

Reliability Analysis Update

Transmission Expansion Advisory
Committee

February 9, 2017



Project Scope Change - B2557

Targeted Violation: The Avon 345/138 kV transformer #92 is overloaded for line fault stuck breaker contingency loss of Avon – Juniper 345 kV circuit and Avon 345/138 kV transformer #91

Original Scope: At Avon 345 kV substation, replace the existing 345/138 kV 448 MVA #92 transformer with a 560 MVA unit

Original Cost: \$5.4M (Updated cost: \$6.0M)

Required IS date: 6/1/2019

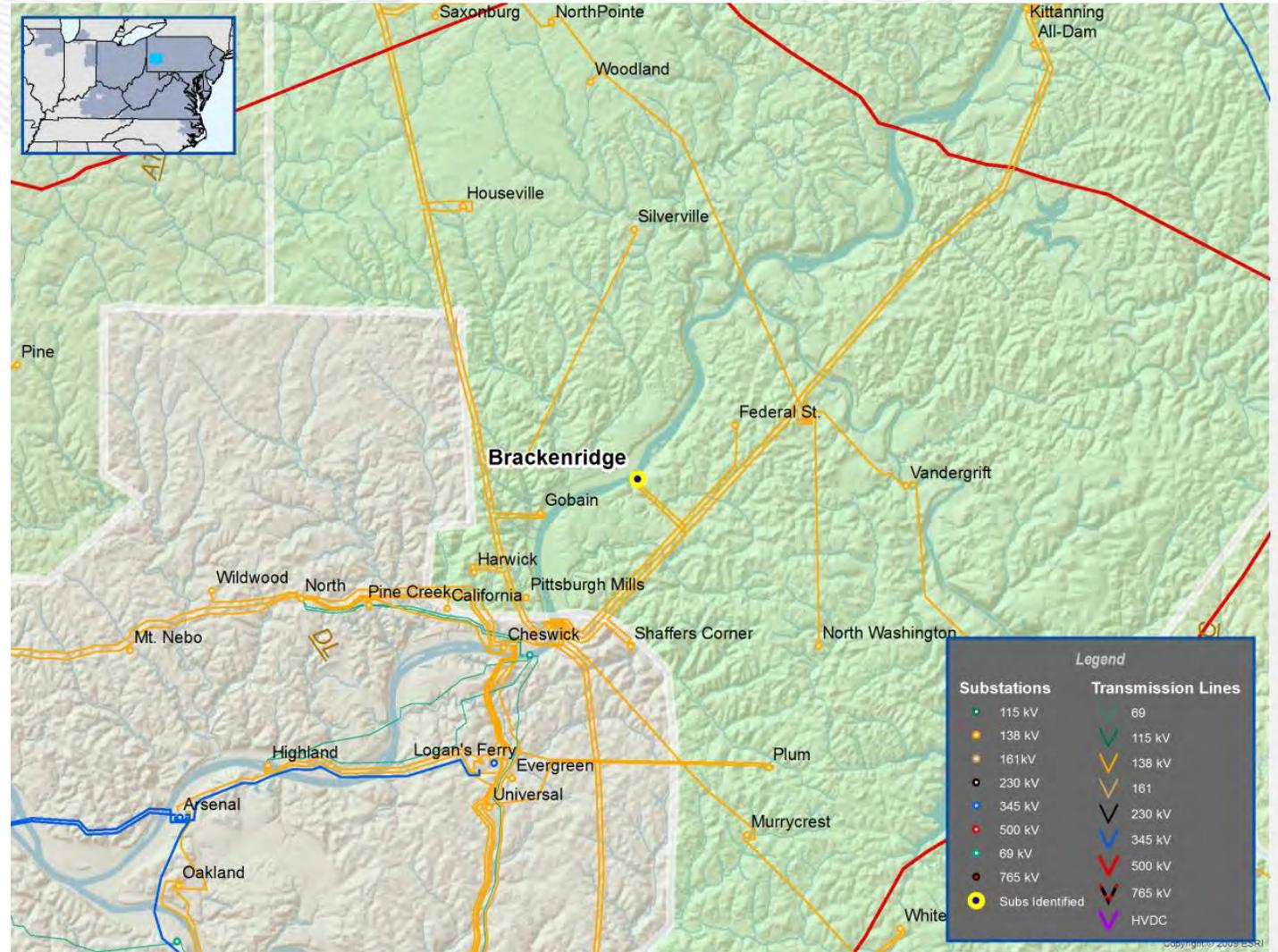
New Scope: Re-configure the existing Avon 345kV substation into a breaker-and-a-half layout

New Cost: \$5.7M

Reasons:

- The new configuration eliminates the contingency (stuck breaker) causing the identified thermal overload.
- Eliminates the 345kV source, bus, and transformer loss at Avon for the stuck breaker contingency.
- New layout provides increased operational flexibility including transformer and breaker maintenance.
- Significant decrease in post contingency loading for the Avon transformers as a result of the new configuration when compared to the transformer replacement project.
- Provides reliability improvement for the broader BES Network by eliminating the thermal violation.
- After additional engineering design and cost reviews, the cost for the 345kV breaker configuration project is the least cost planning alternative.





- **Project Change- B2341, B2612.1, B2612.2 and B2612.3**
- **Cancel B2341:** Install 39.6 MVAR Capacitor at Shaffers Corner 138 kV Substation
Original Required IS Date: 6/1/2018
- **Advance B2612.1, B2612.2 and B2612.3:**
- B2612.1: Relocate All Dam 6 138 kV line and the 138 kV line to AE units 1&2
- B2612.2: Install 138 kV 3000A bus tie breaker, foundation, control cable and associated facilities at Springdale substation.
- B2612.3: Install a 6-pole manual switch, foundation, control cable, and all associated facilities
- **Original Required IS Date:** 6/1/2019
- **New Required IS Date:** 6/1/2018
- **Reasons:** Baseline RTEP projects b2612.1, b2612.2 and b2612.3 eliminates the contingency (stuck tie breaker at Springdale) that resulted in the need for B2341, which is driven by the low voltage at Brackenridge 138kV bus for the tie breaker failure at Springdale. With the Springdale project modeled, b2612.1, b2612.2 and b2612.3, the Shaffers Corner capacitor is no longer needed.

Clean Power Plan (CPP) Reliability Studies

- Provide a representative overview of the types of reliability issues that could be expected
- Each scenario has a distinct portfolio of generation additions and retirements derived from PJM's [CPP Compliance Assessment](http://www.pjm.com/~media/library/reports-notice/clean-power-plan/20160901-cpp-compliance-assessment.ashx)
 - <http://www.pjm.com/~media/library/reports-notice/clean-power-plan/20160901-cpp-compliance-assessment.ashx>
- The 2019/2020 RPM power flow model was used as the starting base case for each of the scenarios
- All scenarios were studied for a 2025 load year



CPP Planning Analysis

Generator Deliverability Results

- Performed on the following scenarios
 - Reference
 - Trade Ready Mass
 - Trade Ready Rate
- Considered single contingencies and tower line outages
- Examined conductor limited transmission facilities (230 kV+)

Scenario	From Bus Name	To Bus Name	kV	Area
Reference	05MADDOX	05E LIMA	345/345	AEP
Reference	26CANYON	26N.MESHYPN	230/230	PENELEC
Reference	26E.TWANDA	26CANYON	230/230	PENELEC
Reference	6CHARLVL	6PROFFIT	230/230	DOM
Reference	6CHSTF B	6BASIN	230/230	DOM
Reference	8BATH CO	8VALLEY	500/500	DOM
Reference	AA2-121 TAP	01WYLIE R	345/345	AEP/APS
Trade Ready Mass	6CHARLVL	6PROFFIT	230/230	DOM
Trade Ready Mass	6CHSTF B	6BASIN	230/230	DOM
Trade Ready Mass	6PRINCE EDW	6FARMVIL	230/230	DOM
Trade Ready Rate	05MADDOX	05E LIMA	345/345	AEP
Trade Ready Rate	6BREMO	6BREMODIST	230/230	DOM
Trade Ready Rate	6BREMODIST	6MTEAGLE	230/230	DOM
Trade Ready Rate	6BUCKING	6BREMO	230/230	DOM
Trade Ready Rate	6CHARLVL	6PROFFIT	230/230	DOM
Trade Ready Rate	6CHSTF B	6BASIN	230/230	DOM
Trade Ready Rate	6FARMVIL	6BUCKING	230/230	DOM
Trade Ready Rate	6MTEAGLE	6CHARLVL	230/230	DOM
Trade Ready Rate	6PRINCE EDW	6FARMVIL	230/230	DOM

- Procedure

- Performed on the Reference scenario power flow model and selected individual LDAs were updated and examined separately to account for the most severe scenario for that LDA if the LDA's forecast CETO exceeds its forecast CETL

Scenario	LDA
Reference	BGE & MAAC
Reference 5 year/20 year	DLCO & EMAAC
State Mass NSC	Dayton
Low Natural Gas Price	APS & AEP

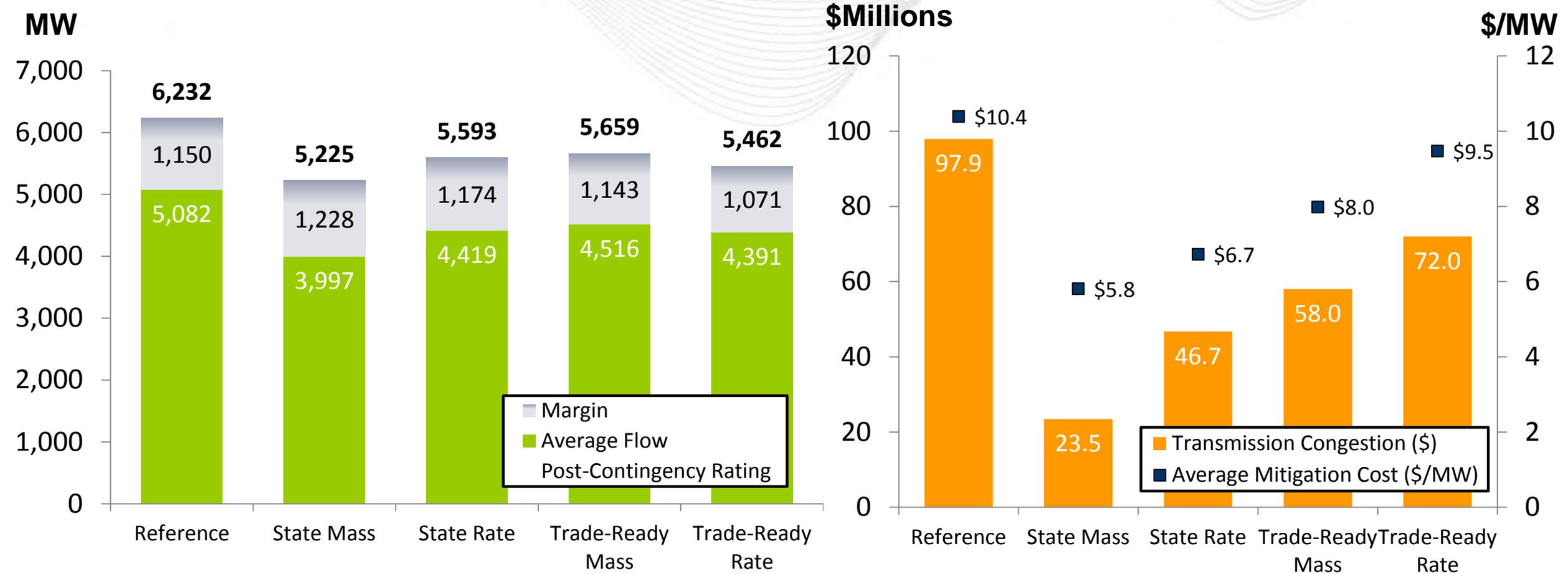
Results

- No 230 kV+ transmission facilities loaded beyond their conductor limit
- Reference scenario showed widespread voltage problems in BGE



Power Transfer-Voltage (PV) Analysis

AP SOUTH L/O BED-BLA (Summer 2025)



Lower transmission congestion is driven by retirements in western PJM that both reduce interface flows and lower cost for mitigating interface constraints.

Immediate Need Reliability Projects

Potential High Voltage Issues During Light Load

- Ongoing high voltages on the EHV system have been occurring in AEP and surrounding areas under light load conditions
- PJM planners worked closely with AEP planners to determine what operational and planning changes area available
 - Reviewed EMS snapshots of high voltage conditions
 - Suggested modelling and operating changes to PJM & AEP Operations
 - Examined impact of planned, approved reactive upgrades
- Outcome of investigation is the proposed addition of two new 300 MVAR 345 kV reactors on the AEP system with a 9/1/2018 in-service date
- Recommended Solution:
 - B2826.1: Install 300 MVAR reactor at Ohio Central 345 kV substation (\$5M)
 - B2826.2: Install 300 MVAR reactor at West Bellaire 345 kV substation (\$5M)



2016 RTEP Proposal Window #3 Update



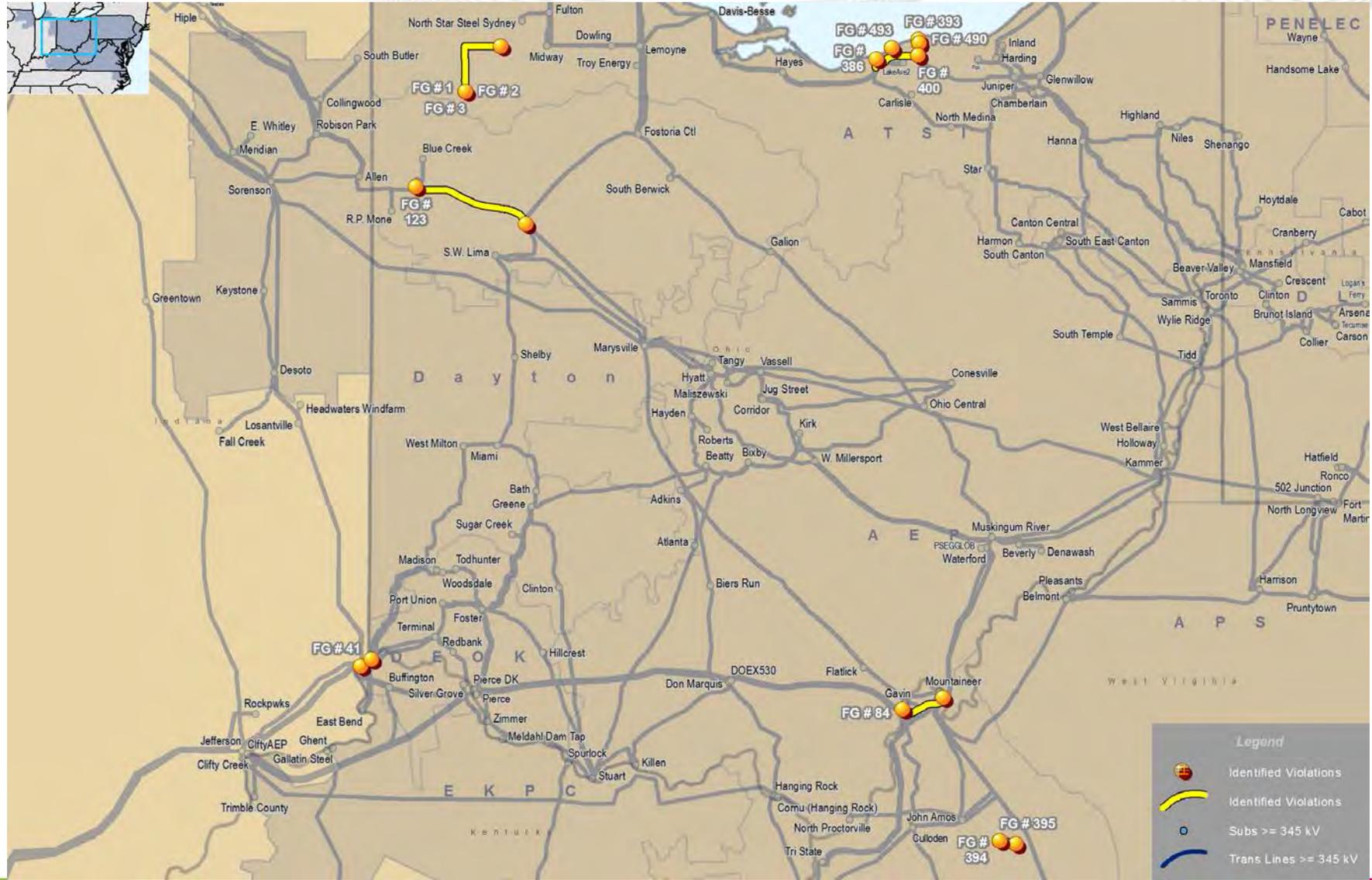
- Status: 30 Day Portion closed 10/31/2016, Final details due 11/15/2016
- Scope:
 - 2016 RTEP Winter Analysis
 - Baseline N-1 (thermal and Voltage)
 - Generation Deliverability and Common Mode Outage
 - N-1-1 (thermal and Voltage)
 - Load Deliverability (thermal and voltage)
 - 2016 RTEP Light Load Analysis
 - Baseline N-1 (thermal and voltage)
 - Generation Deliverability and Common Mode Outage
 - Short Circuit Analysis

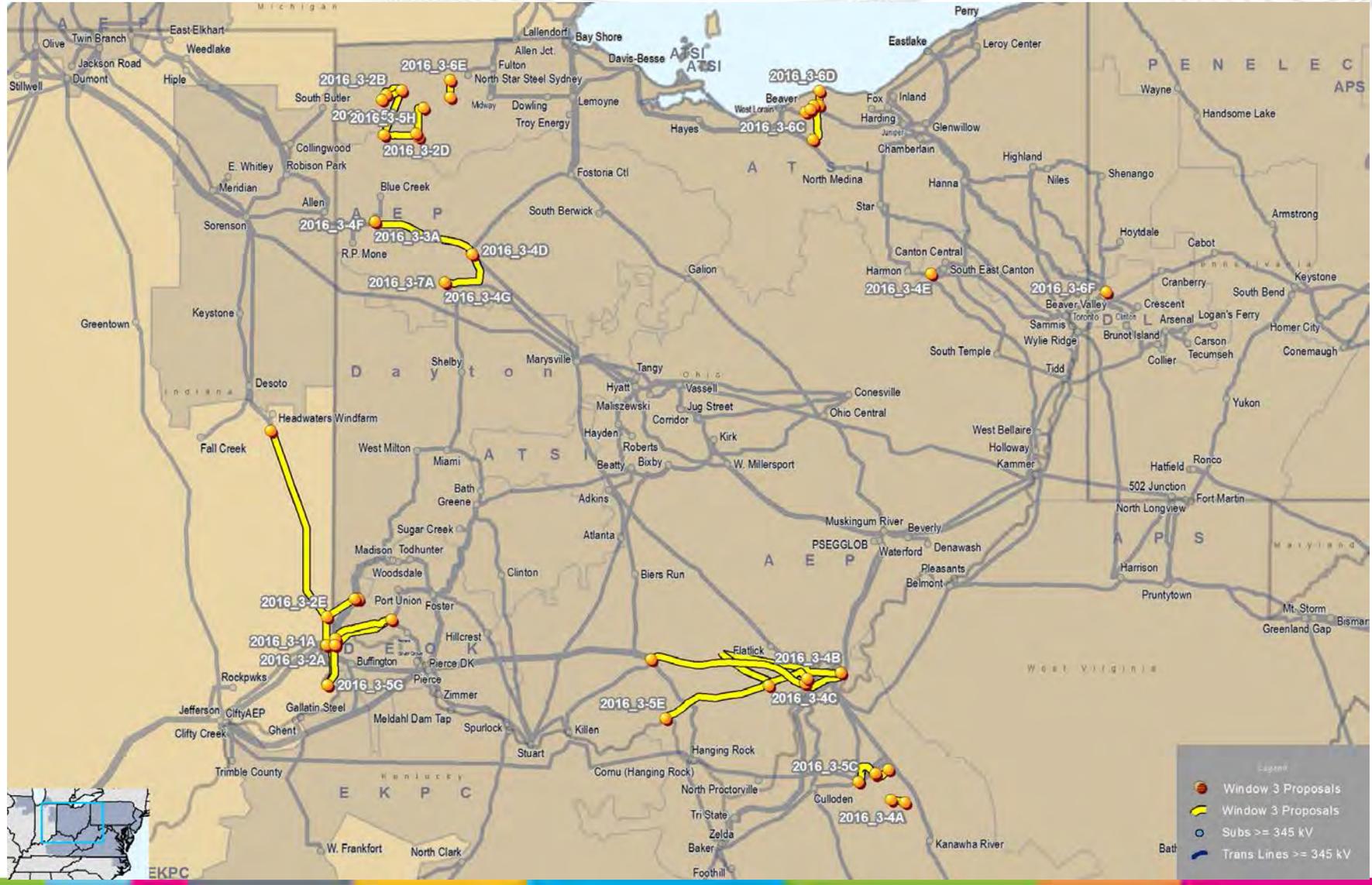
- Timeline
 - Window Opened: 9/30/2016
 - Window Closed: 10/31/2016
 - Proposal definitions, simulation data and planning cost estimate due
 - Detailed Cost due: 11/15/2016
 - Additional 15 days to develop and provide detailed cost data
 - See the window documentation for additional information

- 25 total flowgates

Test/kV Level*	<200 kV	230 kV	345 kV	500 kV	765 kV	Total
Short Circuit	2		1			3
Winter Baseline N-1						0
Winter Gen Deliv/CMO	17		3			20
Winter N-1-1						0
Winter Load Deliv						0
Light Load N-1						0
Light Load Gen Deliv						0
Gen Deliv	1					1
Winter Baseline Thermal	1					1
Total	21	0	4	0	0	25

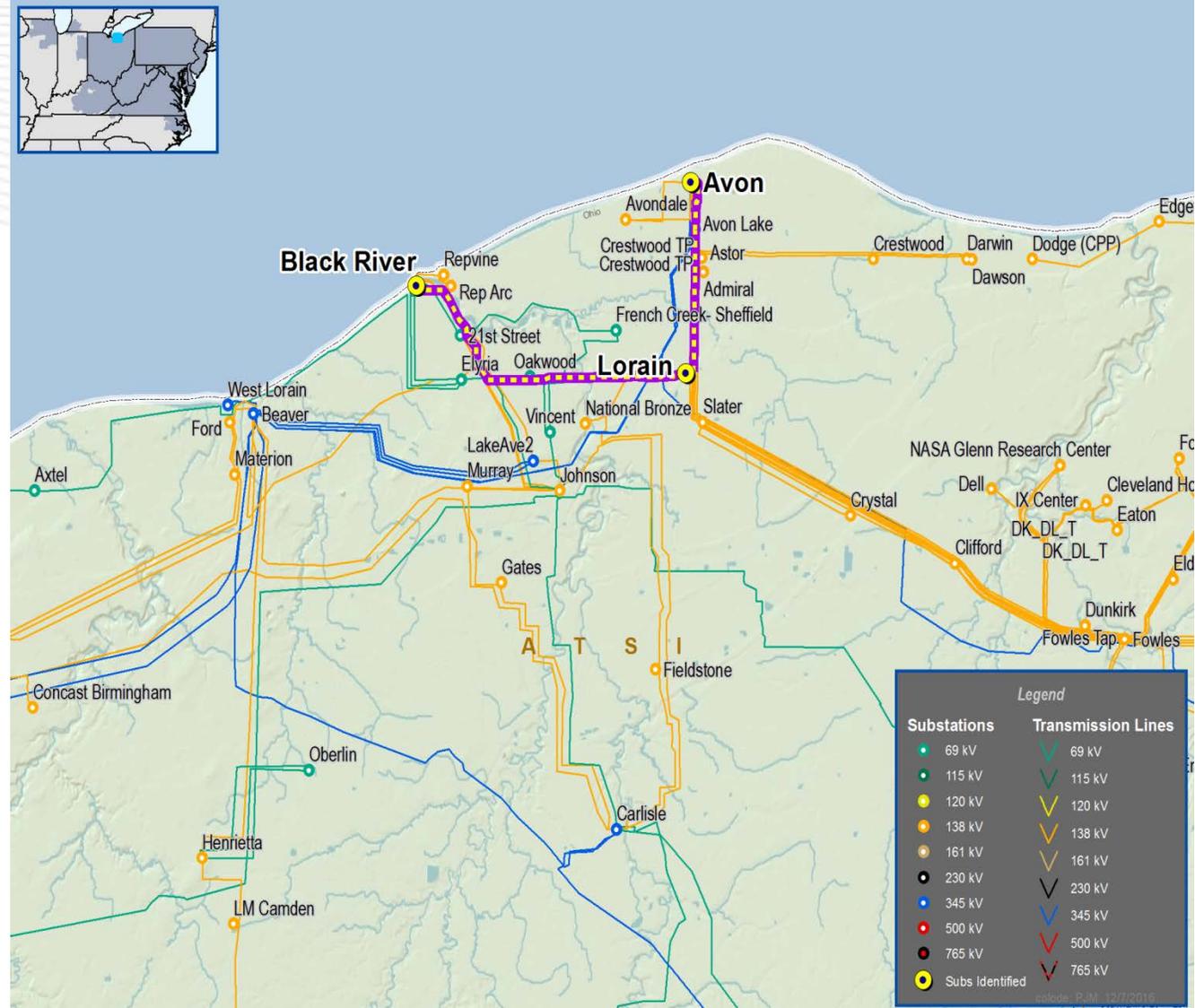
*Transformers are categorized based on low side kV



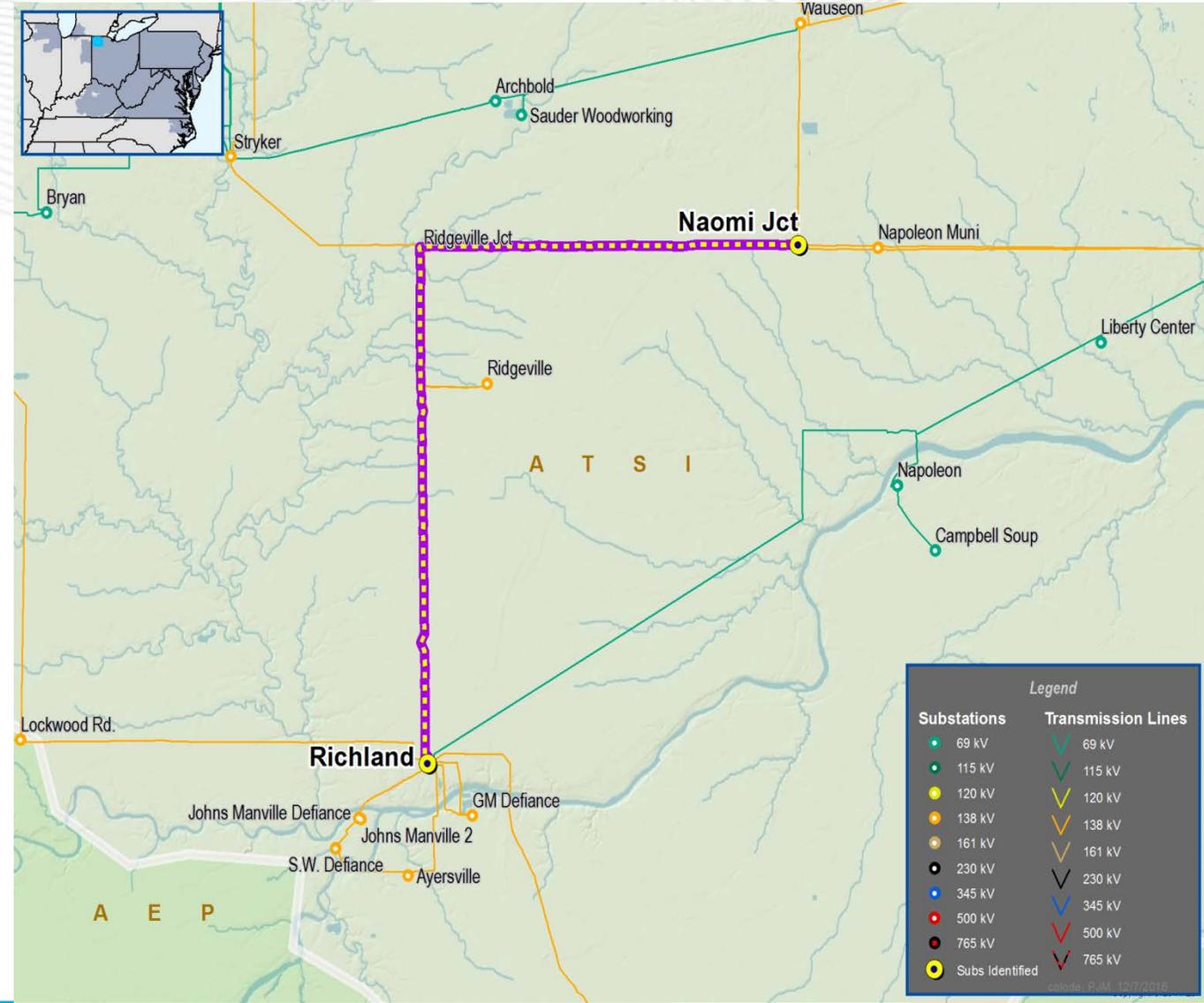


- 25 flowgates recommended for proposals
- 29 Proposals Received from 7 entities addressing 6 Target Zones
 - 17 Greenfield
 - 12 Transmission Owner Upgrade

- Generation Deliverability and Common Mode Outage (FG# 392, 393, 400, 407, 489, 490, 493 and 504) :
- Black River – Lorain - Avon 138 kV circuit is overloaded for tower outage loss of Avon – Lake Ave 345 kV circuits and line fault stuck breaker contingency loss of the Avon – Lake Ave 345 kV circuits.
- **Alternatives considered:**
 - 2016_3-2C
 - 2016_3-5B
 - 2016_3-5D
 - 2016_3-6B
 - 2016_3-6C
 - 2016_3-6D
- **Status:**
 - Evaluation in progress
 - PJM will continue to evaluate these proposals along with those submitted in 2016 RTEP Proposal Window 3 Addendum



- Common Mode Outage (FG# 1, 2, and 3) :
- Richland to Naomi Junction 138 kV circuit is overloaded for multiple bus and line fault stuck breaker contingencies.
- **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)
- **Status:**
 - Evaluation in progress





2016 RTEP Proposal Window #3 Addendum Recommendations



- Status: Window Closed 12/13/2016
- Scope:
 - 2021 RTEP Winter Reliability Analysis
 - 2021 RTEO Summer Reliability Analysis overlap
- Timeline
 - Window Opened: 11/28/2016
 - Window Closed: 12/13/2016
 - Proposal definitions, simulation data and planning cost estimate including detailed cost data

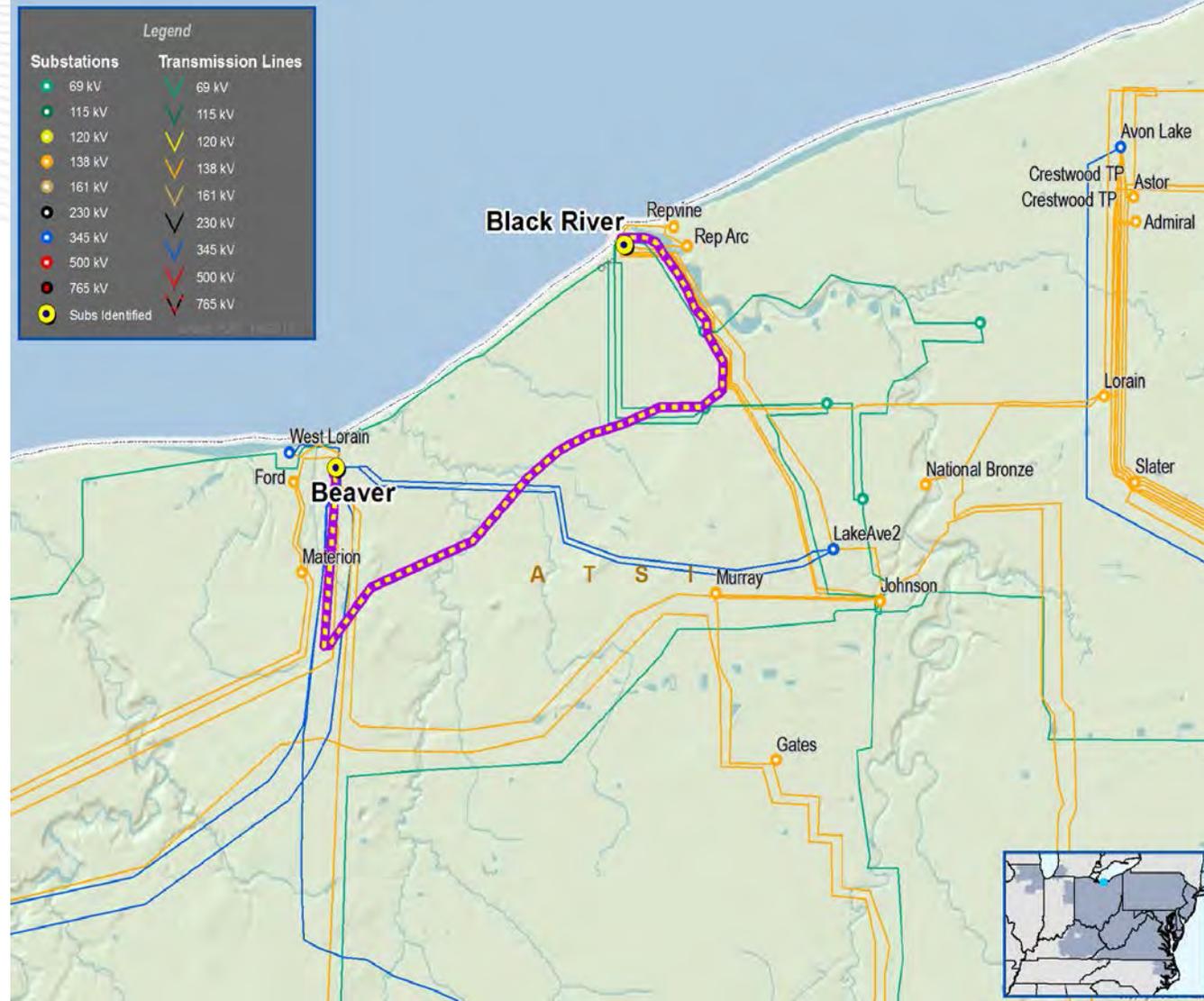
- 2 flowgates recommended for proposals
 - 8 additional flowgates, may be related



- 6 Proposals Received from 3 entities addressing 1 Target Zone
 - 3 Greenfield
 - \$44.6M - \$62.8M
 - 3 Transmission Owner Upgrade
 - \$3.2M-\$19.9M



- Common Mode Outage (Summer - FG# 915 and Winter – FG# 386) :
- The Beaver to Black River 138 kV circuit is overloaded for tower line contingency loss of the Lake Ave – Beaver 345 kV circuits .
- **Alternatives considered:**
 - 2016_3-2C/ 2016_3A-1A (\$44.9 M)
 - 2016_3-5B (\$ 19 M)
 - 2016_3-5D (\$ 35.4 M)
 - 2016_3-5F (\$ 12.4 M)
 - 2016_3A-3A (\$ 19.97 M)
 - 2016_3A-1B (\$ 50.56 M)
 - 2016_3A-2A (\$ 62.8 M)
- **Status:**
 - Study in progress



PSE&G End Of Life Assessment Newark Switch Review

- Refer to PSE&G criteria:

VII. EQUIPMENT ASSESSMENT AND STORM HARDENING

<http://www.pjm.com/~media/planning/planning-criteria/PSE&G-planning-criteria.ashx>

- Risk of a transformer fire that may result in the entire building on fire and thus the loss of ~>300 MVA of load for a long duration. Nearby school/church & healthcare facility.
- Several common mode of failures

- Age: Substation: 1957
- T1: 1972 – T2 & T3: 1958
- Spare: 1992
- Special transformer: Dual ratio (138/26/13)
 - Wye-Wye 13 kV All PSEG 13 kV transformers are delta-wye (30°)
- Maintenance and Maintenance outages
- Rooftop transmission system
- Lower level indoor transformers
- Critical Station (City of Newark - Downtown) ~300 MVA Load
 - Financial buildings
 - City Hall
 - Other Government Buildings
 - NJIT, Rutgers
 - PATH Train, NJ Transit
 - 26kV and 13kV Source station
 - Several Data Centers
 - Downtown Newark
 - Prudential Arena, NJ Performing Arts Center
 - United States Citizenship and Immigration Services (USCIS)

- Basement: Oil rooms, 13 & 26 kV feeders & transmission lines entering the station
- 1st Floor: 26 kV switchgear & Transformers' vaults
- 2nd floor: Distribution reactors
- 3rd floor: Control room/AUX power rooms
- Roof: 138 kV Yard

- Station age and condition
 - Based on unique design, aged equipment and obsolete equipment Newark Switch is considered at end-of-Life.
- Potential risks and consequences
 - Any transformer fire or catastrophic failure would result in the destruction of the whole facility and the loss of 300 MVA of critical load for an extended period of time.
- 26/13 kV bus faults
- Other risks and common modes of failure
- Environmental/structural concerns

- Urban location
- Proximity to existing transmission system



- Distribution feeds below transformer vaults



- Transformers located below the 138 kV rooftop switchyard.
- A transformer fire would be significant and result in catastrophic loss



* Newark Switch transformer



* PSE&G Pierson transformer fire

Potential Project Scope: Build new Newark GIS station in a building located adjacent to the existing Newark Switch and demolish the existing Newark Switch

- New layout is five bay breaker and a half GIS on same property
- 26kV feeders above transformers would move to new GIS building
- 13kV feeders would move to new GIS building
- New (3) story building would require notching out corner of existing building
- Gas Insulated bus (GIB) would run from GIS back through old building
- 13kV and 26kV conductors would run in building to new feeders above GIS back down to underground splices
- Long transformer outages required for cutovers
- Selective demolition of existing building would be done around remaining transformers and new GIB

Anticipated Project Risks

- Construction/demolition in and around live equipment
- Possible extensive structural modifications to support work in building
- Little to no construction laydown
- Long cutover outages on existing circuits
- No stormwater retention to meet city requirements

Cost Estimate

- \$353M

Other Alternatives Considered:

Alternative #2: Find a large property and build a new substation challenges: No large property available in the city of Newark

- Find new property
 - Challenge: No large property available in the city of Newark
- Relocate four (4) 138 kV transmission lines
- Relocate over thirty 26 & 13 kV distribution feeders.
- Requires extended transmission & distribution outages
- Assuming available property, the cost to relocate and rebuild Newark Switch will be ~\$458M (September 2016)

Alternative #3:

- Status quo: Risk of a transformer fire that may result in the loss of entire building and station. The result is the loss of ~>300 MVA of load for a long duration.

PSE&G hired a third party consultant to refine scope

- Evaluate placing new transformers adjacent to new GIS building
- Develop new building design
- Address stormwater retention
- Validate costs and quantify risk

Contacted GIS and switchgear suppliers for alternate equipment configurations

- Validate compact GIS design
- Obtained switchgear/LCC layouts

Conducted constructability reviews

- Developed construction sequencing plan and laydown needs

Public Outreach

- Contacted adjacent property owners regarding expansion
- Continued to evaluate alternates sites for construction laydown
- Met with Mayor and City Council members to identify concerns

Estimate

- Refined costs and modified risk and contingency

Build new Newark GIS station in a building located adjacent to the existing Newark Switch and demolish the existing Newark Switch

Existing Scope from Alternative #1

- New layout is five bay breaker and a half GIS on same property
- 13kV feeders would move to new GIS building

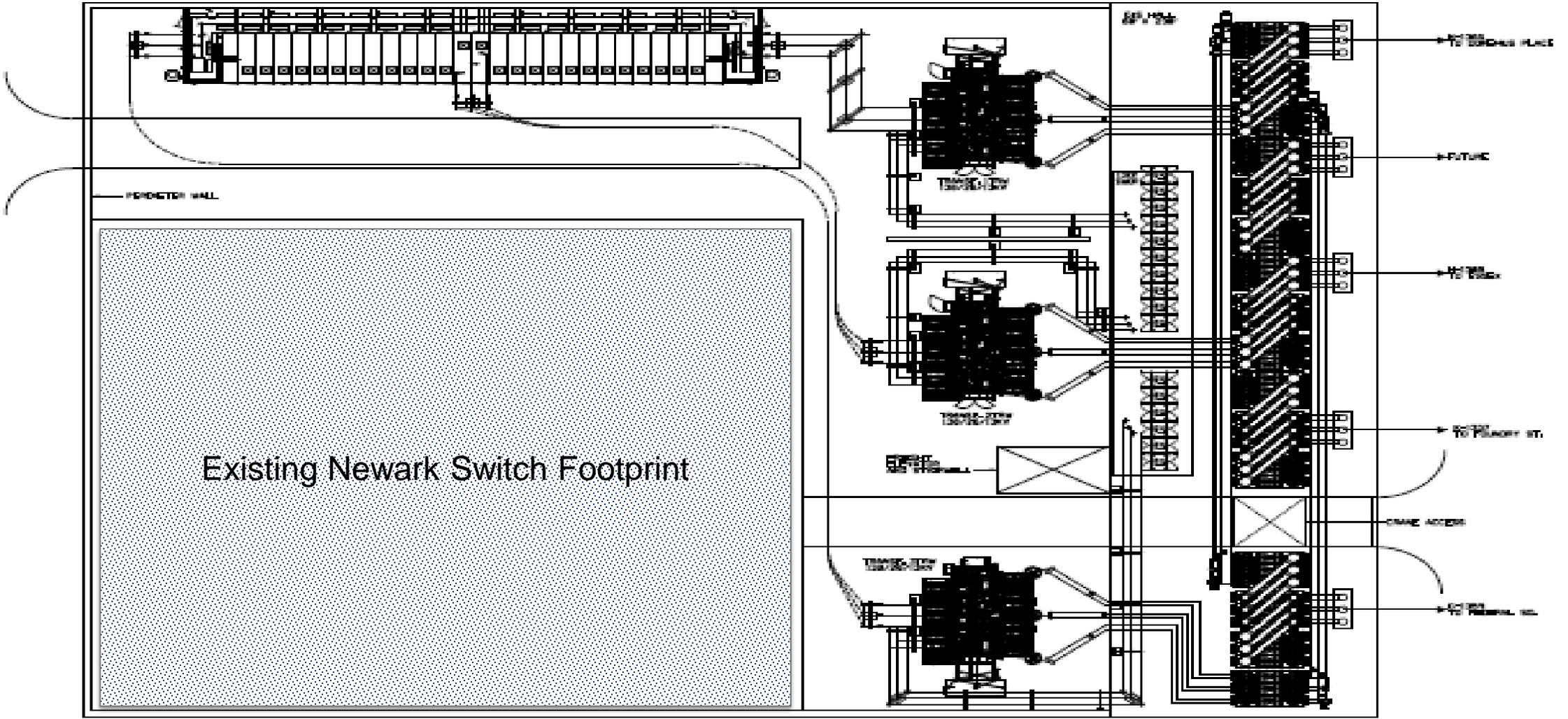
Updated Project Scope for Alternative #1A

- Purchase 3 new dual ratio transformers and place outside of existing building
- 26kV feeders above transformers would move outside on ground level adjacent to new access driveway
- Arrange GIS in compact layout making building narrower, longer and lower
- Build new (3) story building isolated from existing Station building with sub-basement for storm water retention
- GIB is entirely within new building
- 13kV and 26kV feeders are at ground level
- Transformer outages required for cutovers are not as long
- Use conventional demolition methods

Alternative #1A Cost Estimate

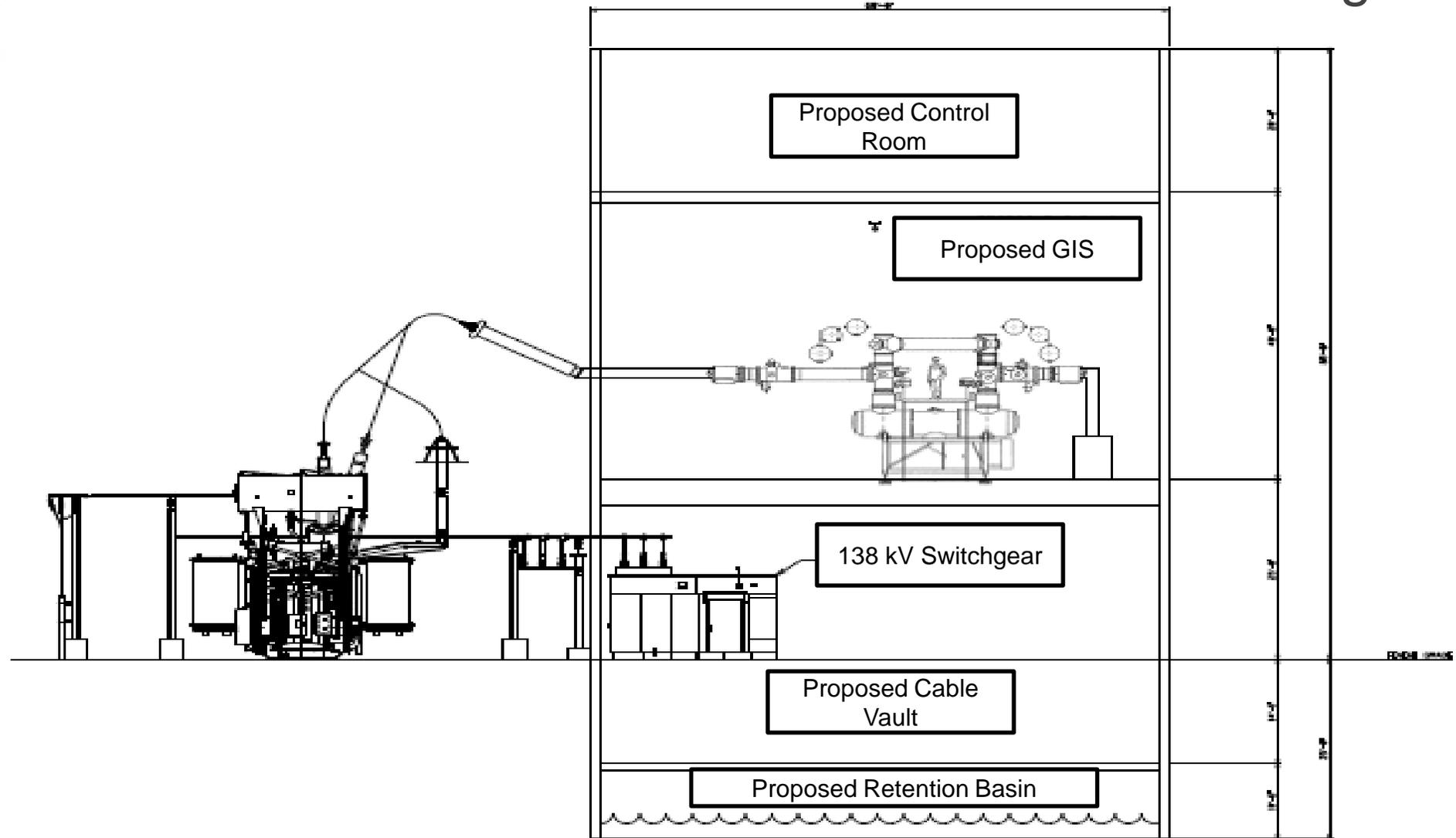
- \$275M

PSE&G Transmission Zone Newark Switch New Design Concept





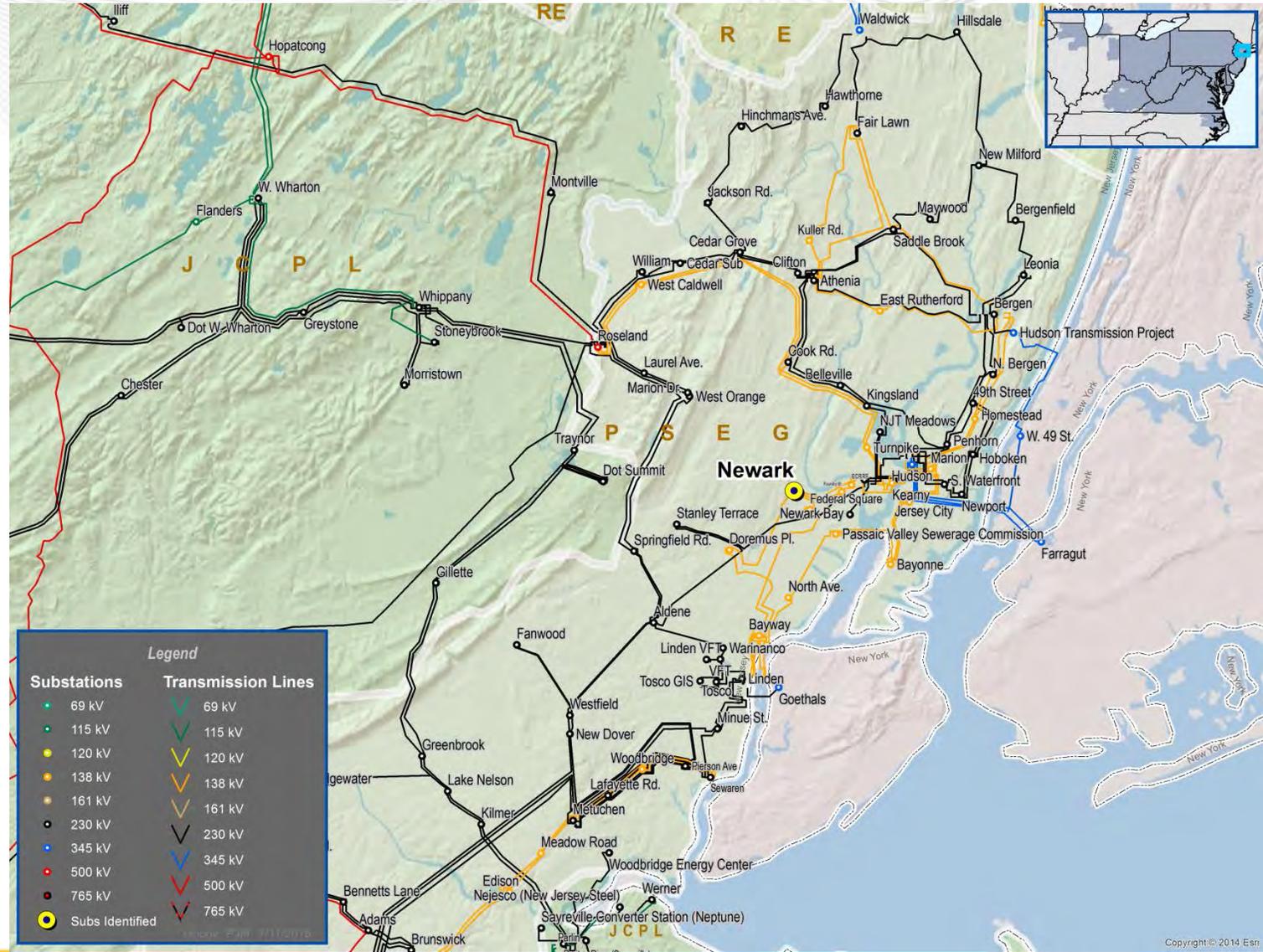
PSE&G Transmission Zone Newark Switch New Design Concept



- Alternate 1A new scope & layout has less constructability concerns than the previous alternative 1 approach
 - All new construction is completely outside of existing building
 - Work can be done on standard work day schedules, reducing construction productivity risks due to construction during outages (i.e. GIB and transformer bushing work)
 - No longer necessary to build GIB over existing transformers
 - Additional property facilitates staging of equipment deliveries
- Transformer arrangement meets standard fire protection criteria and oil-filled cables are no longer next to transformers
 - GIB is no longer over energized equipment in existing building
- Transformer outage cutovers are reduced
 - GIS and GIB can be fully tested prior to starting cutovers
- Reduction in cost estimate of \$78M
 - \$18M in direct costs
 - \$60M in risk/contingency
- Property negotiations are underway
- All equipment fully energized by June 2021



PSE&G Transmission Zone



Problem:
PSE&G FERC 715 Transmission Owner Criteria
Newark Switch Aging Infrastructure

PSE&G FERC 715 Transmission Owner Criteria

- Age
 - Substation: 1953
 - Transformer 1: 1972
 - Transformer 2&3: 1958
 - Spare: 1992
- Housed in an urban building
- Equipment condition assessment
- Equipment has reached its end of life

Alternatives Considered:

1. Build new Newark GIS station in a building (layout #1) located adjacent to the existing Newark Switch and demolish the existing Newark Switch
- 1A. Build new Newark GIS station in a building (layout #1A) located adjacent to the existing Newark Switch and demolish the existing Newark Switch
3. Build a new Newark GIS station elsewhere in Newark and relocate all transmission and distribution cables and protection equipment
4. Status quo, do nothing.

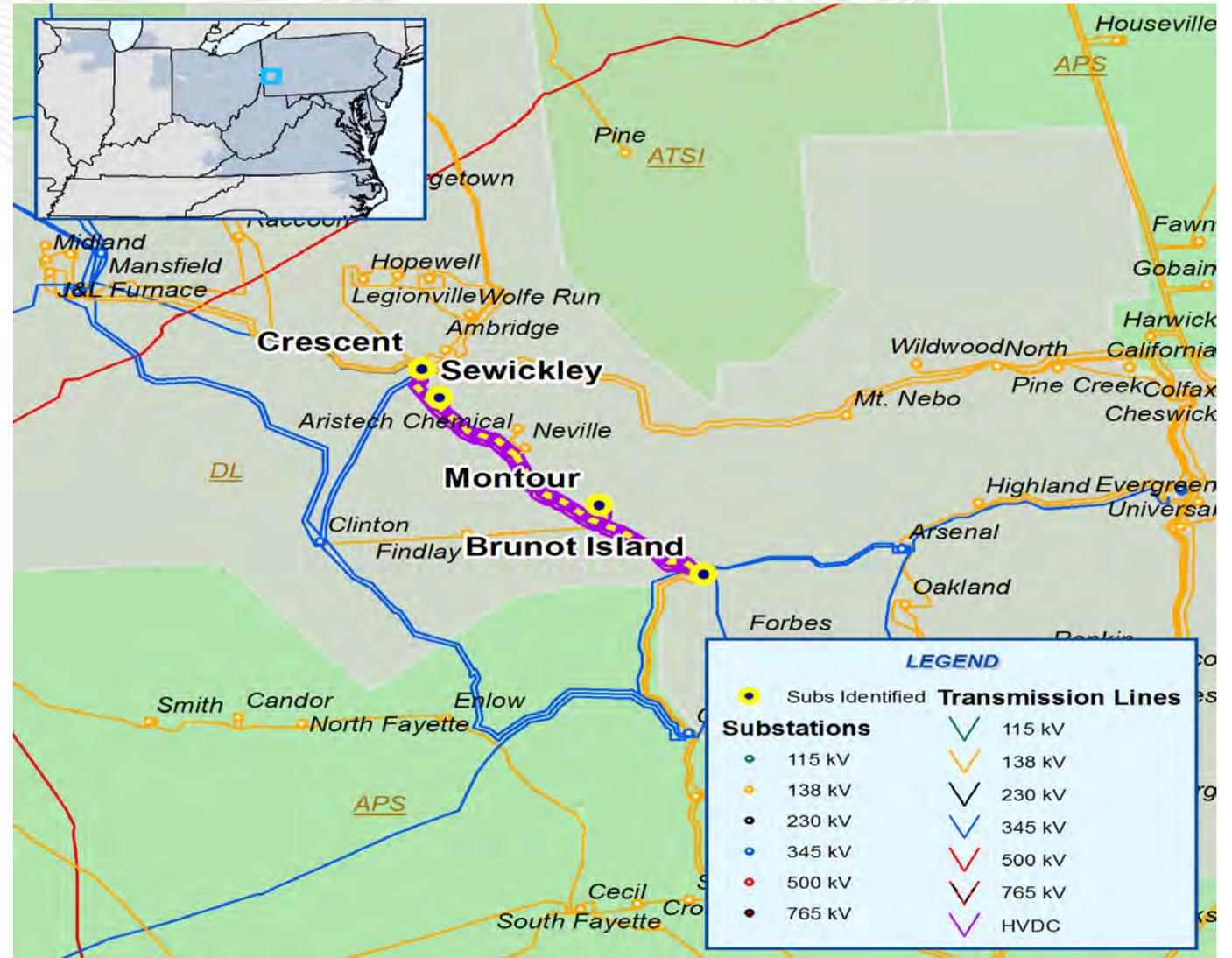
Potential Solution:

Alternative #1A - Build new Newark GIS station in a building (layout #1A) located adjacent to the existing Newark Switch and demolish the existing Newark Switch

Current Alternative #1 Estimated Cost: In-progress : \$275 M (January 2017)

Supplemental Projects

- **Project Scope Change – S0320**
- **Previous Scope:** Rebuild aging double circuit 138 kV tower line between Brunot Island and Crescent substations with 345/138 kV tower line.
- **Old Cost:** \$40M
- **Projected IS Date:** 6/1/2021
- **New Scope:** Rebuild aging double circuit 138 kV tower line between Brunot Island and Crescent substations with 138 kV tower line.
- **New Cost:** \$40M
- **Projected IS Date:** 6/1/2021
- The underlying need for the project has not changed; the replacement of this tower line is needed to address aging infrastructure. DLC plans to build the replacement structures such that the ultimate operating voltage for one circuit will be 345kV and the second circuit will be 138kV. Since the operation of one circuit at 345kV is not required for reliability, DLC will energize both circuits on the replacement structures at 138kV.



RTEP Anticipated Schedule

- Finalize Models
- Analysis
 - 2022 Baseline N-1
 - 2022 Summer Generator Deliverability and Common Mode Outage
 - 2022 Light Load Reliability Analysis
 - 2022 Winter Generator Deliverability and Common Mode Outage
 - 2022 Winter Load Deliverability
 - 2022 Winter N-1-1
 - 2022 Summer Load Deliverability
 - 2022 Summer N-1-1
 - Short Circuit Analysis
 - Annual Stability Assessment
 - Transmission Owner Criteria

RTEP Next Steps

- Artificial Island – continue coordination with PJM Operations, validation of technical results, documentation
- Finalize 2017 Models
- Begin 2017 RTEP Analysis
- Lower Voltage Filing to be implemented with first 2017 RTEP Proposal Window
 - PJM will post the violations we expect to not go through a window consistent with filing

Questions?

Email: RTEP@pjm.com

- Revision History
 - V1 – 2/6/2017 – Original Version Posted to PJM.com
 - V2 – 2/8/2017
 - Add more details for Slide #43 (S0320 scope change)
 - Add Slide #3 – Advancement of B2612.1, B2612.2 and B2612.3
 - V3 – 3/2/2017 – Updated baseline upgrade IDs on Slide 11