At Tidd station, replace the failed 150 MVA 345-138kV transformer with a 450 MVA unit; install a 138kV series reactor on the low-side of the transformer, to control fault currents in the 138kV yard; install a 345kV 3-breaker string on the high side of the transformers, along with new relay panels and SCADA functionality. Reconductor tie-line from 345kV yard to 138kV yard at Tidd, on the low-side of transformer B, due to increased capacity of the transformer.

Estimated Transmission Total Cost $7.8M

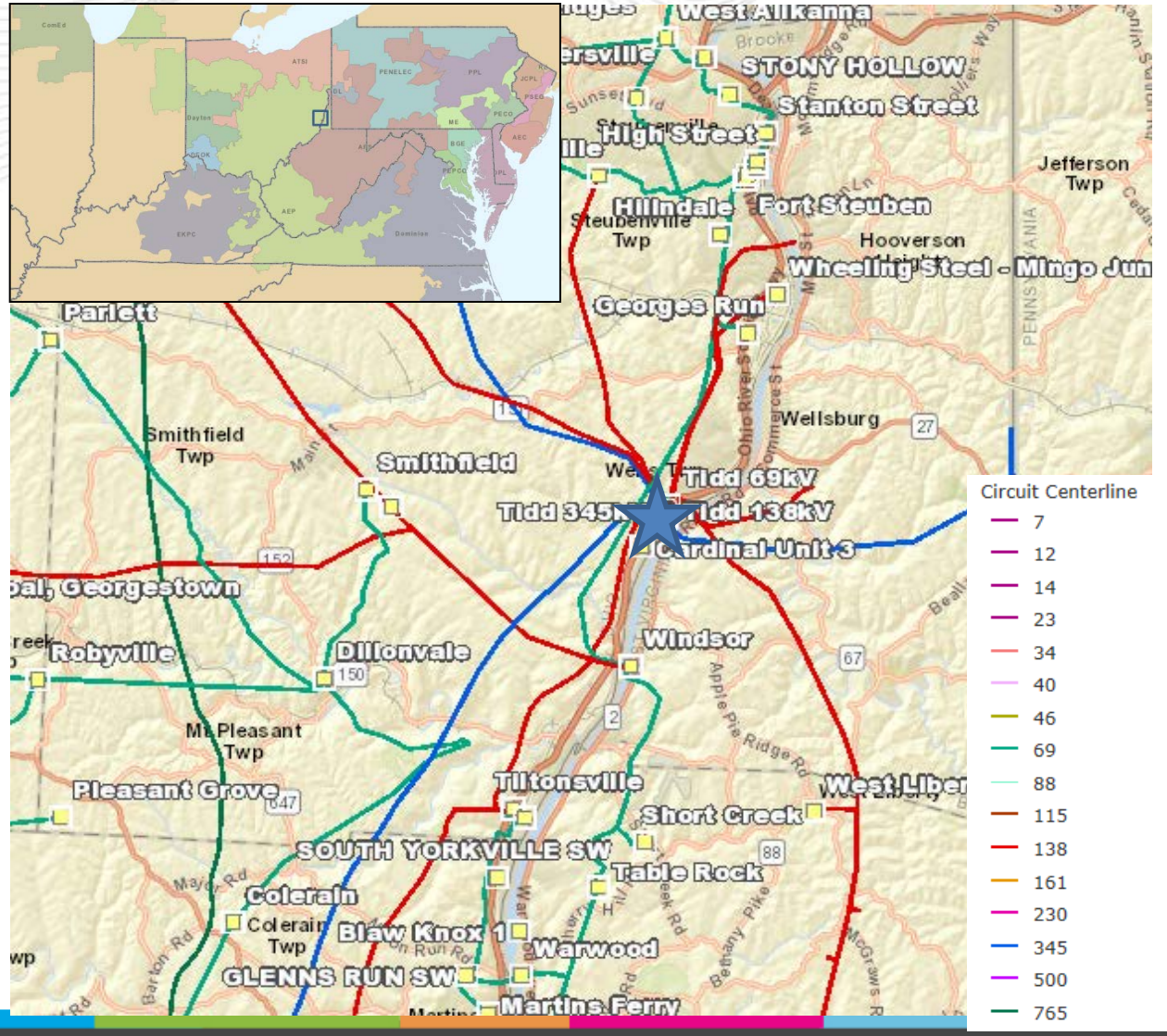
Alternative

As this was driven by a transformer failure, limited options were available to replace the transformer in a timely manner and restore the transmission system back to its normal state. The 138kV series reactor on the low side of the transformer was compared against the alternative of replacing all overdutied 138kV 63kA breakers with 80kA units (26 breakers total). However, replacing 26 breakers would have been significantly more expensive than installing the 138kV series reactor, and the construction and system outages would have required many years to implement.

Estimated cost: $15M

Projected In-service: 12/01/2018

Project Status: Engineering



ComEd Transmission Zone: Supplemental Davis Creek Breaker and a half

Supplemental Project

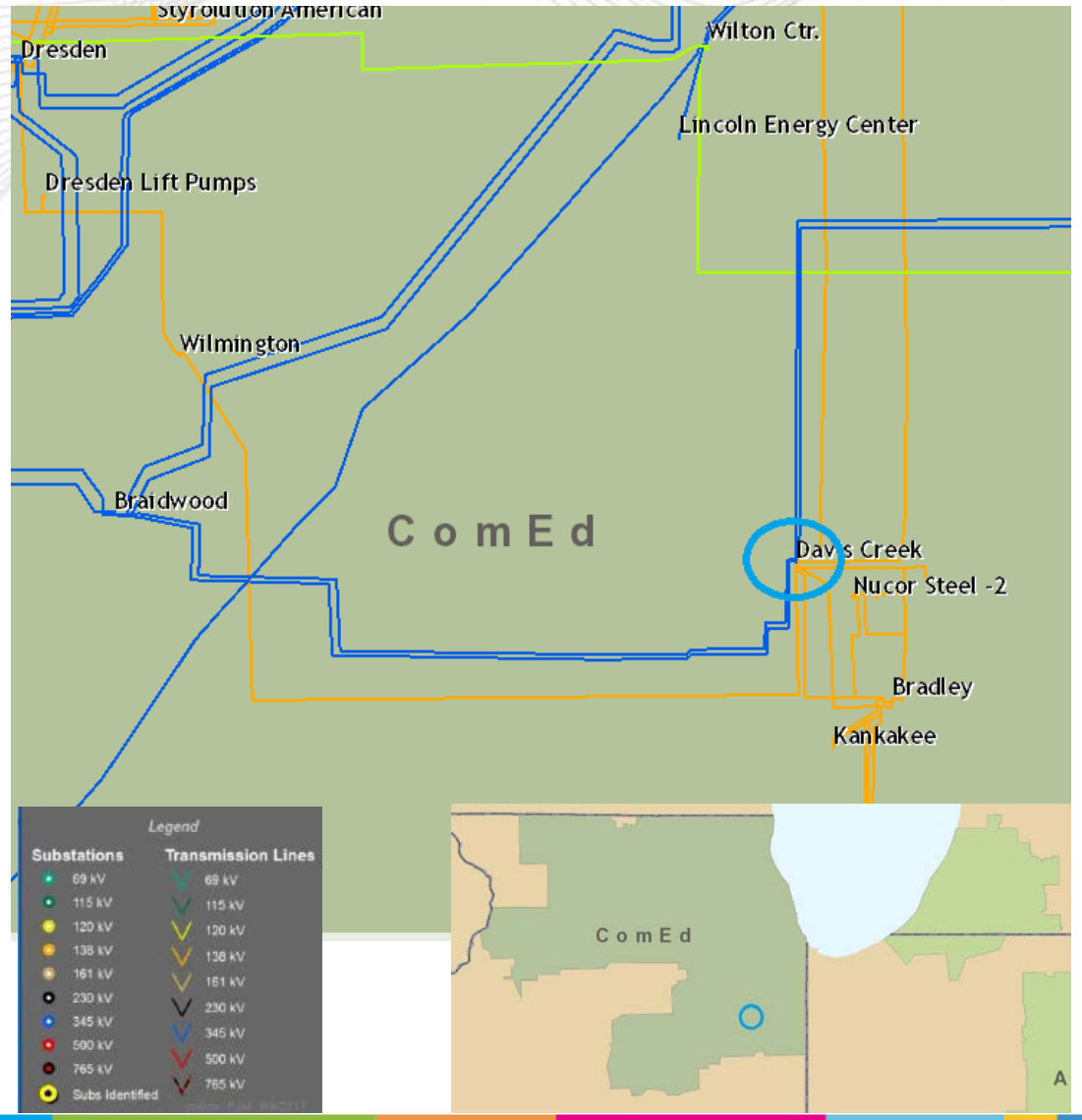
Problem Statement:
Davis Creek 345kV substation bus configure does not comply with current design standards
Single 345kV breaker failure will trip 63 miles of 345kV transmission and one to two 345-138kV auto-transformer(s)
345kV Breaker maintenance can only be performed during generator planned outages.
345-138kV auto-transformer maintenance requires generation outages and line outages due to current configuration

Potential Solutions:
Expand Davis Creek 345kV straight busses to breaker and half

Alternative:
Install line breakers and transformer high side breaker. Station configuration will still be a straight bus, and single 345kV breaker failure will trip 63 miles of 345kV transmission and one to two 345-138kV auto-transformer(s)

Do nothing and continue to have difficulty scheduling outages to maintain the 345kV breakers and auto-transformers

Estimated Cost: $34M
Projected In-service: 12/1/2018
Status: Engineering



ComEd Transmission Zone: Supplemental Northbrook

Supplemental Project

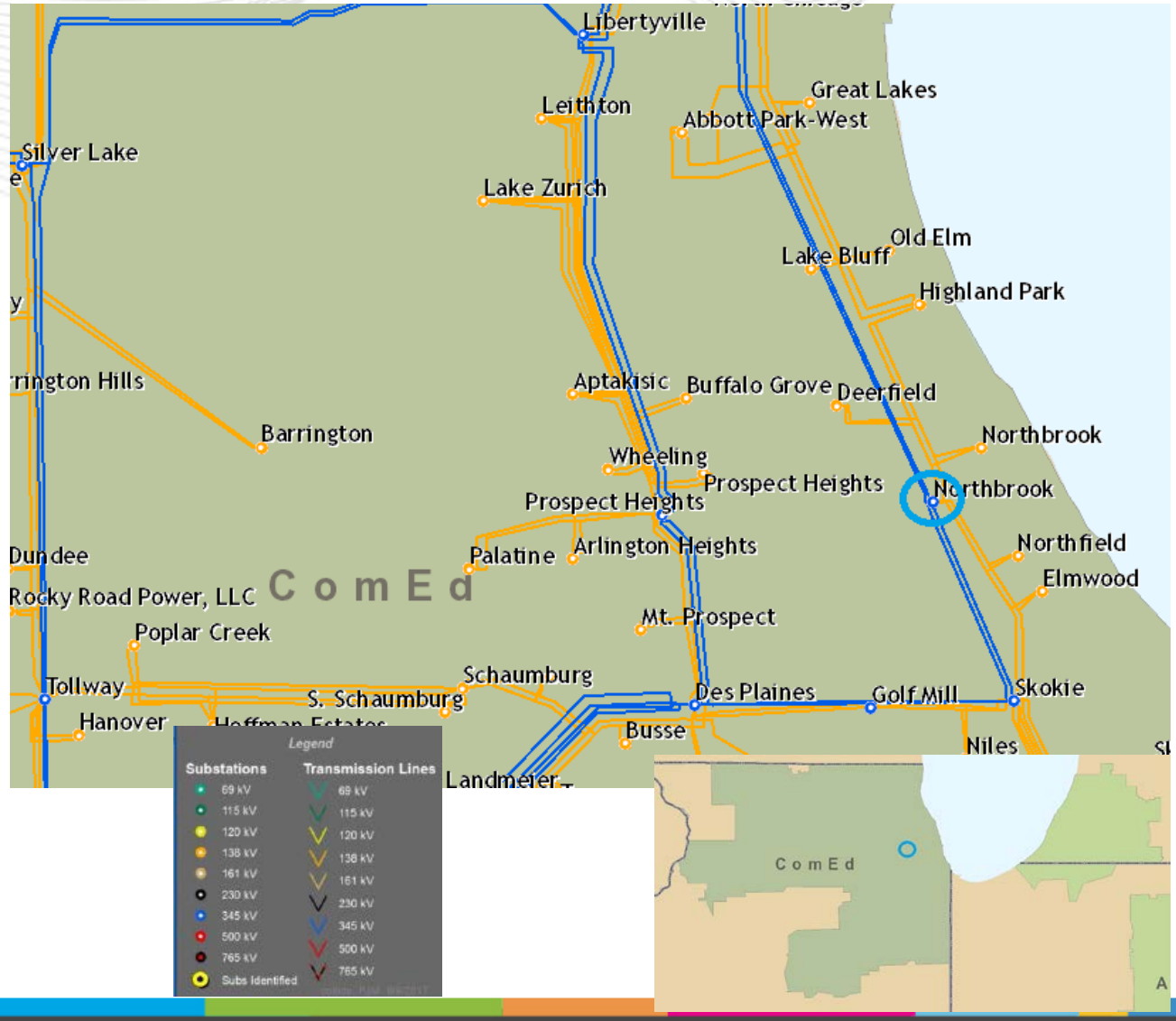
Problem Statement:
Address Ferro-Resonance and induced voltage issues at Northbrook 345kV
Special switching is required on the 345kV system at Northbrook and Waukegan
Station configuration does not meet current design standards
Single breaker failure trips 27 miles of 345kV transmission lines and one 345-138kV auto-transformer

Potential Solutions:
Install three 345kV breakers at Northbrook and allow independent operation of the transmission lines and transformers;
Retire SPOG 3-34, requiring switching to be performed in a specified order.

Alternative:
Do nothing and continue to operate the Northbrook 345-138kV transformers with know operation limitations stated in SPOG 3-34

Estimated Cost: $8.5M
Projected In-service: 12/1/2019

Status: Engineering



ComEd Transmission Zone: Supplemental Bedford Park

Supplemental Project

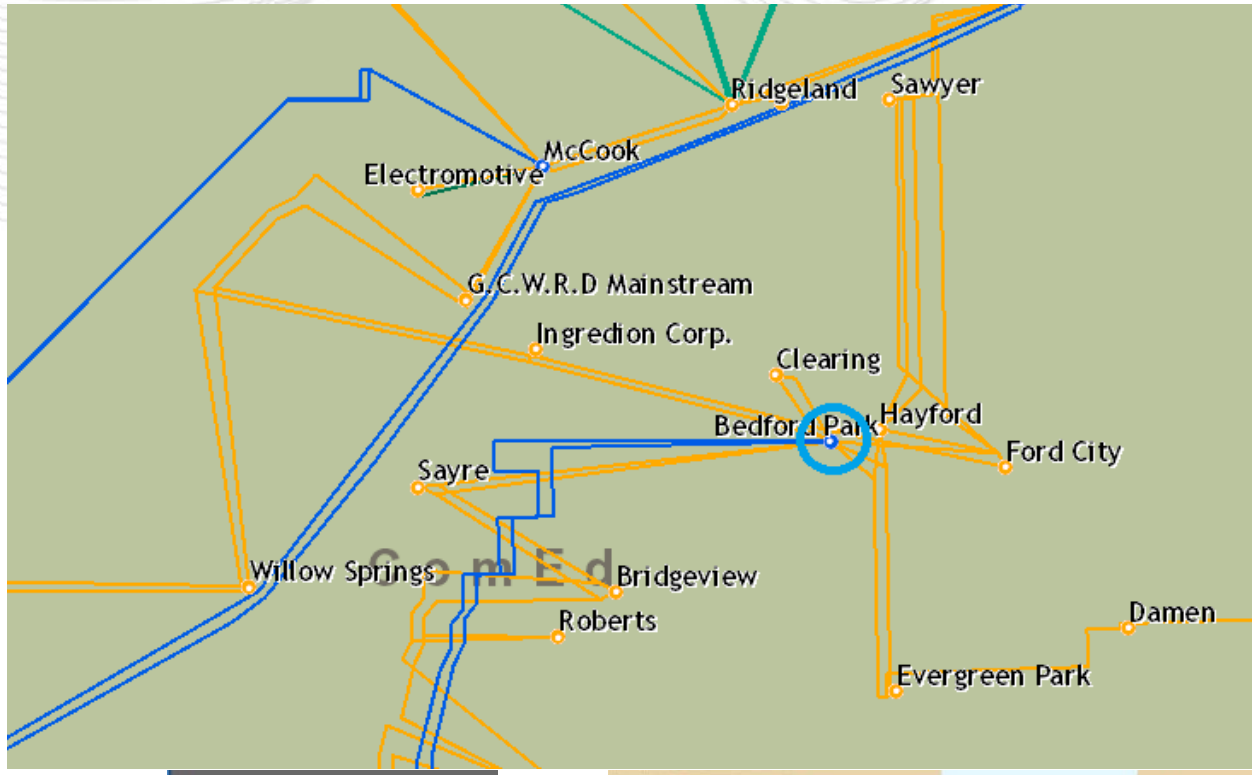
Problem Statement:
Bedford Park 345kV is radially fed from Goodings Grove substation
Bedford Park is currently a straight bus with a disconnect for a bus tie
For a loss of one transmission line the disconnect is closed to restore two 345-138kV transformers. In order to open the disconnect and return the station to normal the two transformers need to be temporarily taken out of service to perform switching
Bedford Park does not meet current design standards
Insufficient water retention/detention presently for yard

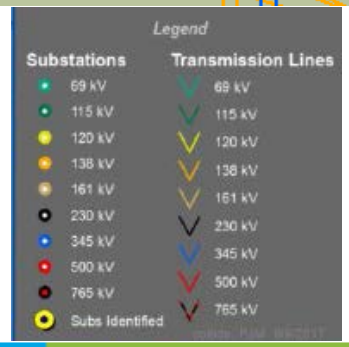
Potential Solutions:
Replace Bedford Park open air 345kV bus with indoor GIS

Alternative:
Convert station to an outdoor ring bus. However, Insufficient water retention/detention to expand the yard for the extra breakers and bus work
Requires a reduction in the total number of 345kV lines in the ultimate

Do nothing and continue to operate with know operation limitations

Estimated Cost: $28M
Projected In-service: 12/1/2020
Status: Engineering





Dominion Transmission Zone: Supplemental Winter's Branch 230kV Delivery

Date Project Last Presented: 10/12/2017 TEAC

Problem Statement:

- Dominion Distribution has submitted a DP Request for a new substation to accommodate a new datacenter campus in Prince William County. Initial installation will include a 84MVA 230-34.5kV transformer.

Selected Solution:

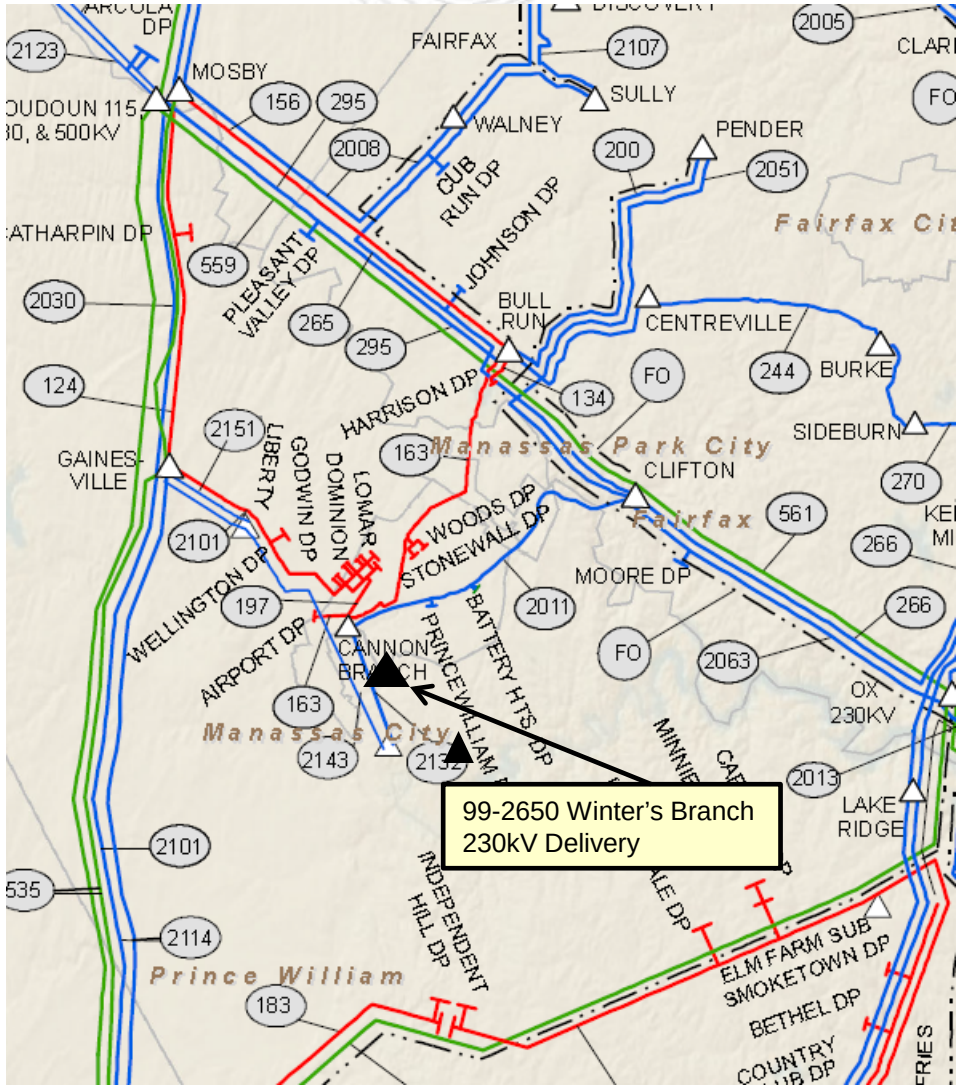
- Interconnect the new substation by tapping the 230kV Line #2132 (Cloverhill – Cannon Branch) to the proposed Winter's Branch Substation. The new substation will be set up for an ultimate six-breaker 230kV ring bus to meet the future growing demands of the region. Install line switches, a 230kV circuit switcher, and high side switches and necessary bus work for the new transformer.

Estimated Project Cost: $4.3 M

Projected In-service Date: 7/15/2019

Project Status: Conceptual

COLOR	VOLTAGE	TRANSMISSION LINE NUMBER
	500 KV.	500 thru 599
	230 KV.	200 thru 299 & 2000 thru 2099
	115 KV.	1 thru 199
	138 KV.	AS NOTED
	69 KV.	AS NOTED



Dominion Transmission Zone: Supplemental
Portugee Road 230kV Switching Station & 230kV Delivery Point

Problem Statement:

- A customer has requested a 230kV delivery point to accommodate a new data center campus in White Oak Technology Park in Henrico County with projected loads over 100 MW.

Potential Solution:

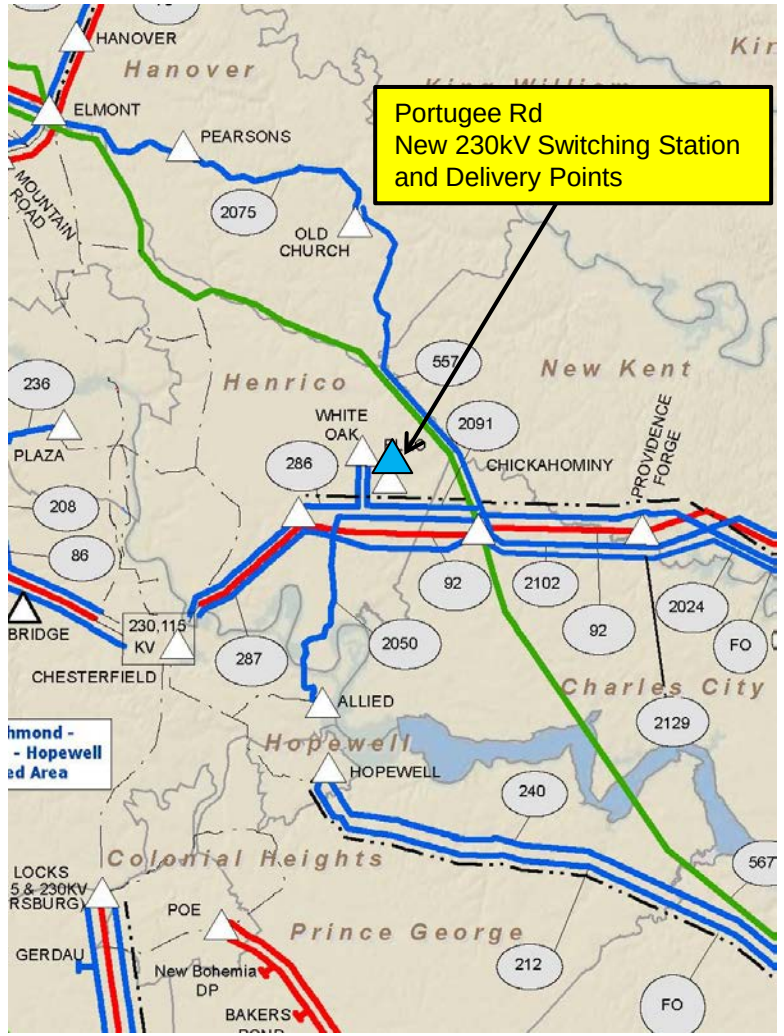
- Install a 230kV switching station and delivery point by tapping the 230kV Line #2091 (Chickahominy – White Oak) in and out of the proposed customer site. The new 230kV switching station will include a four breaker ring bus with space provided for an ultimate six-breaker ring bus to meet the future growing demands of the area.

Alternatives: No feasible alternatives

Estimated Project Cost: $11 M

Possible In-service Date: 10/25/2018

Project Status: Engineering



COLOR	VOLTAGE	TRANSMISSION LINE NUMBER
	500 KV.	500 thru 599
	230 KV.	200 thru 299 & 2000 thru 2099
	115 KV.	1 thru 199
	138 KV.	AS NOTED
	69 KV.	AS NOTED

Dominion Transmission Zone: Supplemental
Green Run Substation - Line #245 & #2025
Wave Trap & Line Terminal Equipment Replacement

Problem Statement:

- 230kV Line #245(Green Run to Greenwich) and 230kV Line #2025 (Green Run to Lynnhaven) wave traps and associated line terminal equipment at Green Run substation need to be replaced due to age.

Potential Solution:

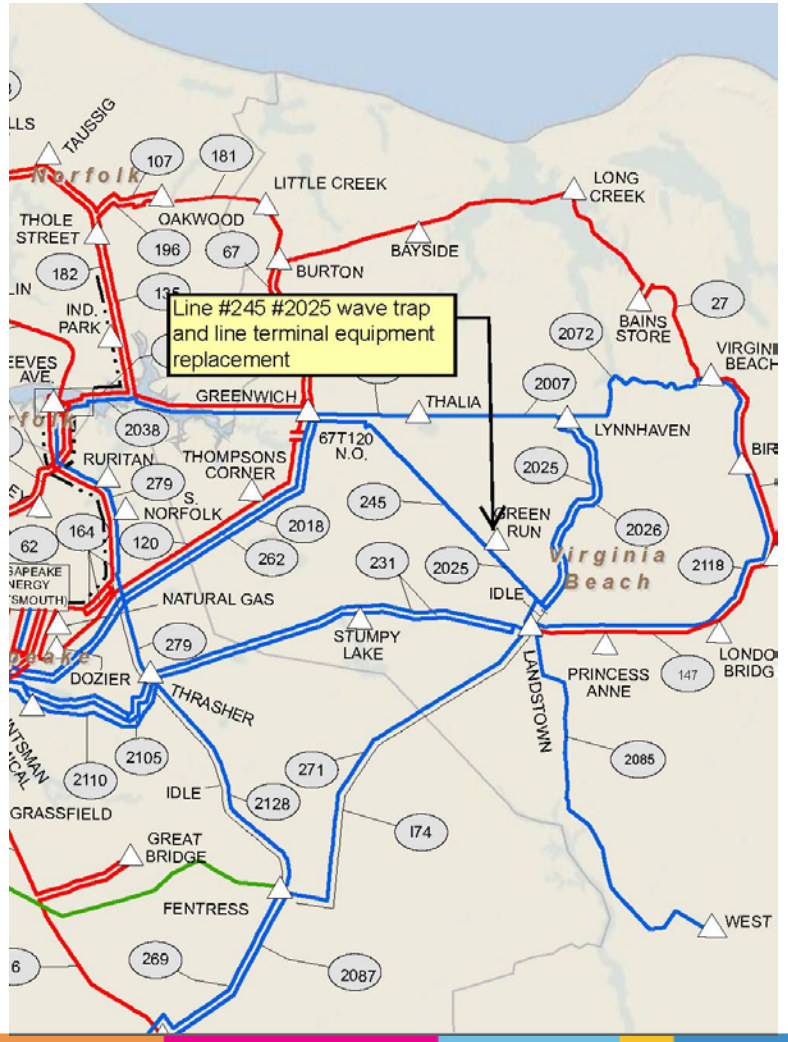
- Replace existing Line #245 & Line #2025 1600A wave traps at Green Run substation with 3000A wave traps. Replace high side circuit switchers at high side of TX#1 and TX#2. Summer emergency rating of Line #245 will be changed from 637MVA to 898MVA. The rating of Line #2025 will be changed from 637MVA to 722MVA.

Alternatives: No feasible alternatives

Estimated Project Cost: $1.2 M

Possible In-service Date: 12/15/2017

Project Status: Under Construction



COLOR	VOLTAGE	TRANSMISSION LINE NUMBER
	500 KV.	500 thru 599
	230 KV.	200 thru 299 & 2000 thru 2099
	115 KV.	1 thru 199
	138 KV.	AS NOTED
	69 KV.	AS NOTED

Dominion Transmission Zone: Supplemental New 230kV DP for Albemarle EMC

Problem Statement:

- NCEMC has requested a new 230kV delivery point on behalf of Albemarle EMC to replace three existing AEMC distribution served delivery points: Burgess, Cisco and Edenton DP's.
- The main drivers for the new 230kV delivery point are AEMC's 1) inability to serve future load from the existing distribution delivery points and 2) aging facilities.

Potential Solution:

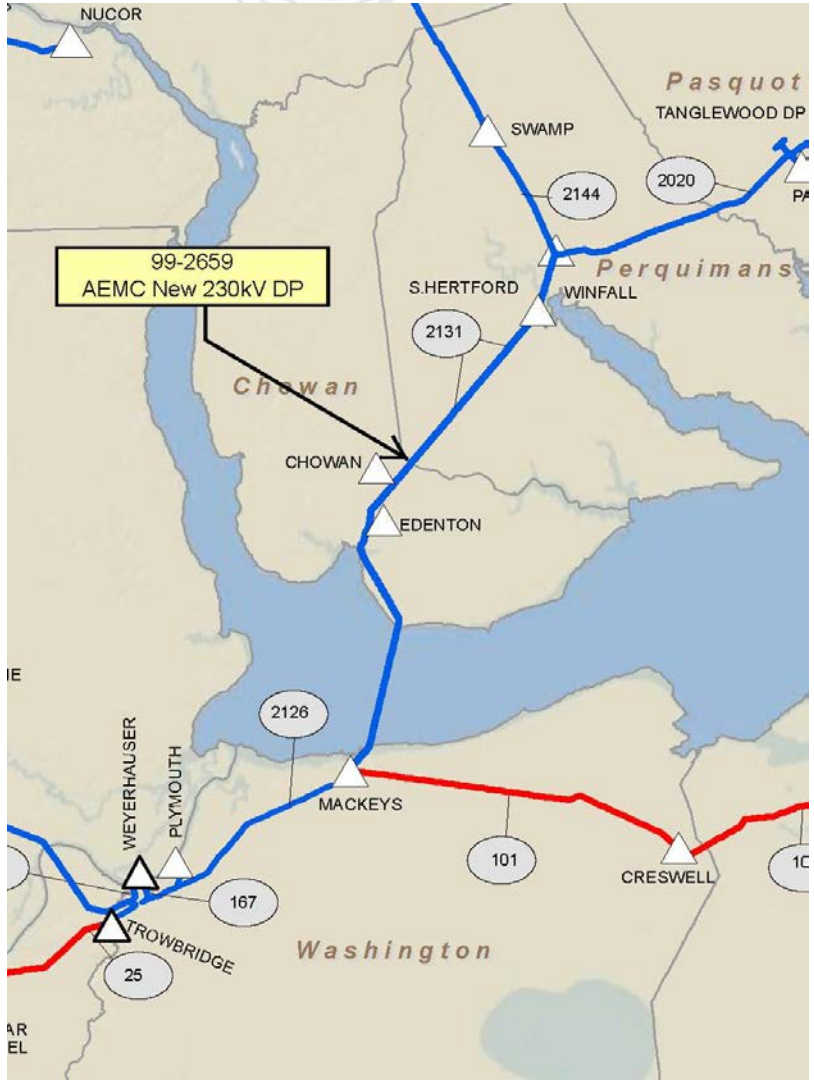
- Dominion Energy to support the installation of AEMC's new 230kV delivery point by installing three H frame structures, three 230kV switches, a 3 pole structure and replacing one single pole structure.

Alternatives: No feasible alternatives

Estimated Project Cost: $2.5 M

Possible In-service Date: 12/1/2019

Project Status: Conceptual



COLOR	VOLTAGE	TRANSMISSION LINE NUMBER
	500 KV.	500 thru 599
	230 KV.	200 thru 299 & 2000 thru 2099
	115 KV.	1 thru 199
	138 KV.	AS NOTED
	69 KV.	AS NOTED

DPL Transmission Zone Supplemental Project
Cool Spring – Indian River 230kV

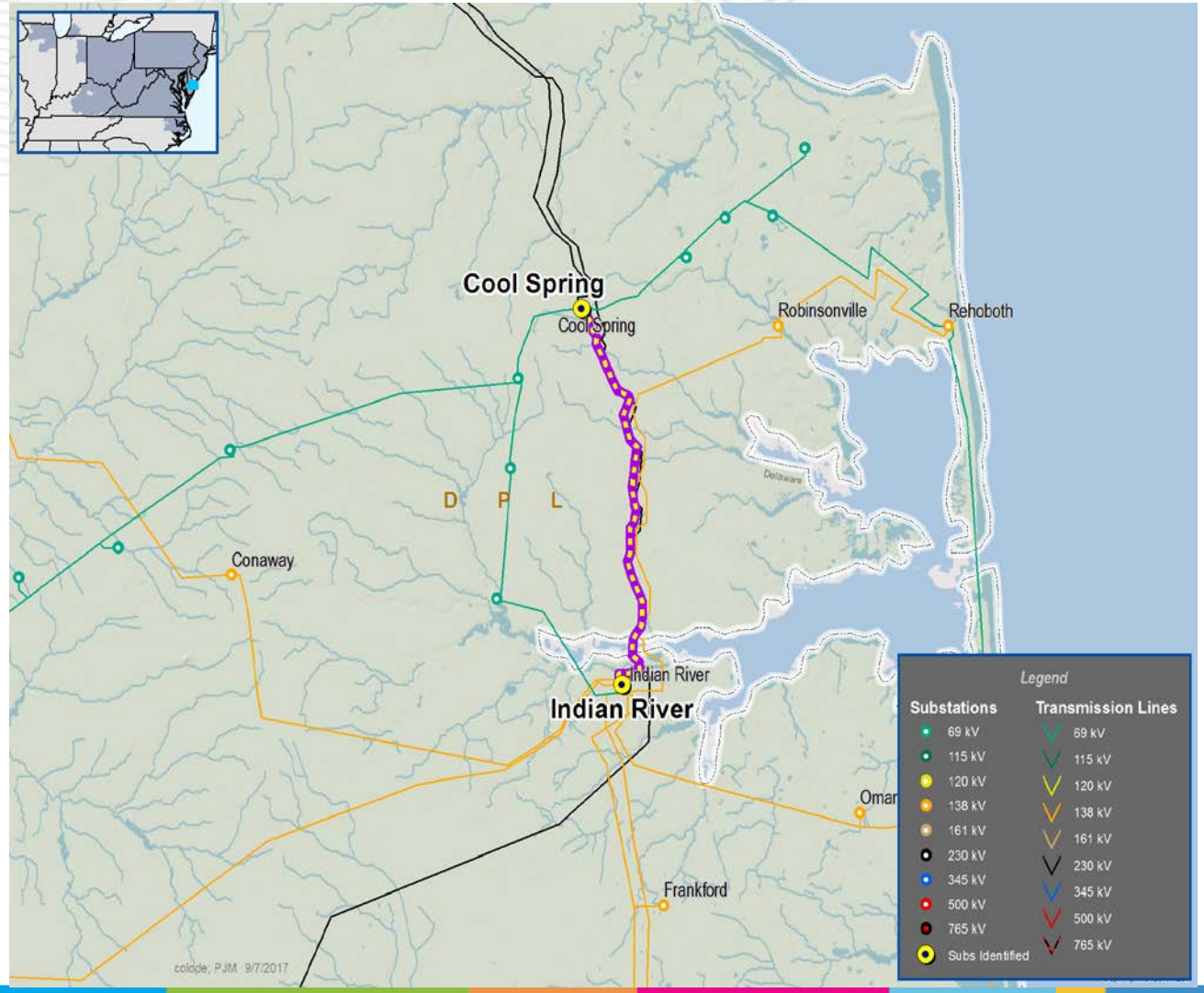
Problem Statement:

- This project is needed to mitigate performance risk associated with the current equipment material and condition. Specifically, based on inspection data, deteriorated, cracked, and weathered crossarms and deteriorated poles were identified, which places this line in the top quartile of the DPL age and condition ranking. This line was originally installed in 1979.

Alternative Solution:

- Rebuild line 23070 between Cool Spring and Indian River substations. All structures, conductor, and static wire will be replaced with new steel poles, conductor, and OPGW. (Estimated cost: approximately $17.8M)
- Obtain new ROW to install a new line

Project Status: Engineering



2017 RTEP Next Steps

Upcoming TEAC Meetings and anticipated PJM Board Review

November

11/02 – Sub-regional RTEP – PJM West – Morning
11/02 – TEAC Reliability Analysis Update – Afternoon
- *2017 RTEP Window #1 - Reliability Recommendations*

11/9 – TEAC Reliability Analysis Update

December

12/04 – PJM Board of Managers Review of November TEAC Recommendations
12/14 – TEAC Reliability Analysis Update and 2018 RTEP Assumptions Review
12/18 – Sub-regional RTEP – PJM South – Morning
12/18 – Sub-regional RTEP – PJM West – Afternoon
12/19 – Sub-regional RTEP – PJM Mid-Atlantic

Previously Reviewed Baseline Upgrades for the December 2017 PJM Board Recommendation:

November 2, 2017 TEAC Reliability Update Presentation

*PJM intends to ask for approval of all projects presented at the 11/2/17 TEAC with the exception of the solution to the Maywood - Saddle Brook 230 kV circuit overload in the PSE&G transmission zone (B2957) due to stakeholder discussion and feedback received at the 11/2/17 TEAC WebEx presentation.

Questions?

Revision History

- V1 – 11/03/2017 – Original Slides Posted