

Transmission Expansion Advisory Committee  
(TEAC)  
Recommendations to the PJM Board

PJM Staff Whitepaper  
February 2017



## **EXECUTIVE SUMMARY**

On December 7, 2016 the PJM Board of Managers approved changes to the Regional Transmission Expansion Plan (RTEP), totaling \$259.34 million, primarily to resolve baseline reliability criteria violations.

Since that time PJM has identified additional baseline reliability criteria violations within the planning horizon as part of the 2016 RTEP. Transmission upgrades have been identified to resolve these reliability criteria violations. The increase in the RTEP to include the upgrades to resolve the new baseline reliability criteria violations is \$1,477.33 million. In addition, a number of previously approved baseline projects have been cancelled or the cost and scope has changed resulting in an increase of \$38.89 million. The net impact due to baseline reliability changes is an increase of \$1,516.22 million.

With these changes, the RTEP includes over \$30,837.98 million of transmission additions and upgrades since the first plan was approved by the Board in 2000.

The additional baseline projects are summarized in the following paper and were presented for the Board Reliability Committee's consideration and for recommendation to the Board for approval. At the February 2017 meeting, the PJM Board approved the updated RTEP as requested.

## Summary of Results

### 2016 Baseline Transmission Upgrades Changes and Additions

One aspect of the development of the Regional Transmission Expansion Plan is an evaluation of the “baseline” system, i.e. the transmission system without any of the generation interconnection requests included in the current planning cycle. This baseline analysis determines the compliance of the existing system with reliability criteria and standards. Transmission upgrades required to maintain a reliable system are identified and reviewed with the Transmission Expansion Advisory Committee (TEAC). The cost of transmission upgrades to mitigate such criteria violations are the responsibility of the PJM load customers.

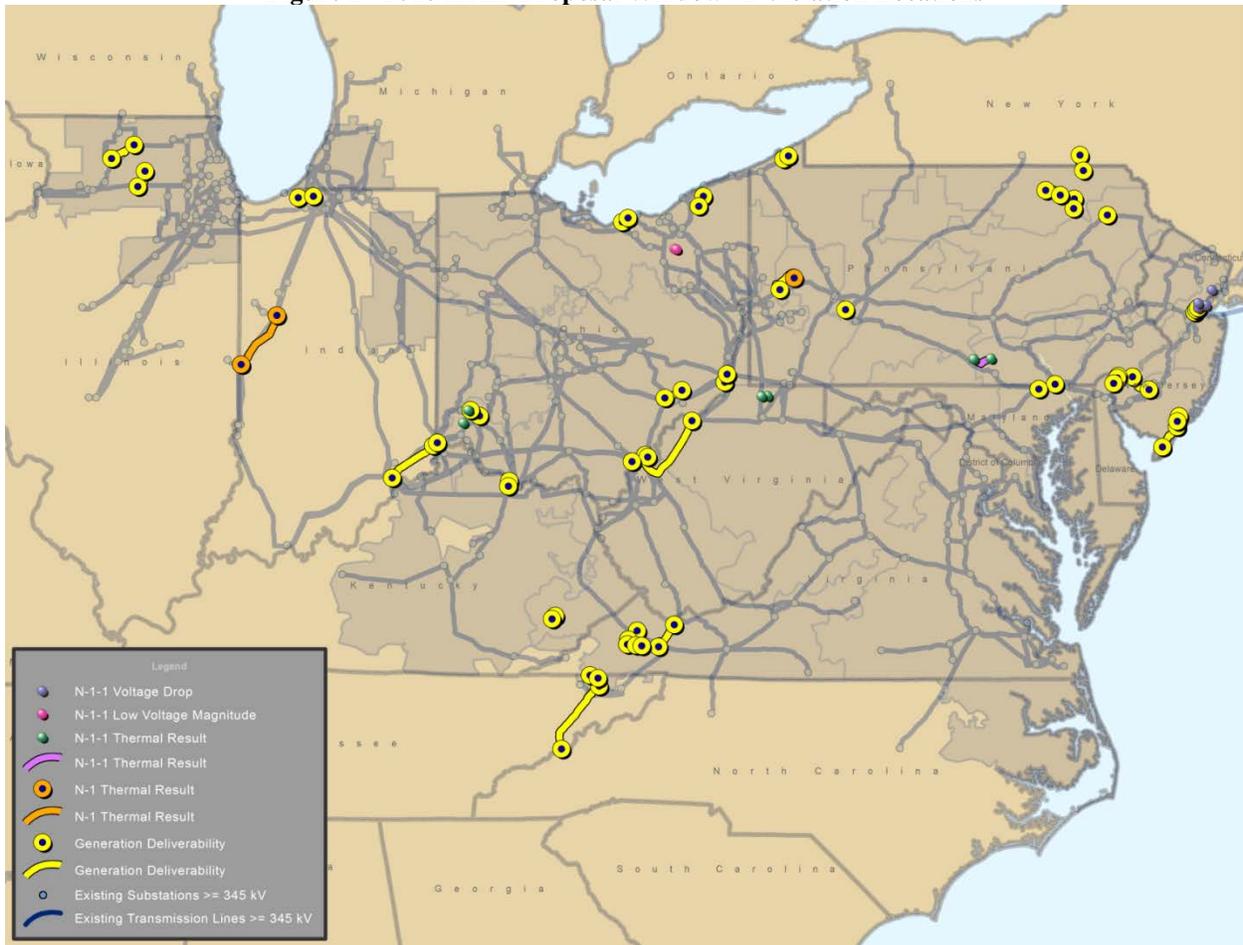
#### Baseline Reliability:

##### 2016 RTEP Proposal Window #2

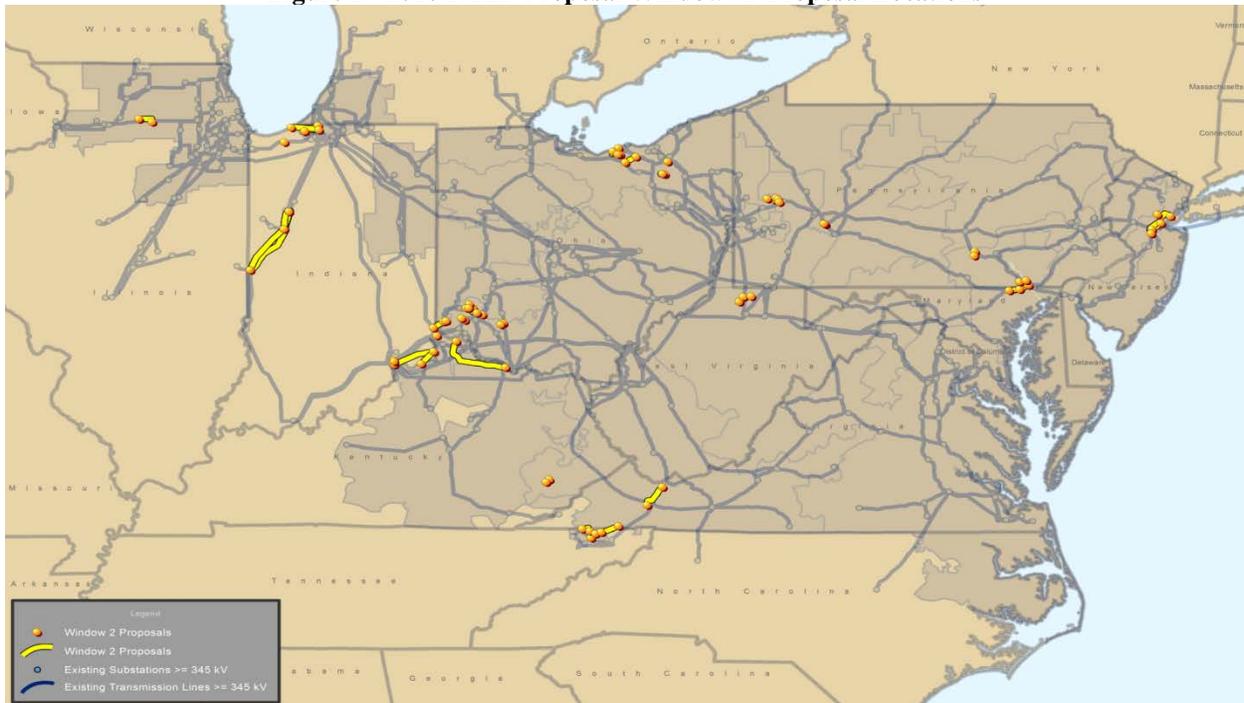
On June 29<sup>th</sup> of last year PJM opened a 30-day proposal window, which closed on July 29<sup>th</sup> with additional detailed costs due on August 15<sup>th</sup>. This window, administered as the PJM 2016 RTEP Proposal Window #2, solicited proposals for a number of PJM reliability criteria violations. The focus for Proposal Window #2 was forecasted Summer 2021 conditions. The PJM reliability criteria violations included Baseline N-1 (thermal and voltage), Generation Deliverability, Common Mode Outage, N-1-1 (thermal and voltage), and Load Deliverability (thermal and voltage) violations. PJM staff identified potential reliability criteria violations associated with 137 flowgates (monitored transmission facility and contingency/outage pairs). Out of the total 137 flowgates, proposals were requested for 71 flowgates. Proposals were not requested for the remaining flowgates as 63 were related to retired generation where the violation will not persist assuming the generator retires as planned, and the remaining 3 were related to suspended generators in the interconnection queue process. Analyses will be updated if the statuses of these generators change.

In response to the 2016 RTEP Proposal Window #2, PJM received 87 baseline proposals to address the reliability criteria violations. The proposals were received from 13 entities, including incumbent Transmission Owners and non-incumbent transmission developers. The non-incumbent transmission developers included Mid-Atlantic MCN, NextEra Energy Transmission, NIPSCO, Northeast Transmission Development/LS Power, Transource Energy, PPL, and Public Service Electric & Gas. Of the total 87 proposals, 41 were Transmission Owner Upgrades and 46 were Greenfield Projects. The locations of the violations associated with Proposal Window #2 are shown below in Figure 1, while Figure 2 identifies the location of the proposals that were submitted for Proposal Window #2.

**Figure 1 - 2016 RTEP Proposal Window #2 Violation Locations**



**Figure 2 - 2016 RTEP Proposal Window #2 Proposal Locations**



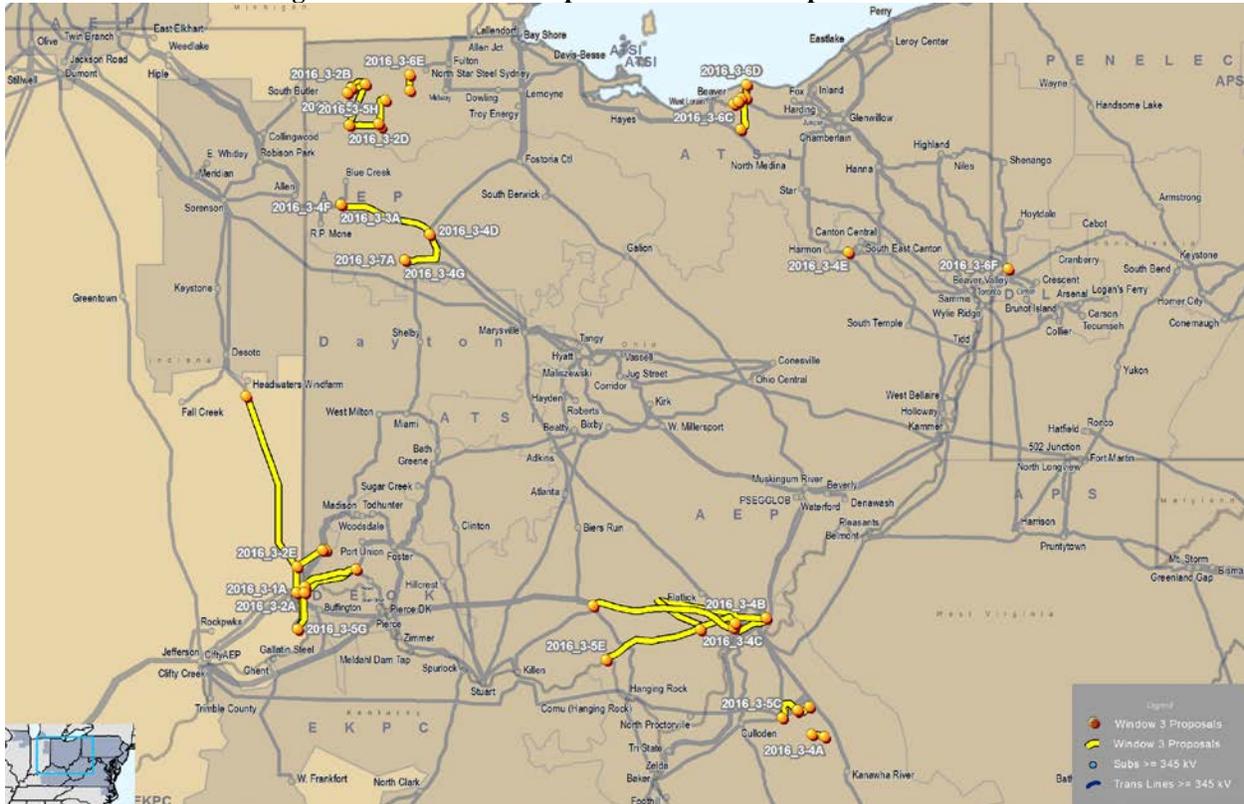
PJM staff reviewed details of all proposals, including an evaluation of the effectiveness of each of the proposals, with stakeholders through the Transmission Expansion Advisory Committee (TEAC). PJM completed evaluation of all proposals, and is recommending 4 projects in addition to the 11 projects which were approved at the December 7, 2016 Board meeting. The recommended projects address violations in the EKPC and DEOK transmission zones. All of the recommended projects are upgrades to existing facilities that were submitted by the incumbent Transmission Owner. The recommended projects include upgrading an existing reactor, installing a new reactor on a PJM tie line that has an existing reactor at the non-PJM end of the line, a transmission line reconductor, and a substation expansion. Additional information about the recommended projects is included in this white paper.

### 2016 RTEP Proposal Window #3

In addition to Proposal Window #2, PJM administered 2016 RTEP Proposal Window #3 which opened on September 30<sup>th</sup> and closed on October 31<sup>st</sup>, with detailed cost estimates due on November 15<sup>th</sup>. Identified PJM reliability criteria violations for Proposal Window #3 included Short Circuit violations along with Baseline Thermal and Generation Deliverability/Common Mode Outage for Winter conditions. This was the first time winter criteria testing was done as part of the RTEP after developing the new winter criteria in 2015. PJM staff identified potential reliability criteria violations associated with 103 flowgates (monitored transmission facility and contingency/outage pairs). Out of the 103 flowgates, proposals were requested for 25 flowgates. Proposals were not requested for the remaining 78 flowgates for the following reasons: 20 violations overlapped with those from Proposal Window #2, 9 violations were related to retired generation which will not persist assuming the generator retires as planned, 38 violations were related to suspended generators in the interconnection queue process (analyses will be updated if the statuses of these



Figure 4 - 2016 RTEP Proposal Window #3 Proposal Locations



PJM staff reviewed details of all proposals, including an evaluation of the effectiveness of each of the proposals, with stakeholders through the Transmission Expansion Advisory Committee (TEAC). PJM recommended 6 projects, which address violations in the ATSI, AEP, and DEOK transmission zones. All of the recommended projects are upgrades to existing facilities that were submitted by the incumbent Transmission Owner. The recommended projects include breaker replacements, a transmission line upgrade, a conversion from two circuits to one, and transmission line reconductors. Additional information about the recommended projects is included in this white paper.

### Immediate Need Projects

Additionally, 32 projects are recommended to address immediate need baseline reliability issues. The immediate need baseline reliability projects include transmission enhancements with a need date of 3 years or less. Due to the critical timing of immediate need projects, PJM did not have time to administer a proposal window to solicit alternative solutions from PJM stakeholders for the associated reliability drivers.

The immediate need projects are being driven by several main categories of criteria drivers. The project drivers include short circuit fault duty issues, a maximum allowable load loss limit violation stemming from a load model update, high voltage issues during Light Load conditions, generator deactivations, facilities impacted by a queue project that recently signed and ISA with an in-service date within the immediate need timeframe, and FERC Form 715 Transmission Owner Criteria. The project drivers categorized as FERC

Form 715 Transmission Owner Criteria include aging infrastructure, direct-connect load limitations, thermal, and voltage issues.

## Reliability Project Summary

A summary of the more significant baseline projects with estimated costs equal to or greater than \$5 million are detailed below. A complete listing of all of the projects that are being recommended along with their associated cost allocations is included as Attachment A and B to this white paper. The projects with estimated costs less than \$5 million include circuit breaker replacements, transmission line reconductors, a capacitor bank installation, a transmission line rebuild, terminal equipment replacements, relay installations and replacements, reactor upgrades and installations, and a circuit conversion project from two circuits to one.

### Mid-Atlantic Region System Upgrade

- ME Transmission Zone
  - Install a 3rd 230/69 kV 224 MVA Transformer at Lyons and install new terminal equipment for existing Lyons - East Penn(865) 69 kV Line - \$5.5 M
  
- PPL Transmission Zone
  - Expand existing Lycoming 69kV yard to double bus double breaker arrangement - \$22 M
  - Reconfigure/Expand the Lackawanna 500 kV substation by adding a third bay with three breakers - \$11.26 M
  
- PSE&G Transmission Zone
  - Install second 230/69 kV transformer at Cedar Grove and build a new 69 kV circuit from Cedar Grove to Great Notch - \$44 M
  - Build 69 kV circuit from Locust Street to Delair - \$13.5 M
  - Construct River Road to Tonnelle Avenue 69kV Circuit - \$31 M
  - PSE&G Reactors
    - Install 2X50 MVAR shunt reactors at Kearny 230 kV substation - \$17.8 M
    - Increase the size of the Hudson 230 kV, 2X50 MVAR shunt reactors to 2X100 MVAR - \$13.5 M
    - Install 2X100 MVAR shunt reactors at Bayway 345 kV substation - \$30.6 M
    - Install 2X100 MVAR shunt reactors at Linden 345 kV substation - \$28.5 M
  - Convert the R-1318 and Q1317 (Edison – Metuchen) 138 kV circuits to one 230 kV circuit - \$125 M
  - Convert the N-1340 and T-1372/D-1330 (Brunswick – Trenton) 138 kV circuits to 230 kV circuits - \$302 M
  - Convert the F-1358/Z1326 and K1363/Y-1325 (Trenton - Burlington) 138 kV circuits to 230 kV circuits - \$312 M

### Western Region System Upgrades

- AEP Transmission Zone
  - Load Loss Limit - \$107.7 M
    - Construction a new 138 kV station, Campbell Road, tapping into the Grabill – South Hicksville 138 kV line
    - Reconstruct sections of the Butler-N. Hicksville and Auburn-Butler 69 kV circuits as 138 kV double circuit and extend 138 kV from Campbell Road station
    - Construct a new 345/138 kV SDI Wilmington Station which will be sourced from Collingwood 345 kV and serve the SDI load at 345 kV and 138 kV respectively
    - Looped 138 kV circuits in-out of the new SDI Wilmington 138 kV station resulting in a direct circuit to Auburn 138 kV and in direct circuit to Auburn and Rob Park via Dunton Lake, and a circuit to Campbell Road; Reconductor 138kV line section between Dunton Lake – SDI Wilmington
    - Expand Auburn 138 kV bus
  - Reconductor the Maddox Creek - East Lima 345 kV circuit with 2-954 ACSS Cardinal conductor - \$18.2 M
  - Reconductor and string open position and “six-wire” 6.2 miles of the Chemical - Capitol Hill 138 kV circuit - \$7.3 M
  
- DEOK Transmission Zone
  - Expand Garver 345 kV sub to include 138 kV. Install 1-345 kV breaker, 1-345/138 kV 400 MVA transformer, 6-138 kV Breakers and bus work. Connect local 138 kV circuits from Todhunter, Rockies Express, and Union. - \$18.7 M
  
- AEP and DEOK Transmission Zone
  - Upgrade the Tanner Creek - Miami Fort 345 kV circuit (AEP portion) - \$3.9 M
  - Upgrade the Tanner Creek - Miami Fort 345 kV circuit (DEOK portion) - \$3.9 M

#### Southern Region System Upgrades

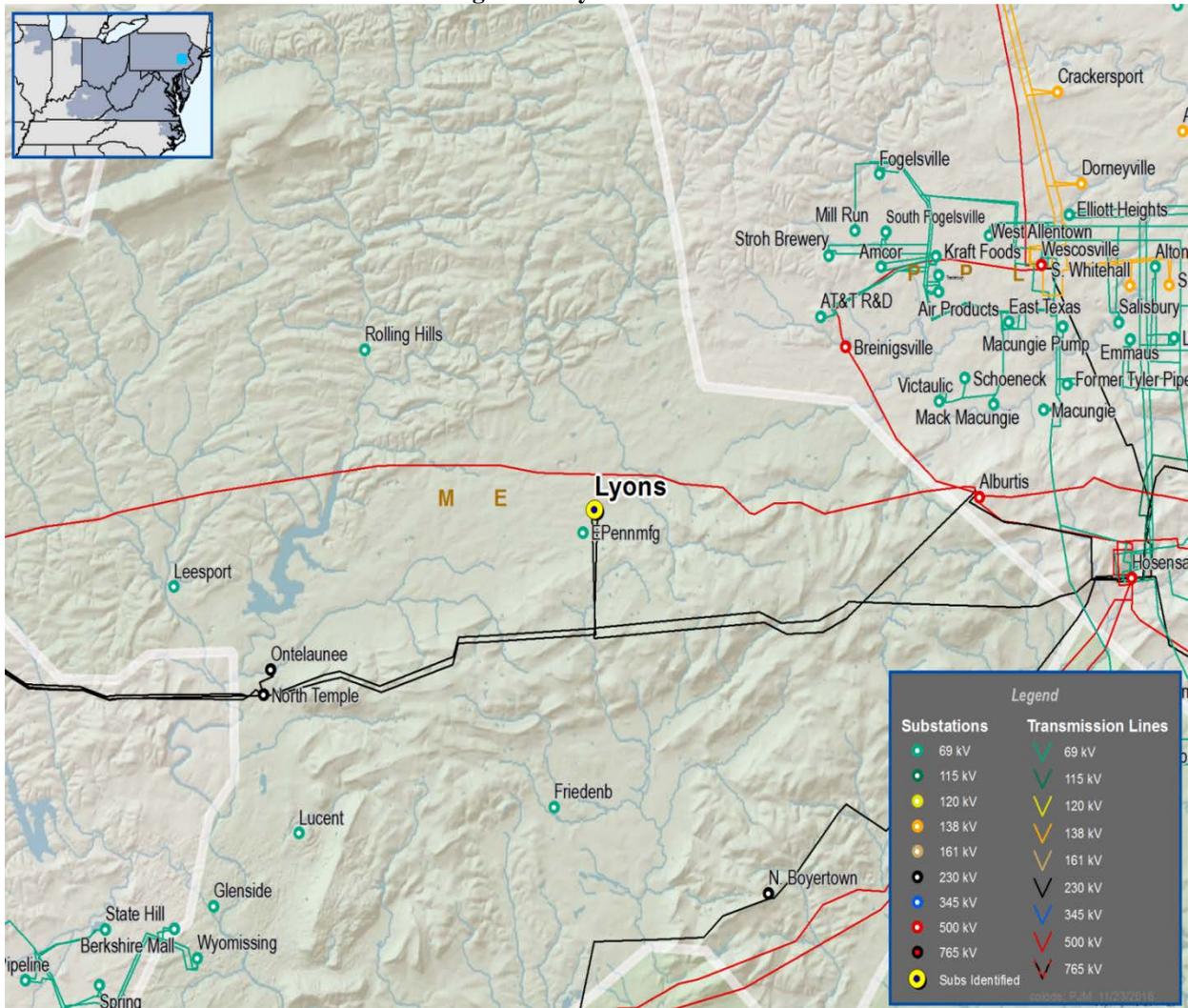
- Dominion Transmission Zone
  - Install a +/-125 MVar Statcom at Colington 230 kV - \$30 M
  - Rebuild Line #549 Doods – Valley 500kV - \$58.16 M
  - Rebuild Line #550 Mt. Storm – Valley 500kV - \$225 M
  - Build a new Pinewood 115kV switching station at the tap serving North Doswell DP with a 115kV four breaker ring bus - \$12.8 M

Following is a more detailed description of the larger scope upgrades that are being recommended to the PJM Board for their consideration. A description of the criteria driving the need for the upgrade as well as the required in-service date is provided.

**Baseline Project B2814 – Lyons 230/69 kV Transformer**

An existing customer in MetEd, served radially from the Lyons 230/69 kV substation, will be increasing their load incrementally starting from 2018 through 2023. Due to the incremental increase in load, the Lyons 230/69 kV transformer #3 is overloaded for the loss of the #5 transformer in the 2019 planning year. The overload is a violation of First Energy’s FERC Form No. 715 N-1 Transmission Planning Criteria, and the recommended solution is to install a third 230/69 kV 224 MVA transformer at Lyons and install new terminal equipment for the existing Lyons – East Penn 69 kV circuit. The estimated cost for this work is \$5.5 million and the required service date is June 1, 2019. This project is an immediate need solution where the timing required to include the violation in an RTEP proposal window was infeasible. The local Transmission Owner, MetEd, is designated to install the equipment.

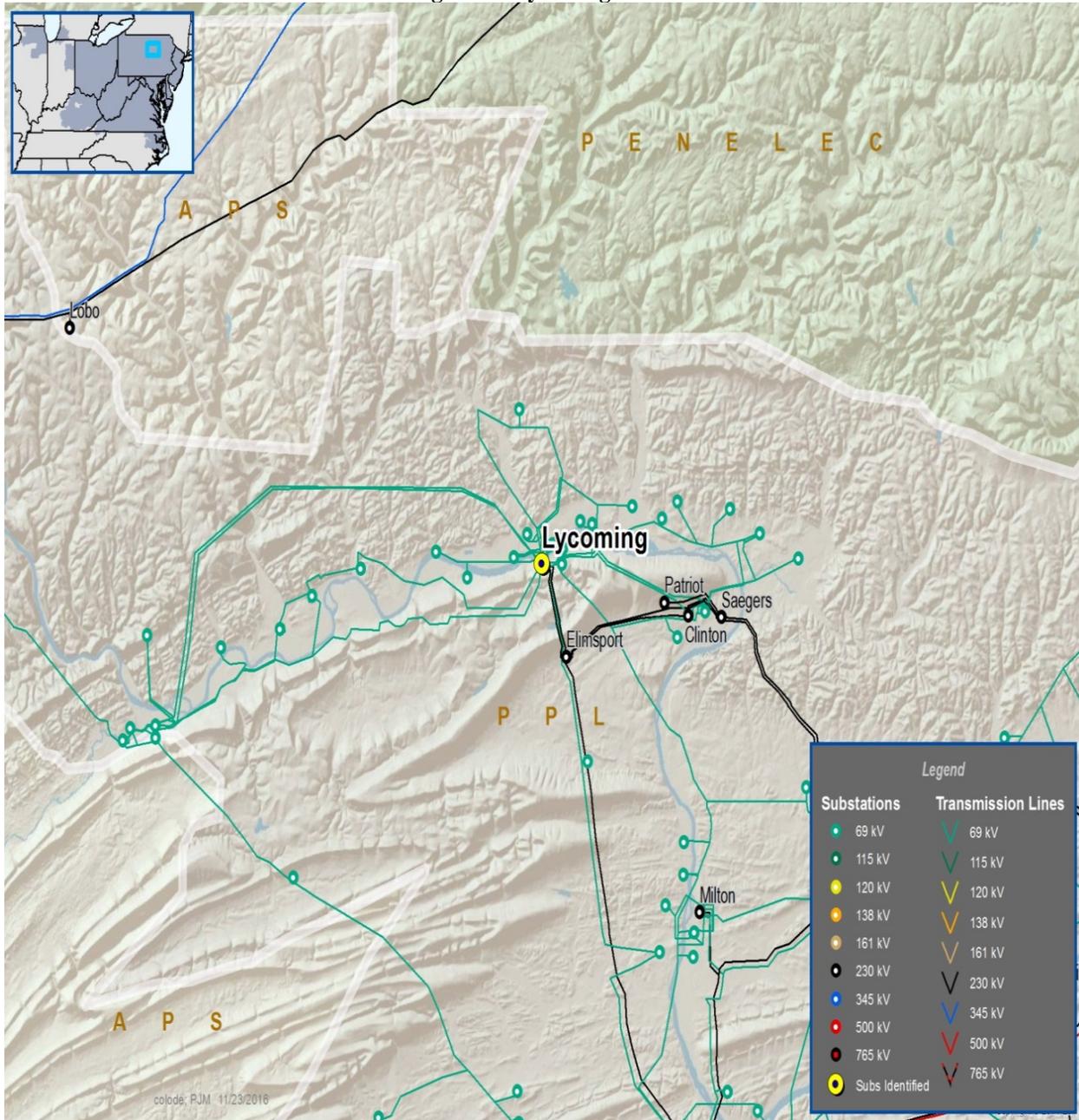
**Figure 5 - Lyons 230/69 kV**



**Baseline Project B2813 – Lycoming 69 kV Yard Expansion**

A stuck 69 kV bus section circuit breaker in the Lycoming 69 kV yard or a bus section failure in the Lycoming 69kV yard leads to more than acceptable voltage drop and creates less than acceptable minimum voltage. PPL's FERC Form No. 715 Transmission Planning Criteria indicates that for their 69 kV system, there should not be more than a 5% voltage drop and not less than 0.90 pu voltage for a stuck bus section circuit breaker or a bus section fault. To resolve the violation at Lycoming 69 kV, an alternative to build a new 230/69 kV regional substation and more than 50 miles of double circuit 230 kV line was considered, but not pursued due to the considerably higher cost. The recommended solution is to expand the existing Lycoming 69 kV yard to a double bus double breaker arrangement. This solution converts the substation from a single operating bus to a double bus configuration and eliminates the risk of losing the Lycoming source under a stuck circuit breaker contingency. The estimated cost is \$22 million and the required in service date is June 1, 2018. This project is an immediate need solution where the timing required to include the violations in an RTEP proposal window was infeasible. The local Transmission Owner, PPL, is designated to expand the substation.

Figure 6 - Lycoming 69 kV

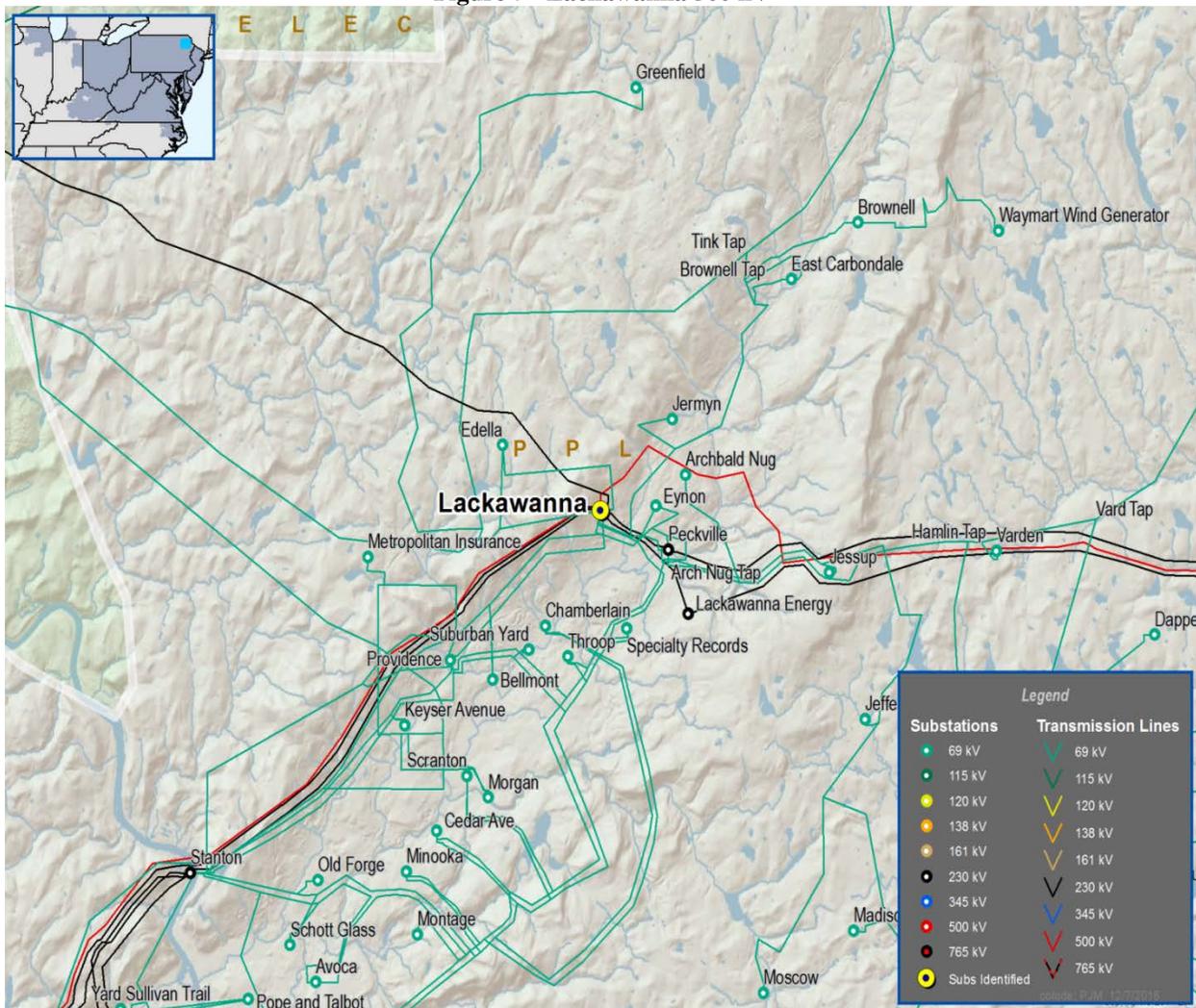


**Baseline Project B2824 – Lackawanna 500 kV Substation Reconfiguration/Expansion**

The Lackawanna 500/230 kV transformers #3 and #4 are each overloaded for the line fault stuck breaker contingency loss of the Lackawanna – Susquehanna 500 kV circuit and the associated other Lackawanna 500/230 kV transformer. PJM solicited proposals to address this issue in the 2016 RTEP Proposal Window #2. However, the Lackawanna 500/230 kV transformers are impacted by a queue project, Y2-089, that recently signed an Interconnection Service Agreement and the PSEG/ConED and RAMAPO PAR setting changes related to termination of the ConEd Wheel transmission service. The in service date of the queue

project is January 31, 2019 and the ConEd Wheel transmission service is expected to terminate in the spring of 2017 which makes the required in service date of a solution within the immediate need timeframe. Despite the immediate need timeframe, PJM was able to determine and review the most competitive projects submitted through the window. One alternative that was considered was to install series reactors along the Lackawanna 500/230 kV transformers. However, this alternative was not recommended as it is not an ideal long term solution to the issue. A couple of other alternatives were also considered, the first was to install a phase angle regulator at the substation, and the second was to replace the transformers in question. However, neither of these solutions were the most cost effective. The recommended solution was proposed by the incumbent Transmission Owner, PPL, to reconfigure/expand the Lackawanna 500 kV substation by adding a third bay with three breakers. The estimated cost is \$11.26 million and the required in service date is January 31, 2019 in conjunction with the queue project in service date.

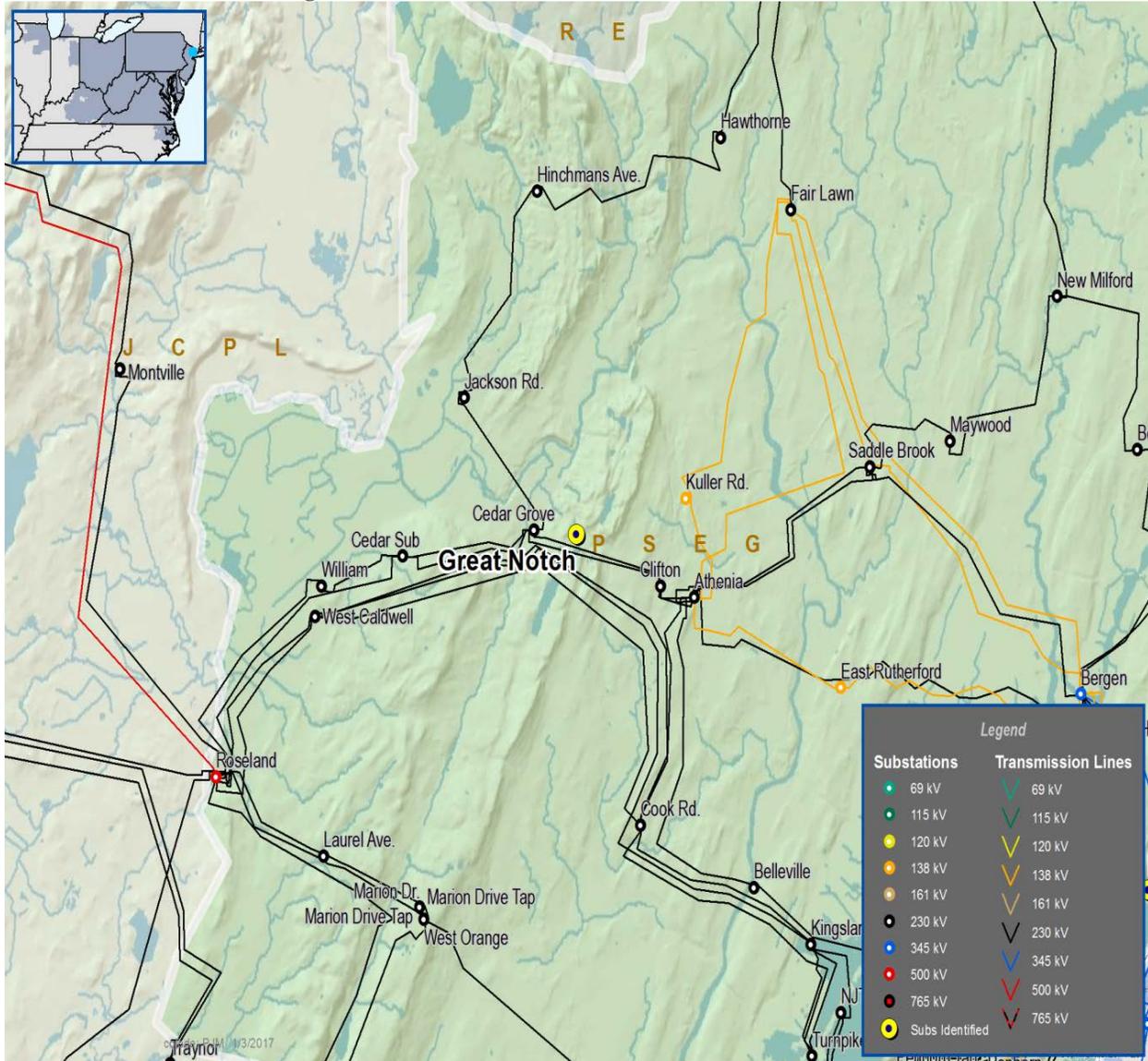
**Figure 7 - Lackawanna 500 kV**



**Baseline Project B2810 – Cedar Grove 230/69 kV**

PSE&G's Great Notch 69 kV substation, currently has two 69 kV circuits as its supply. During an N-1-1 contingency event, the Great Notch 69 kV substation loses its electric supply, and this is a violation of PSE&G's FERC Form No. 715 Transmission Planning Criteria. One alternative considered was to connect Great Notch to the Jackson Rd. 69 kV station. However, the route is much longer than the recommended solution and would require major highway and river crossing, making the estimated cost higher. The recommended solution is to install a second 230/69 kV transformer at Cedar Grove 230/69 kV substation and build a new Cedar Grove – Great Notch 69 kV circuit. The estimated cost is \$44 million, and the required in service date is June 1, 2019. This project is an immediate need solution where the timing required to include the violation in an RTEP proposal window was infeasible. The local Transmission Owner, PSE&G, is designated to implement the recommended solution.

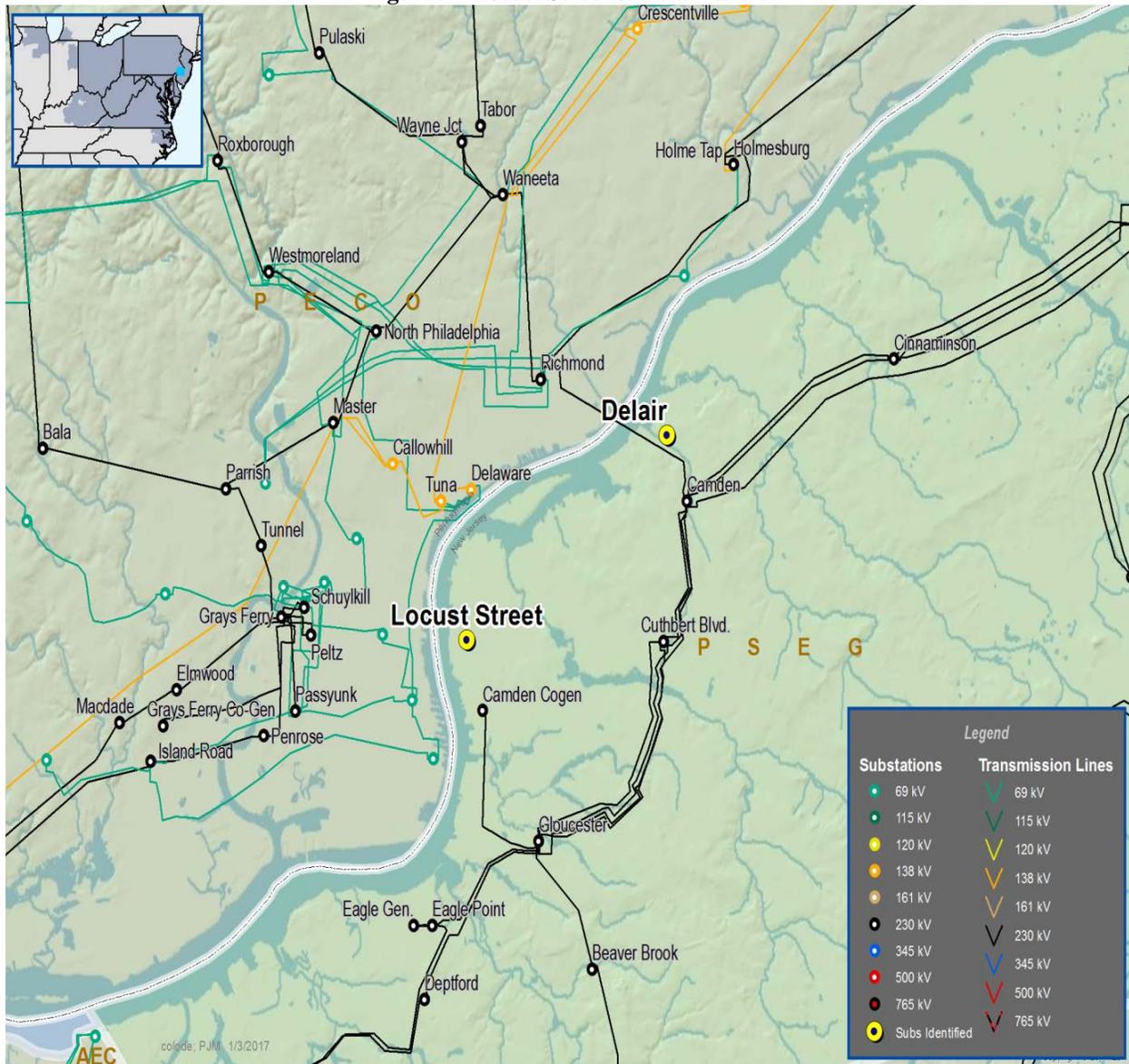
**Figure 8 – Great Notch 69 kV & Cedar Grove 230/69 kV**



**Baseline Project B2811 – Locust Street – Delair 69 kV**

PSE&G's Locust Street and Delair 69 kV substations, currently have two 69 kV circuits as their supply. During an N-1-1 contingency event, Delair and Locust Street 69 kV substations lose their electric supply, and this is a violation of PSE&G's FERC Form No. 715 Transmission Planning Criteria. One alternative considered was to connect Locust Street to the East Riverton 69 kV station. However, this route is approximately 60% longer than the recommended solution, making the estimated cost higher. The recommended solution is to build a new Locust Street – Delair 69 kV circuit. The estimated cost is \$13.5 million and the required in service date is June 1, 2017. This project is an immediate need solution where the timing required to include the violation in an RTEP proposal window was infeasible. The local Transmission Owner, PSE&G, is designated construct the line.

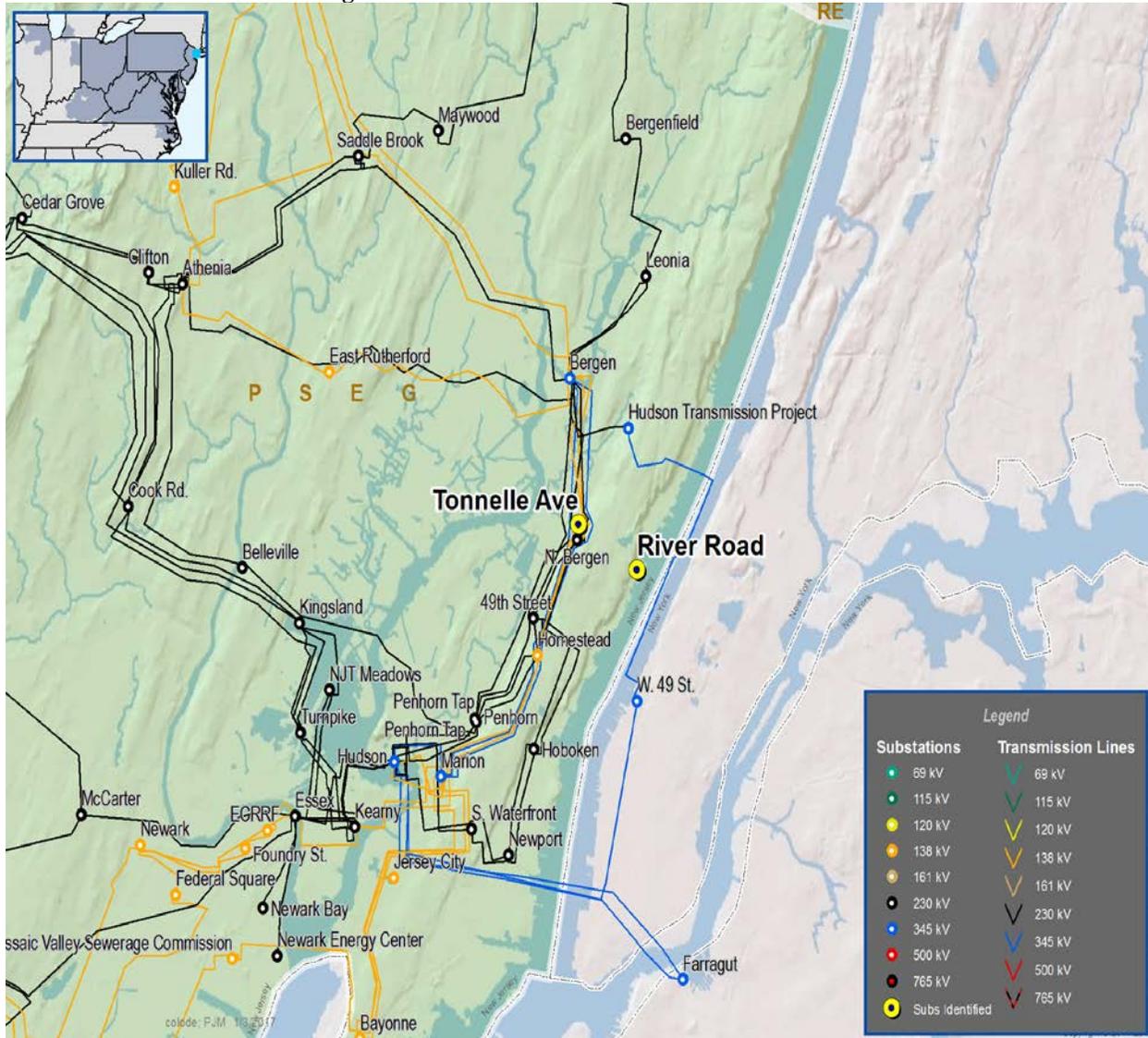
**Figure 9 - Locust Street & Delair 69 kV**



**Baseline Project B2812 – River Road – Tonnelle Avenue 69 kV**

PSE&G's River Road and Tonnelle Avenue 69 kV substations, currently have two 69 kV circuits as their supply. During an N-1-1 contingency event, River Road and Tonnelle Avenue 69 kV substations lose their electric supply, and this is a violation of PSE&G's FERC Form No. 715 Transmission Planning Criteria. One alternative considered was to connect River Road to the Union City 69 kV station. However, this route would be double in distance, all of which would be underground construction. This alternative would also include a second circuit to be added from Bergen SW to Tonnelle Avenue with an expansion of the GIS at Bergen SW, making the estimated cost higher than the recommended solution. The recommended solution is to build a River Road – Tonnelle Avenue 69 kV circuit. The estimated cost is \$31 million and the required in service date is June 1, 2017. This project is an immediate need solution where the timing required to include the violation in an RTEP proposal window was infeasible. The local Transmission Owner, PSE&G, is designated construct the line.

Figure 10 - River Road & Tonnelle Avenue 69 kV

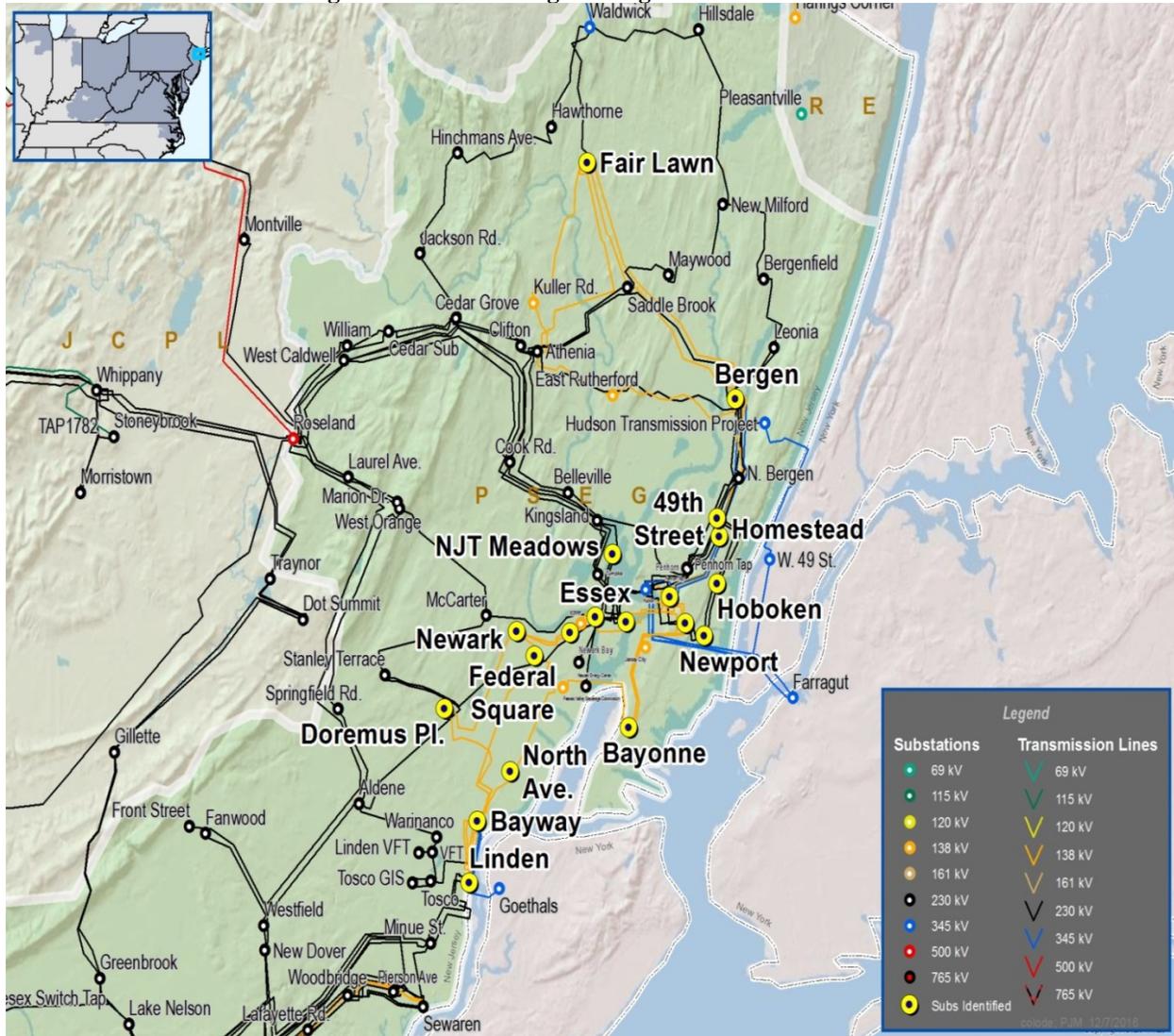


**Baseline Project B2825 – PSE&G Reactors**

PJM completed retool analyses during Light Load conditions to determine if high voltage violations would exist after the Bergen – Linden Corridor (BLC) project is fully energized. The BLC project in northern PSE&G is currently under construction and is expected to be completed by June, 2018. The project includes several sections of underground 345 kV cable, which will exacerbate previously experienced high voltage issues. The average load in PSE&G for the last three years was approximately 4,000 MW during Light Load conditions and specifically, 3,900 MW for the 2015 – 2016 Light Load periods. Using the most recent average load levels, PJM performed voltage analysis using the 2021 RTEP Light Load case, and identified several high voltage violations in northern PSE&G. The system transmission topology is unchanged between 2019 and 2021, and therefore the high voltage issues are expected to occur during the

2018/2019 Light Load planning year. Figure 11 below depicts the stations where high voltage violations were identified.

**Figure 11 - PSE&G High Voltage Violation Locations**



The recommended solution to address the high voltage issues is to install two 50 MVAR shunt reactors at Kearny 230 kV, two 100 MVAR shunt reactors at Bayway and Linden 345 kV, and to increase the size of the two existing 50 MVAR shunt reactors at Hudson 230 kV to 100 MVAR each. This solution adds a total of 600 MVAR reactive capability in the area to address the high system voltages. The total estimated cost for this work is \$90.4 million, and the required in service date is September 1, 2018. Since the violations are expected to occur during the 2018/2019 Light Load planning year, this project is an immediate need solution where the timing required to include the violation in an RTEP proposal window was infeasible. The local Transmission Owner, PSE&G, is designated to install the additional reactive capability in the area.

**PSE&G End of Life Assessment – Metuchen – Edison – Trenton – Burlington Corridor**



Three alternatives were considered to address the issues identified on the Metuchen – Burlington 138 kV corridor. The first was to remove the corridor without replacement. The second was to install new parallel circuits on a new right of way and remove the existing corridor. The third was to replace / rebuild the corridor in with new foundations, and hardware designed to either 138 kV or 230 kV.

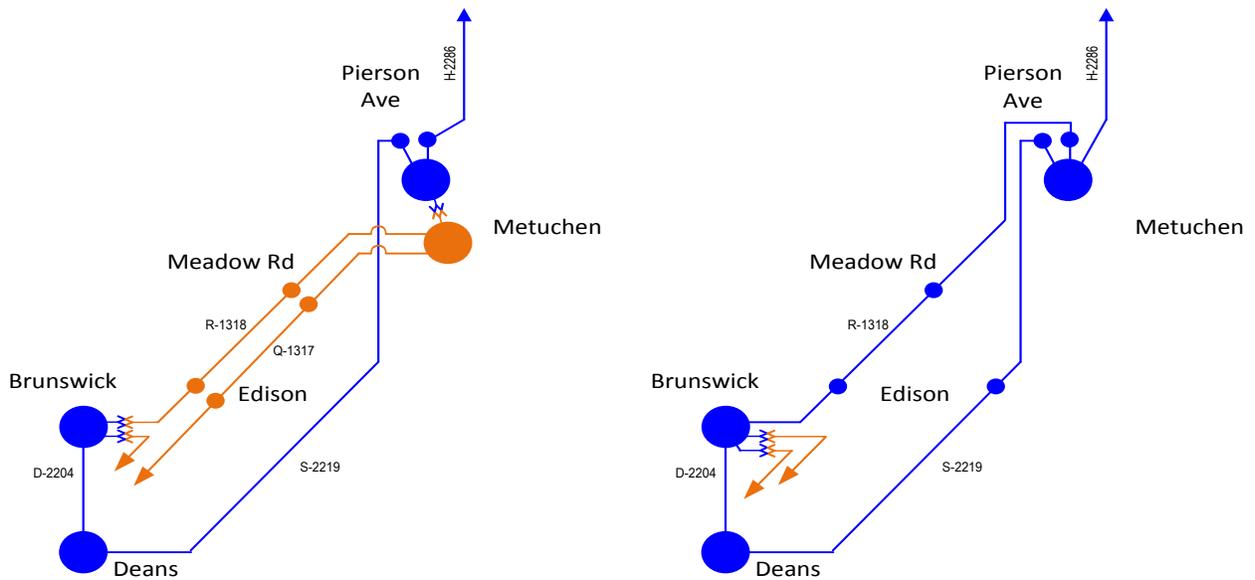
The first alternative, to remove the existing corridor entirely, would require an alternative load supply, of approximately 544 MVA, at nine stations that are tapped off of the existing lines. This alternative was dismissed because no transmission supplies are available near Devils Brook, Plainsboro, Yardville, Crosswicks, and Bustleton. This solution would also require extensive new underground 69 kV line construction through densely populated areas.

The second alternative, to install a new parallel circuit on a new right-of-way, was dismissed because it would be extremely challenging if not impossible to obtain the new right-of-way required. Additionally, extensive underground construction would be required to supply the nine existing stations, thus requiring new circuits to loop in and out of the existing stations. Similar to the first alternative, this solution would also require extensive 69 kV line construction, with limited 69 kV circuit capacity and line length due to voltage drop.

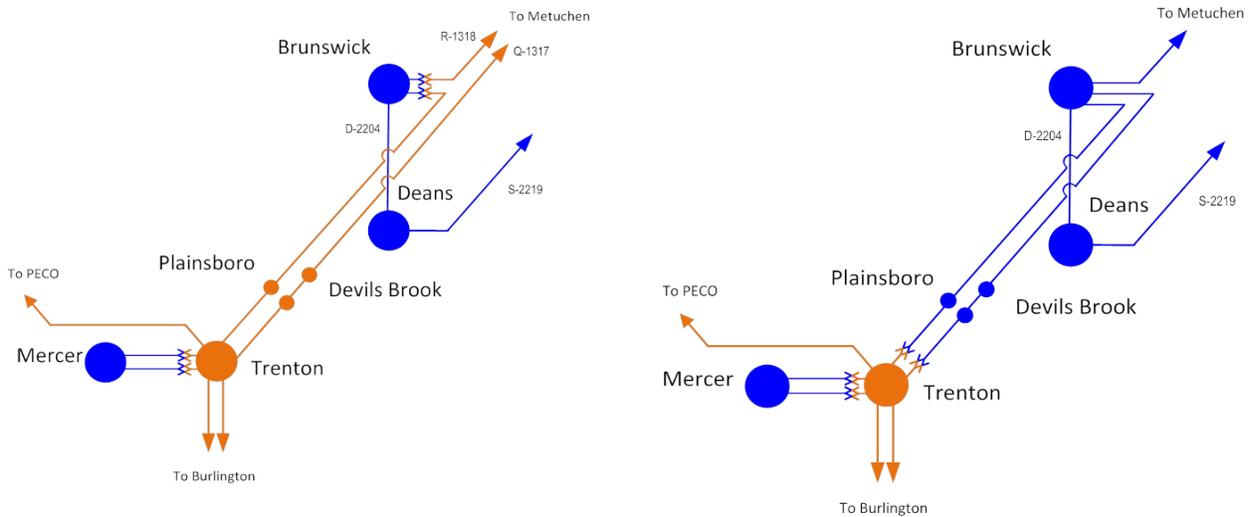
The third alternative, to replace / rebuild the corridor, does resolve the end of life violation. Staff evaluated rebuilding the facilities in kind at 138 kV or rebuilding the facilities at 230 kV. As described below, staff is recommending the corridor be rebuilt at 230 kV.

The recommended solution ultimately converts the existing Metuchen – Burlington 138 kV corridor to 230 kV. The first part of the solution is to convert the two existing Metuchen – Edison 138 kV circuits to one 230 kV circuit. Doing so resolves the voltage violations in the Metuchen vicinity from the 2016 RTEP Window #2 that would have otherwise need to have been addressed with a reactive upgrade. This part of the solution also eliminates the need for previously approved baseline upgrade B2590 to install two 75 MVAR 230 kV capacitors at the Sewaren station. The second part of the solution is to convert the two existing Brunswick – Trenton 138 kV circuits to 230 kV circuits. The converted circuits will be terminated at the existing Brunswick 230 kV station and the Trenton 138 kV station with two 230/138 kV transformers. The third and final part of the recommended solution is to convert the two existing Trenton – Burlington 138 kV circuits to 230 kV circuits. This work also entails replacing the Trenton 138 kV substation with a six bay breaker and a half 230 kV substation, and terminating the new converted 230 kV circuit at the Trenton 138 kV station with two 230/138 kV transformers. This part of the solution eliminates the need for previously approved baseline upgrade B2589 to install a 100 MVAR 230 kV shunt reactor at the Mercer station. Also, as a whole the recommended solution strengthens the system by replacing 138 kV circuits with 230 kV circuits, improving capacity and voltage. This solution also creates a strong tie between southern and central PSE&G, increasing transfer capability to Central PSE&G and addresses future aging infrastructure needs at several stations including Trenton, Brunswick, Metuchen a several distribution stations tapped off of the existing lines. The cost estimates for the individual parts of the solution are \$125 million, \$302 million, and \$312 million consecutively, resulting in a total estimated project cost of \$739 million. The required in service date is June 1, 2017. This upgrade is an immediate need solution where the timing required to include the violation in an RTEP proposal window was infeasible. The local Transmission Owner, PSE&G, is assigned the designation for this conversion project.

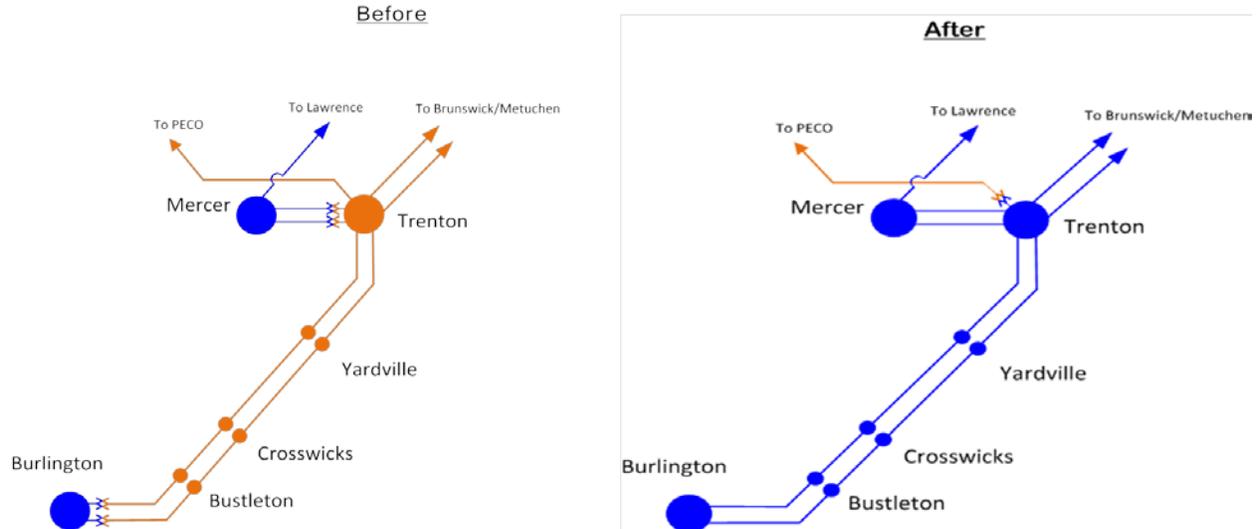
**Figure 13 - Metuchen – Brunswick Existing and Future Diagram**  
Before After



**Figure 14 - Brunswick – Trenton Existing and Future Diagram**  
Before After



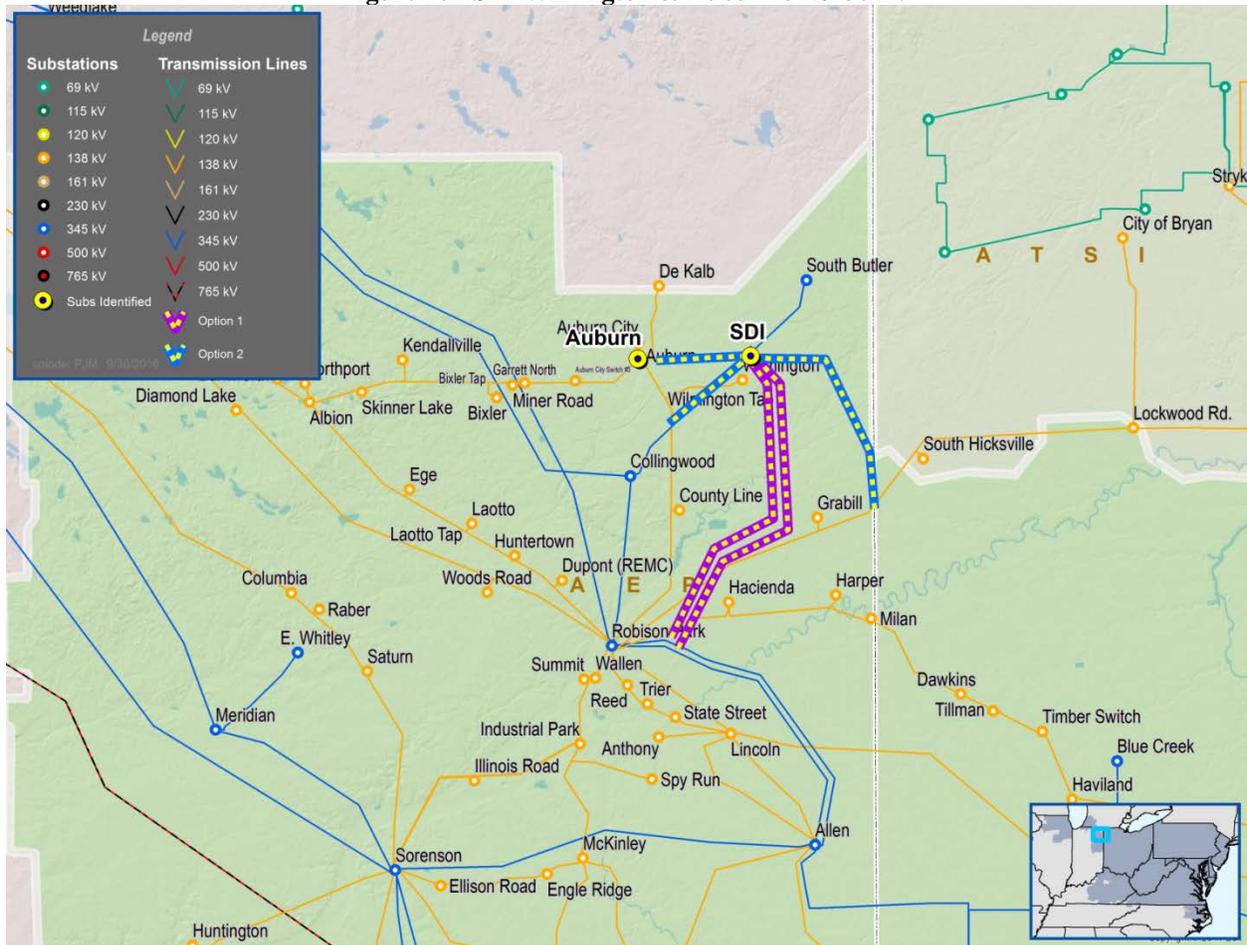
**Figure 15 - Trenton – Burlington Existing and Future Diagram**



**Baseline Project B2779 – AEP Load Loss Limit**

Due to a recent load model update, a consequential load loss greater than 300 MW occurs in the AEP transmission zone for the loss of the South Butler – Collingwood 345 kV circuit. This is a violation of PJM’s maximum load loss due to a single event criteria. Additionally, there are pre-existing local 69 kV issues in the area stemming from aging infrastructure and continued area industrial growth. One alternative was considered to construct a new 345 kV switching station near the customer (SDI), by tapping the Rob Park – Allen 345 kV line, and extending a new double circuit 345 kV line (around 17 miles) into the new station. However, this solution requires approximately 17 miles of additional right-of-way, does not address the local area needs, and does not provide flexibility for future area outage scheduling. The recommended solution is to construct a new 138 kV station, to be called Campbell Road, by tapping the Grabill – South Hicksville 138 kV circuit. A section of the Butler – N. Hicksville and Auburn – Butler 69 kV circuits will be reconstructed as 138 kV double circuit using 796ACSR and the 138 kV circuit from the Campbell Road station will be extended. A new 345/138 kV SDI Wilmington Station which will be constructed and sourced from Collingwood 345 kV and serve the SDI load at 345 kV and 138 kV respectively. The 138 kV circuits will be looped in-out of the new SDI Wilmington station resulting in a direct circuit to Auburn 138 kV which will undergo a bus expansion. This recommended solution requires less new right-of-way acquisition, addresses the local 69 kV area needs noted above, and allows for easier future outage scheduling in the area. The estimated cost is \$107.7 million, and is required as soon as possible. This upgrade is an immediate need solution where the timing required to include the violation in an RTEP proposal window was infeasible. The local Transmission Owner, AEP, is designated to construct this project.

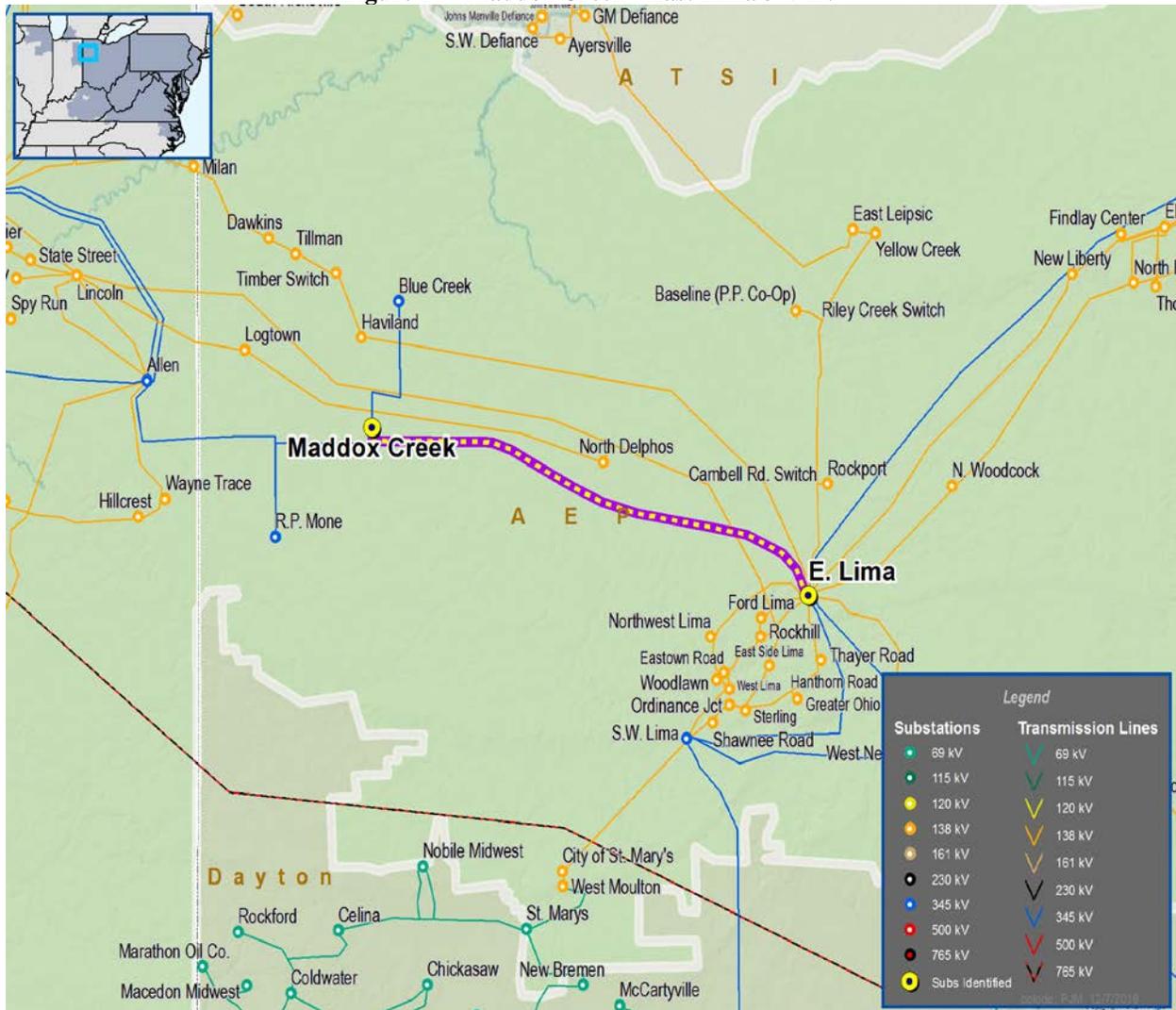
**Figure 16 - SDI Wimington & Auburn 345/138 kV**



**Baseline Project B2833 – Maddox Creek – East Lima 345 kV Reconductor**

The Maddox Creek – East Lima 345 kV circuit is overloaded for the single contingency loss of the Marysville – Sorenson 765 kV circuit during winter conditions. PJM solicited proposals to address this issue in the 2016 RTEP Proposal Window #3. Five baseline proposals (three of which were Greenfield) from three separate entities, AEP, PSE&G, and NextEra Energy, were submitted to address this reliability criteria violation. The cost of the proposals ranged from \$5.95 million to \$69.3 million. One of the non-incumbent, Greenfield proposal entailed adding a series reactor to the Maddox Creek – East Lima 345 kV circuit. The other two Greenfield proposals were proposed by both a non-incumbent and the incumbent Transmission Owner and entailed the construction of a new Maddox Creek – Southwest Lima 345 kV circuit. The two remaining proposals by AEP were upgrades to existing facilities and entailed either rebuilding or reconductoring the Maddox Creek – East Lime 345 kV circuit. The recommended solution is to reconductor the Maddox Creek – East Lime 345 kV circuit with 2-954 ACSS Cardinal conductor, as it resolves the reliability criteria violation and is the most cost effective long term solution. The incumbent Transmission Owner, AEP, submitted the proposal with an estimated cost of \$18.2 million. The required in service date is December 1, 2021.

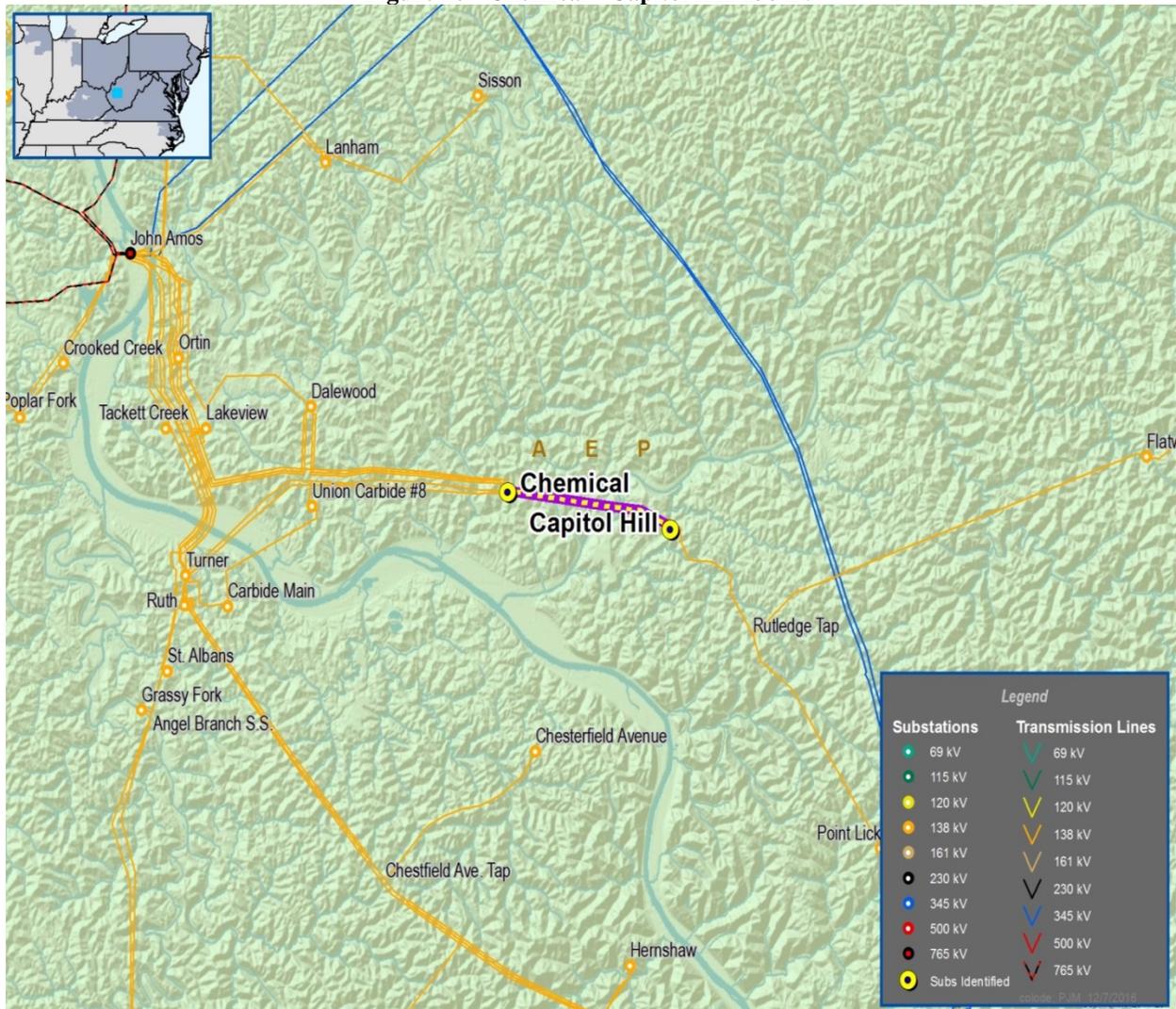
**Figure 17 - Maddox Creek - East Lima 345 kV**



**Baseline Project B2834 – Chemical – Capitol Hill 138 kV Reconductor**

The Chemical – Capitol Hill 138 kV circuit is overloaded for several tower outages during winter conditions. PJM solicited proposals to address this issue in the 2016 RTEP Proposal Window #3. Two baseline proposals from two separate entities, AEP and Northeast Transmission Development, were submitted to address this reliability criteria violation. The cost of the non-incumbent / Greenfield proposal was \$30 million and entailed building a 138 kV new switching station to interconnect the Amos – Lanham and Sission – Lanham 138 kV lines, building a new line from the switching station to Coco 138 kV, and removing one of the Campbells Branch – Lanham 138 kV lines from service. The incumbent Transmission Owner, AEP, proposed to reconductor the small portion of the existing single circuit and string open position and “six-wire” 6.2 miles of the Chemical – Capitol Hill 138 kV circuit. This proposal resolves the reliability criteria violation and is the most cost effective solution. The estimated cost is \$7.3 million with a required in service date of December 1, 2021.

**Figure 18 - Chemical - Capitol Hill 138 kV**

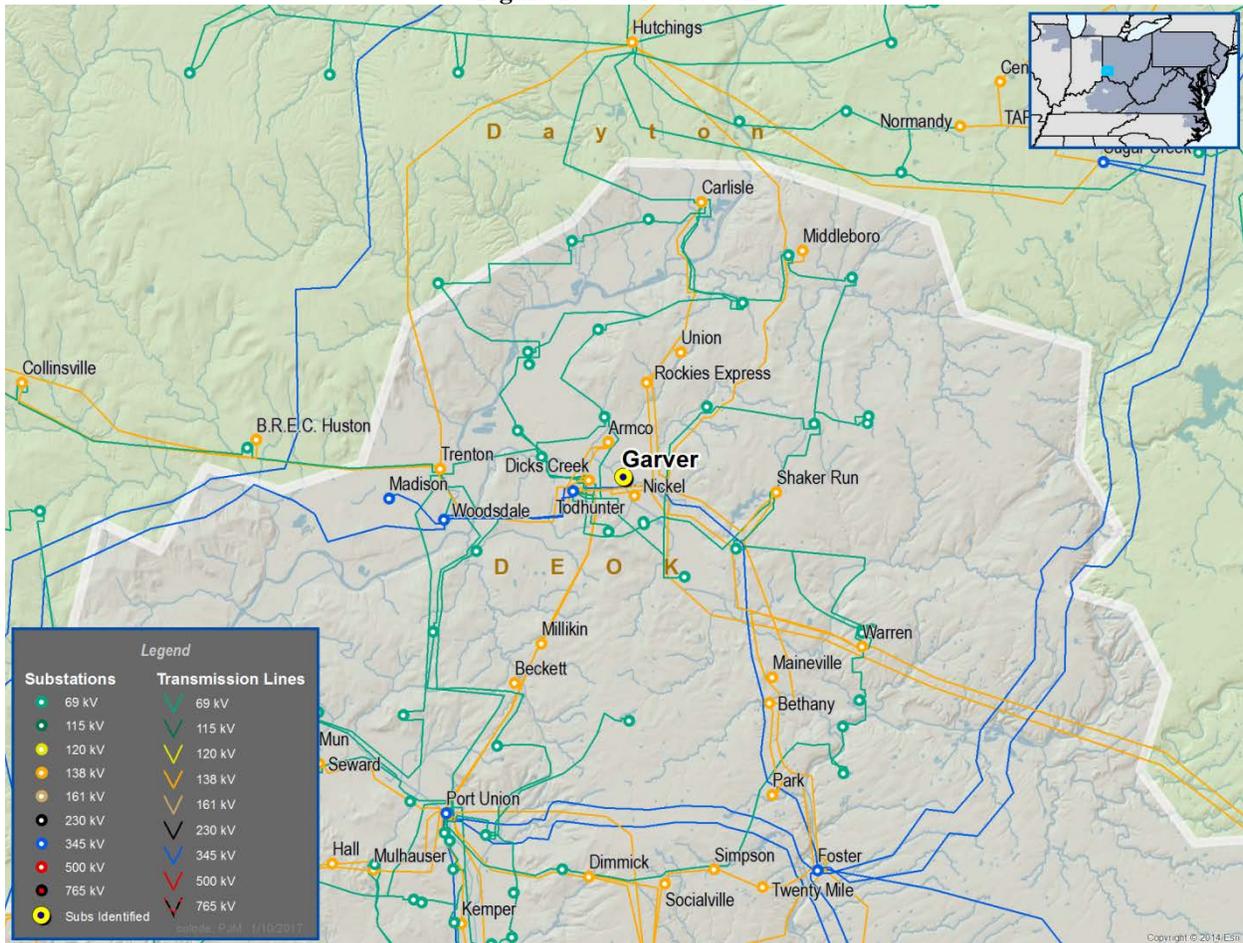


**Baseline Project B2830 – Garver 345 kV Substation Expansion**

The Nickel – Warrant 138 kV circuit is overloaded for the loss of the Todhunter – Rockies Express 138 kV and Foster – Garver 345 kV tower lines in the 2021 Common Mode Outage study. Additionally, the remaining one of the three Todhunter 345/138 kV transformers is overloaded for the loss of any two in the 2021 N-1-1 Thermal study. PJM solicited proposals to address these issues in the 2016 RTEP Proposal Window #2. A total of nine baseline proposals were submitted to address either one or both of these reliability criteria violations. The proposals included both incumbent and non-incumbent proposals from six separate entities, DEOK, PPL, Transource Energy, NetEra Energy Transmission, Northeast Transmission Development, and Mid-Atlantic MCN. Three of the proposals only addressed the Common Mode Outage violation, while the other six addressed both Common Mode outage and N-1-1 Thermal violations. Combined with other violations in the DEOK and EKPC region, PJM conducted constructability evaluations and in-depth analytical analyses to determine the best pairing of projects to resolve all of the reliability violations. As a result, three main competitive proposals were identified, one of which was an upgrade from

the incumbent Transmission Owner and the other two were Greenfield proposals from non-incumbent entities. From a constructability stand point, aside from endangered species potentially requiring time-of-year work restrictions, none of the proposals appeared to cause any significant permitting or siting issues. Both greenfield proposals entailed building a new 345/138 kV substation to be interconnected with existing lines. The independent cost estimates from constructability evaluations identified potential missing cost factors for the greenfield proposals. In one instance, the needed Foster substation expansion would cause a scope increase and have a potential impact of up to \$7.4 million to the proposal in question. For the other, circuit breakers were not included in the proposed cost estimate for the new Greenfield substation, so PJM adjusted the estimate to include the additional required breakers. In comparison, the competing incumbent Transmission Owner upgrade proposal had less risk and a lower estimated cost. Therefore, the recommended solution is the project proposed by the incumbent Transmission Owner, DEOK, to expand the Garver 345 kV substation to include 138 kV and connect the local 138 kV circuits from Todhunter, Rockies Express, and Union 138 kV. The estimated cost is \$18.7 million with a required in service date of June 1, 2021.

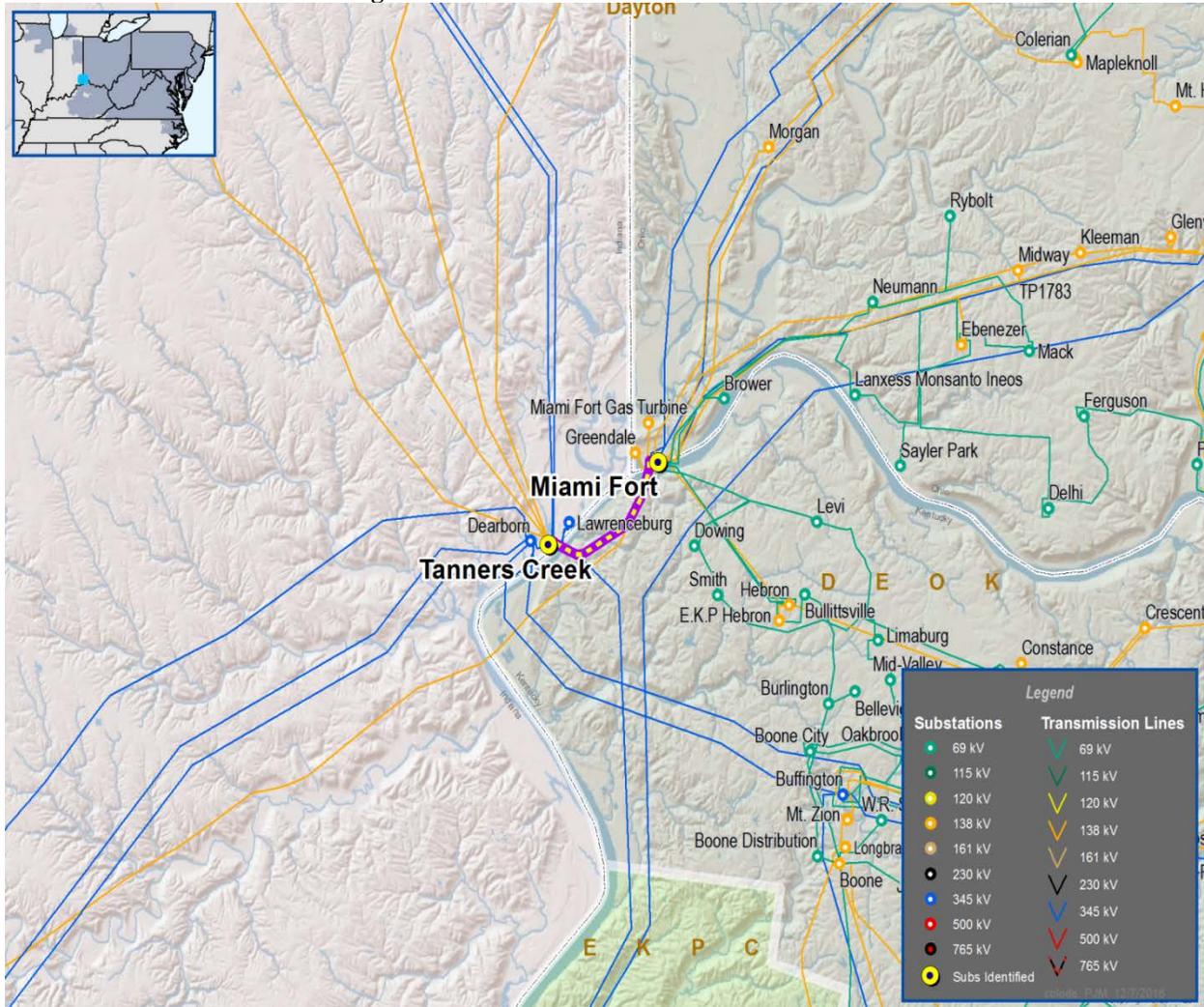
**Figure 19 - Garver 345 kV**



**Baseline Project B2831 – Tanner Creek – Miami Fort 345 kV**

The Tanner Creek – Miami Fort 345 kV circuit is overloaded for the loss of the Terminal – East Bend 345 kV circuit during winter conditions. PJM solicited proposals to address this issue in the 2016 RTEP Proposal Window #3. One incumbent Transmission Owner upgrade (a joint proposal from DEOK and AEP) and three Greenfield proposals from Transource Energy and Northeast Transmission Development were submitted for evaluation. The cost of the proposals ranged from \$7.8 million to \$59.8 million. Two of the Greenfield proposals included the construction of a new 345 kV switching station to interconnect with existing circuits, and the other entailed the construction of two new substations (345 kV and 345/138 kV), to be interconnected with existing circuits. The recommended solution is the project proposed by the incumbent Transmission Owners, DEOK and AEP, to upgrade the Tanner Creek – Miami Fort 345 kV circuit. DEOK will replace the DEOK owned portion of the circuit (3.4 miles, double bundle) with two different types of conductor. AEP will perform a sag study including a LiDAR survey on the AEP portion of the circuit (0.36 miles, double bundle). The estimated cost is \$7.8 million and the required in service date is December 1, 2021.

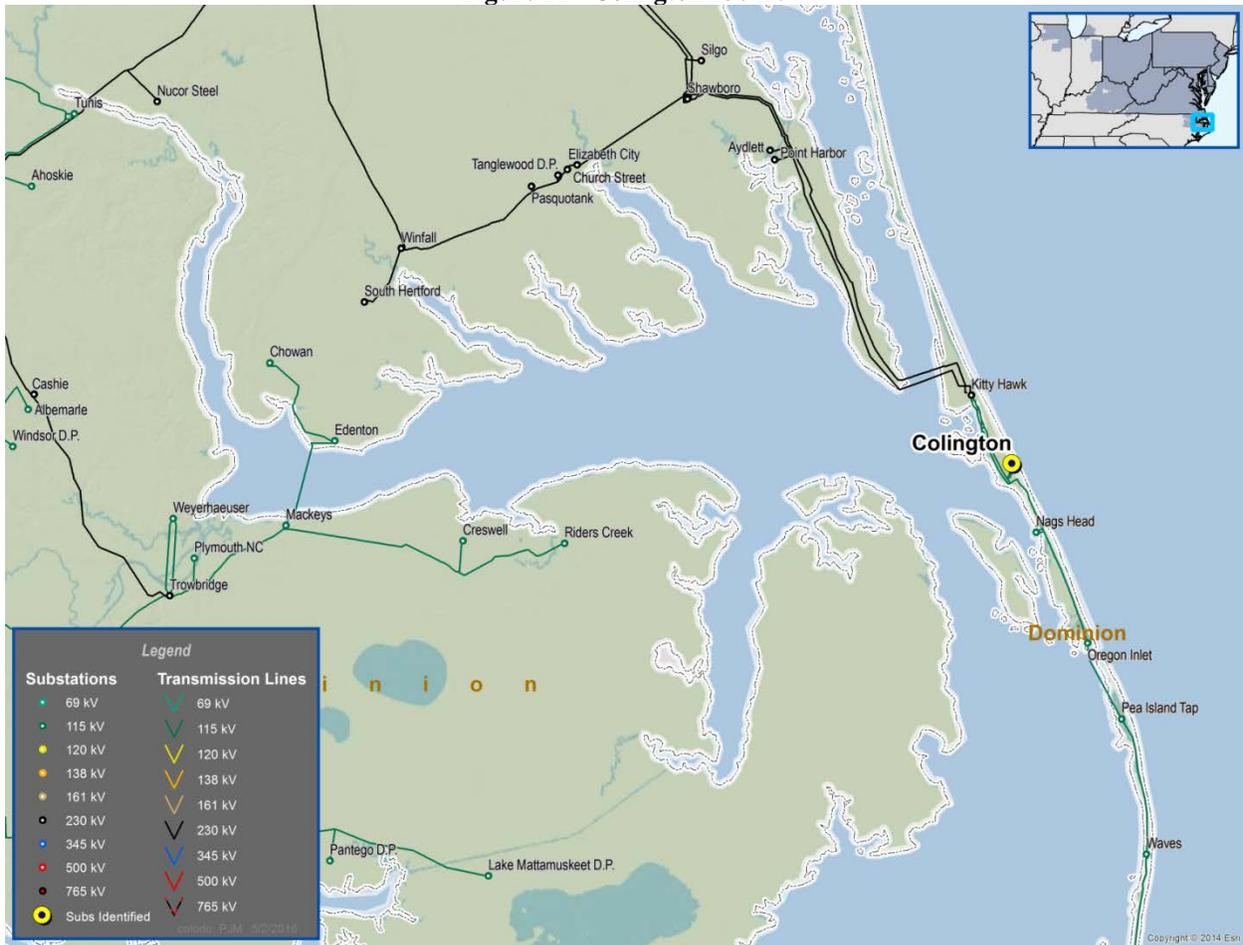
**Figure 20 - Tanner Creek - Miami Fort 345 kV**



**Baseline Project B2757 – Colington 230 kV Statcom**

Dominion has identified the Colington 230 kV SVC as having reached its end of life in accordance with their FERC Form No. 715 End of Life criteria. The Colington station is on the outer banks and the harsh high salt environment has resulted in contamination and component corrosion, ultimately leading to the end of life for the capacitors and filters. The SVC also has a non-redundant design and has unique components with no spares. The recommended solution is to replace the SVC with a +/-125 MVAR statcom at Colington 230 kV. The estimated cost for this work is \$30 million and the required in service date is June 1, 2017. This upgrade is an immediate need solution where the timing required to include the violation in an RTEP proposal window was infeasible. The local Transmission Owner, Dominion, is designated to replace the piece of equipment.

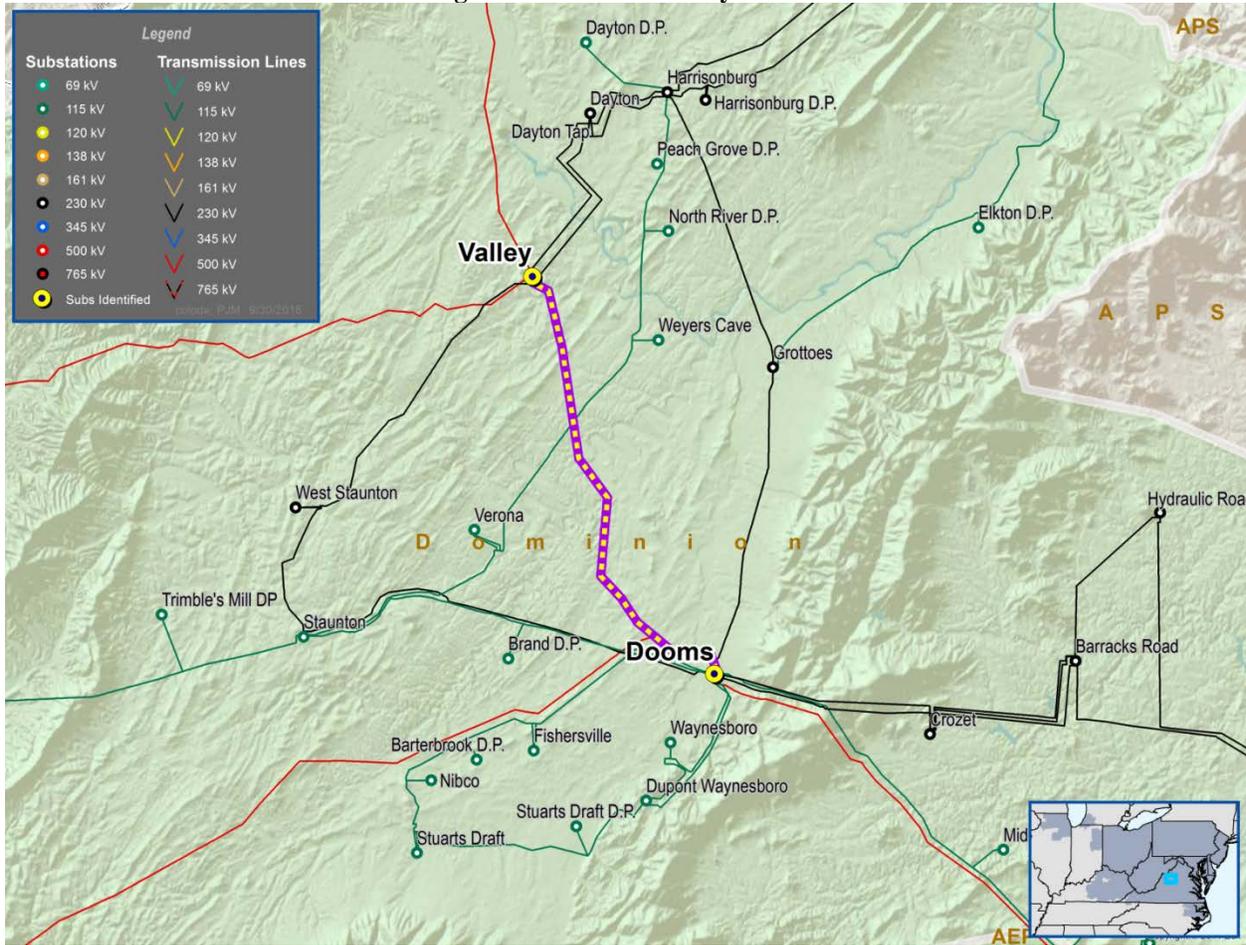
**Figure 21 - Colington 230 kV**



**Baseline Project B2758 – Doods - Valley 500 kV Rebuild**

Dominion has identified the Doods – Valley 500 kV line as having reached its end of life based on their FERC Form No.715 End of Life criteria. A third party evaluation confirmed that this line has reached its end of life. Per the Dominion criteria PJM conducted reliability assessments without the line which resulted in numerous thermal and voltage violations for various contingencies around and at Bath County, Lexington, Clifton, Lowmoor, and Doods 500/230 kV stations. The recommended solution is to rebuild the Doods – Valley 500 kV circuit. The estimated cost is \$58.16 million and it is required as soon as possible. This upgrade is an immediate need solution where the timing required to include the violations in an RTEP proposal window was infeasible. The local Transmission Owner, Dominion, is designated to rebuild the facilities.

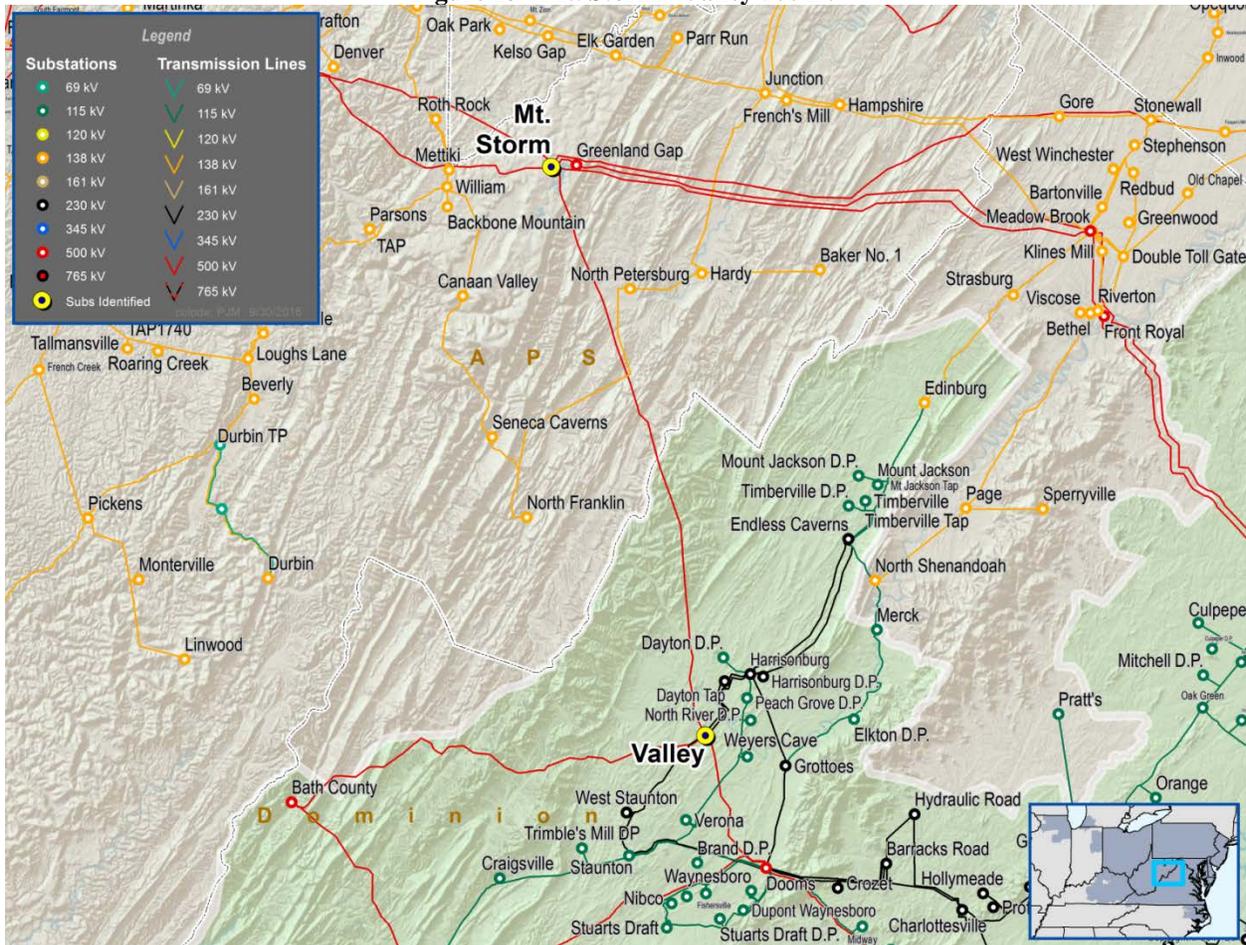
**Figure 22 - Dooms - Valley 500 kV**



**Baseline Project B2759 – Mt. Storm - Valley 500 kV Rebuild**

Dominion has identified the Mt. Storm – Valley 500 kV line as having reached its end of life based on their FERC Form No.715 End of Life criteria. A third party evaluation confirmed that this line has reached its end of life. Per the Dominion criteria, PJM conducted reliability assessments without the line which resulted in numerous thermal and voltage violations for various contingencies around and at Barrack Road, Charlottesville, Bath County, Lexington, Clifton, Endless Caverns, Ox, and Possum 500/230 kV stations. The recommended solution is to rebuild the Mt. Storm – Valley 500 kV circuit. The estimated cost is \$225 million and the required as soon as possible. This upgrade is an immediate need solution where the timing required to include the violations in an RTEP proposal window was infeasible. The local Transmission Owner, Dominion, is designated to rebuild the facilities.

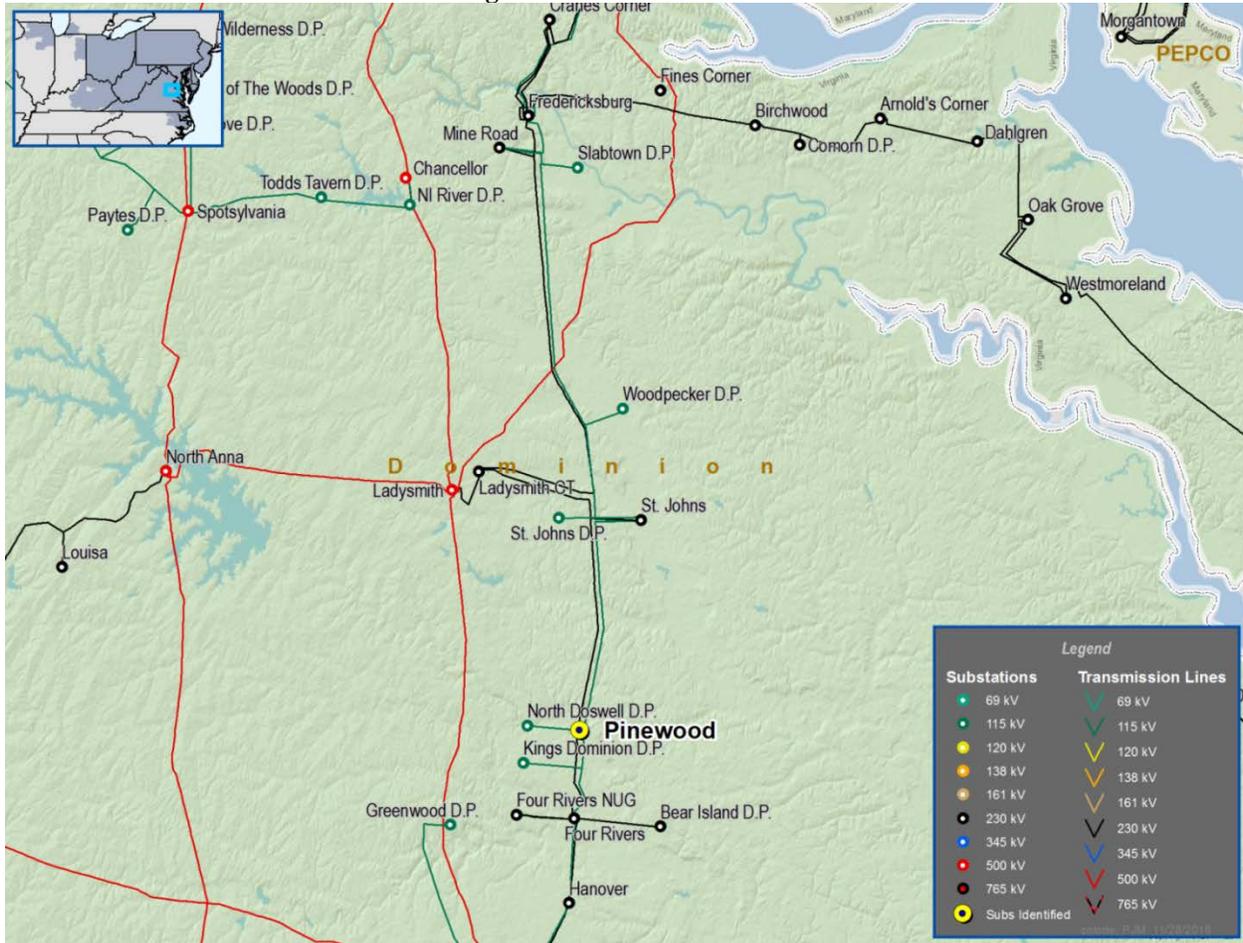
**Figure 23 - Mt. Storm - Valley 500 kV**



**Baseline Project B2815 – Pinewood 115 kV Switching Station**

Four Rivers – Fredericksburg 115 kV is a 34 mile long circuit that serves five delivery points. The tap line for North Doswell is also greater than one mile. This is a violation of the Dominion FERC Form No. 715 criteria. The Transmission Planning Criteria states that the number of delivery points on a transmission line should be limited to four. Also, the Facility Interconnection Requirements state that transmission tap lines greater than a mile should be protected by a breaker to improve the reliability of the line. The recommended solution to these issues is to build a new switching station, Pinewood 115 kV, at the tap serving North Doswell DP with a 115 kV four breaker ring bus. The estimated cost is \$12.8 million and the required in service date is June 1, 2017. This upgrade is an immediate need solution where the timing required to include the violations in an RTEP proposal window was infeasible. The local Transmission Owner, Dominion, is designated to construct the new facility.

**Figure 24 - Pinewood 115 kV**



### **Changes to Previously Approved Projects**

Cost and scope of a number of previously approved RTEP baseline projects have changed. In addition, a project has been cancelled as it is no longer required. The net result of these changes to previously approved baseline projects is a net increase in the RTEP of \$38.89 million. Some of the more significant cost changes are noted below.

The cost of the previously Board approved RTEP project B2588 in the MetEd transmission zone to install a 36.6 MVAR capacitor at the North Bangor 115 kV substation has increased. The installation of the capacitor requires reconfiguration of the North Bangor 115 kV substation, and the original estimated cost of \$0.98 million did not take the substation work into consideration. For this reason, the estimated cost has increased by \$5.52 million, making the total cost approximately \$6.5 million.

The cost of the previously Board approved RTEP project B2750 in the AEP transmission zone to retire the existing Betsy Layne station and replace it with a new Stanville station about a half mile north of the existing Betsy Layne station (the capacitor bank, currently located on the 46 kV bus, will be relocated to the 69 kV bus at Stanville and increased in size from 9.6 MVAR to 14.4 MVAR) has increased. The cost

increase stems from AEP finalizing the detailed scoping and engineering for the project. The majority of the increase is driven by the line work to connect existing lines to the new station. Additional larger structures are required due to the mountainous terrain surrounding both the Betsy Lane station and the new Stanville station site, increasing the line costs from the original estimate of approximately \$2 million to \$11 million. Also, the Greenfield station cost has increased from \$10 million to \$14 million after detailed engineering. For these reasons and additional minor cost increases, the estimated cost has increased by \$14.1 million, making the updated total cost approximately \$28.1 million.

The cost of the previously Board approved RTEP project B1794 in the Dominion transmission zone to build a new 230/115 kV switching station (Hathaway) west of Edgecombe NUG and to reconfigure Battleboro – Benson 115kV, Nash-Hornertown 230kV, and Edgecombe NUG – Rocky Mt 230kV to terminate into the new Hathaway switching station has increased. The cost increase is due to additional substation expense, cost of land, expense for storm drainage, and escalation of materials and labor costs. The estimated cost has increased by \$6.4 million, making the total cost of the project approximately \$25.4 million.

The scope and cost of the previously Board approved RTEP project B2653 in the Dominion transmission zone to network two existing lines (#82 and #189) by building a 20 mile 115 kV line from Pantego to Trowbridge 115 kV with a summer emergency rating of 262 MVA has been modified. The scope of the project has changed to include the increased line mileage and final routing for the Pantego – Trowbridge 115 kV circuit, which has increased from 20 miles to 22 miles with a summer emergency rating target increase from 262 MVA to 346 MVA. The estimated cost has increased by \$9.2 million, making the total cost of the project approximately \$44.6 million. The cost increase is due to the scope change along with a refined cost estimate update from the incumbent Transmission Owner, Dominion.

The scope and cost of the previously Board approved RTEP project B2654 in the Dominion transmission zone to network existing lines (#126) by building a 16 mile 115 kV line from Scotland Neck to South Justice Branch with a summer emergency rating 346 MVA has been modified. The original scope also included the installation of a 115 kV three breaker ring at South Justice Branch and a 115 kV breaker at Scotland Neck. The scope of the project has been updated to include the increased line mileage and final routing for the Scotland Neck – South Justice Branch 115 kV circuit, which has increased from 15 miles to 16 miles with a summer emergency rating target increase from 262 MVA to 346 MVA. Also, the South Justice Branch three breaker ring configuration has been modified to a four breaker ring for breaker failure reliability. The estimated cost has increased by \$12.7 million, making the total cost of the project approximately \$46 million. The cost increase is due to the scope modification along with a refined cost estimate update from the incumbent Transmission Owner, Dominion.

### **Review by the Transmission Expansion Advisory Committee (TEAC)**

The need for the projects was reviewed with stakeholders at several meetings throughout 2016 and 2017, most recently at the January 2017 TEAC and Sub Regional RTEP Committee meetings. Written comments were requested to be submitted to PJM to communicate any concerns with the recommendations and any alternative transmission solutions for consideration.

### **Cost Allocation**

Preliminary cost allocations for the projects being recommended are shown in Attachment A for projects that will be allocated to a single transmission zone and in Attachment B for projects that will be allocated to multiple transmission zones.

Cost allocations for the projects were calculated in accordance with the Schedule 12 of the OATT. Baseline reliability project allocations are calculated using a distribution factor methodology that allocates the cost to the load zones that contribute to the loading on the new facility. The allocations will be filed at the FERC 30 days following approval by the Board.

### **Board Approval**

The PJM Board Reliability Committee endorsed the new baseline reliability projects and associated cost allocations, and recommend to the PJM Board of Managers, approval of the baseline upgrades to the 2016 RTEP. The PJM Board of Managers has approved all recommended changes to the RTEP.

**Reliability Project Single Zone Allocations**

Upgrade ID	Description	Cost Estimate (\$M)	Trans Owner	Cost Responsibility	Required IS Date
b2733	Replace South Canton 138 kV breakers 'L' and 'L2' with 80 kA rated breakers	\$0.78	AEP	AEP	6/1/2021
b2757	Install a +/-125 MVar Statcom at Colington 230 kV	\$30.00	Dominion	Dominion	6/1/2017
b2758	Rebuild Line #549 Doods – Valley 500kV	\$58.16	Dominion	Dominion	6/1/2016
b2759	Rebuild Line #550 Mt. Storm – Valley 500kV	\$225.00	Dominion	Dominion	6/1/2016
b2774	Reconductor the Emilie - Falls 138 kV line, and and replace station cable and relay	\$4.50	PECO	PECO	6/1/2017
b2775	Reconductor the Falls - U.S. Steel 138 kV line	\$2.50	PECO	PECO	6/1/2017
b2779.1	Construction a new 138 kV station, Campbell Road, tapping into the Grabill – South Hicksville138 kV line	\$107.70	AEP	AEP	6/1/2016
b2779.2	Reconstruct sections of the Butler-N.Hicksville and Auburn-Butler 69 kV circuits as 138 kV double circuit and extend 138 kV from Campbell Road station	\$0.00	AEP	AEP	6/1/2016
b2779.3	Construct a new 345/138 kV SDI Wilmington Station which will be sourced from Collingwood 345 kV and serve the SDI load at 345 kV and 138 kV respectively	\$0.00	AEP	AEP	6/1/2016
b2779.4	Looped 138 kV circuits in-out of the new SDI Willington 138 kV station resulting in a direct circuit to Auburn 138 kV and in direct circuit to Auburn and Rob Park via Dunton Lake, and a circuit to Campbell Road; Reconductor 138kV line section between Dunt	\$0.00	AEP	AEP	6/1/2016
b2779.5	Expand Auburn 138 kV bus	\$0.00	AEP	AEP	6/1/2016
b2780	Replace Bruce Mansfield 345 kV breaker 'B57' with an 80 kA breaker, and associated gang-operated disconnect switches D56 and D58	\$1.28	ATSI	ATSI	6/1/2021
b2785	Install a 13.776 MVAR cap bank at Three Links 69 kV	\$0.35	EKPC	EKPC	12/1/2017
b2802	Rebuild Line #171 from Chase City - Boynton Plank Road tap by removing end-of-life facilities and installing 9.4 miles of new conductor. The conductor	\$3.50	Dominion	Dominion	6/30/2019

Attachment A – Single Zone Baseline Cost Allocations  
Presented by PJM Staff to the Board Reliability Committee

February 14, 2017

	used will be at current standards with a summer emergency rating of 393 MVA at 115kV				
b2803	Reconductor 3.7 miles of the Bethlehem - Leretto 46 kV circuit and replace terminal equipment at Summit 46 kV	\$4.00	PENELEC	PENELEC	6/1/2017
b2804	Install a new relay and replace 4/0 CU bus conductor at Huntingdon 46 kV station, on the Huntingdon - C tap 46 kV circuit	\$0.50	PENELEC	PENELEC	6/1/2017
b2805	Install a new relay and replace 4/0 CU & 250 CU substation conductor at Hollidaysburg 46 kV station, on the Hollidaysburg - HCR Tap 46 kV circuit	\$0.50	PENELEC	PENELEC	6/1/2017
b2806	Install a new relay and replace meter at the Raystown 46 kV substation, on the Raystown - Smithfield 46 kV circuit	\$0.50	PENELEC	PENELEC	6/1/2017
b2807	Replace the CHPV and CRS relay, and adjust the IAC overcurrent relay trip setting; or replace the relay at Eldorado 46 kV substation, on the Eldorado - Gallitzin 46 kV circuit	\$0.30	PENELEC	PENELEC	6/1/2017
b2808	Adjust the JBC overcurrent relay trip setting at Raystown 46 kV, and replace relay and 4/0 CU bus conductor at Huntingdon 46 kV substations, on the Raystown - Huntingdon 46 kV circuit	\$0.30	PENELEC	PENELEC	6/1/2017
b2809	Install a bypass switch at Mount Pleasant 34.5 kV substation to allow the Mount Pleasant substation load to be removed from the N14 line and transfer to O769 line	\$0.01	JCPL	JCPL	6/1/2017
b2810.1	Install second 230/69 kV transformer at Cedar Grove	\$44.00	PSEG	PSEG	6/1/2019
b2810.2	Build a new 69 kV circuit from Cedar Grove to Great Notch	\$0.00	PSEG	PSEG	6/1/2019
b2811	Build 69 kV circuit from Locust Street to Delair	\$13.50	PSEG	PSEG	6/1/2017
b2812	Construct River Road to Tonnelle Avenue 69kV Circuit	\$31.00	PSEG	PSEG	6/1/2017
b2813	Expand existing Lycoming 69kV yard to double bus double breaker arrangement	\$22.00	PPL	PPL	6/1/2018
b2814	Install a 3rd 230/69 kV 224 MVA Transformer at Lyons and install new terminal equipment for existing Lyons - East Penn(865) 69 kV Line	\$5.50	ME	ME	6/1/2019
b2815	Build a new Pinewood 115kV switching station at the tap serving North Doswell DP with a 115kV four breaker ring bus	\$12.80	Dominion	Dominion	6/1/2017
b2817	Replace Delaware 138 kV breaker 'P' with a 40 kA breaker	\$1.00	AEP	AEP	6/1/2019

Attachment A – Single Zone Baseline Cost Allocations  
Presented by PJM Staff to the Board Reliability Committee

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b2818	Replace West Huntington 138 kV breaker 'F' with a 40 kA breaker	\$1.00	AEP	AEP	6/1/2019
b2819	Replace Madison 138 kV breaker 'V' with a 63 kA breaker	\$1.00	AEP	AEP	6/1/2019
b2820	Replace Sterling 138 kV breaker 'G' with a 40 kA breaker	\$1.00	AEP	AEP	6/1/2019
b2821	Replace Morse 138 kV breakers '103', '104', '105', and '106' with 63 kA breakers	\$4.00	AEP	AEP	6/1/2019
b2822	Replace Clinton 138 kV breakers '105' and '107' with 63 kA breakers	\$2.00	AEP	AEP	6/1/2019
b2825.1	Install 2X50 MVAR shunt reactors at Kearny 230 kV substation	\$17.80	PSEG	PSEG	9/1/2018
b2825.2	Increase the size of the Hudson 230 kV, 2X50 MVAR shunt reactors to 2X100 MVAR	\$13.50	PSEG	PSEG	9/1/2018
b2825.3	Install 2X100 MVAR shunt reactors at Bayway 345 kV substation	\$30.60	PSEG	PSEG	9/1/2018
b2825.4	Install 2X100 MVAR shunt reactors at Linden 345 kV substation	\$28.50	PSEG	PSEG	9/1/2018
b2827	Upgrade the current 5% impedance 1200A line reactor, which connects the 4SPURLOCK - 4SPUR-KENT-R and 4SPUR-KENT-R - 4KENTON 138kV line sections, to a 6.5% impedance 1600A line reactor	\$2.50	EKPC	EKPC	6/1/2021
b2828	Install 5% reactors at Miami Fort 138 kV to limit current	\$1.00	DEOK	DEOK	6/1/2021
b2829	Reconductor feeder from Port Union to East Provident 138 kV line for 300MVA	\$2.19	DEOK	DEOK	6/1/2021
b2830	Expand Garver 345 kV sub to include 138 kV. Install 1-345 kV breaker, 1-345/138 kV 400 MVA transformer, 6-138 kV Breakers and bus work. Connect local 138 kV circuits from Todhunter, Rockies Express, and Union.	\$18.70	DEOK	DEOK	6/1/2021
b2832	Six wire the Kyger Creek - Sporn 345 kV circuits #1 and #2 and convert them to one circuit	\$0.30	AEP	AEP	12/1/2021
b2833	Reconductor the Maddox Creek - East Lima 345 kV circuit with 2-954 ACSS Cardinal conductor	\$18.20	AEP	Dayton	12/1/2021
b2834	Reconductor and string open position and sixwire 6.2 miles of the Chemical - Capitol Hill 138 kV circuit	\$7.30	AEP	AEP	12/1/2021
b2835	Convert the R-1318 and Q1317 (Edison – Metuchen) 138 kV circuits to one 230 kV circuit	\$125.00	PSEG	PSEG	6/1/2017

Attachment A – Single Zone Baseline Cost Allocations  
Presented by PJM Staff to the Board Reliability Committee

February 14, 2017

b2836	Convert the N-1340 and T-1372/D-1330 (Brunswick – Trenton) 138 kV circuits to 230 kV circuits	\$302.00	PSEG	PSEG	6/1/2017
b2837	Convert the F-1358/Z1326 and K1363/Y-1325 (Trenton - Burlington) 138 kV circuits to 230 kV circuits	\$312.00	PSEG	PSEG	6/1/2017

**Reliability Project Multiple Zone Allocations**

Upgrade ID	Description	Cost Estimate (\$M)	Trans Owner	Cost Responsibility	Required IS Date
b2824	Reconfigure/Expand the Lackawanna 500 kV substation by adding a third bay with three breakers	\$11.26	PPL	AEC - 0.85%, AEP - 7.08%, APS - 2.75%, ATSI - 4.02%, BGE - 2.08%, COMED - 6.67%, ConEd - 0.28%, DAYTON - 1.05%, DEOK - 1.67%, DL - 0.88%, DPL - 1.30%, Dominion - 6.16%, ECP - 0.10%, EKPC - 0.91%, HTP - 0.10%, JCPL - 1.88%, ME - 0.93%, NEPTUNE - 0.21%, PECO - 2.64%, PENELEC - 0.92%, PEPCO - 2.08%, PPL - 52.22%, PSEG - 3.09%, RE - 0.13%	1/31/2019
b2831.1	Upgrade the Tanner Creek - Miami Fort 345 kV circuit (AEP portion)	\$3.90	AEP	DAYTON - 34.34%, DEOK - 56.45%, EKPC - 9.21%	12/1/2021
b2831.2	Upgrade the Tanner Creek - Miami Fort 345 kV circuit (DEOK portion)	\$3.90	DEOK	DAYTON - 34.34%, DEOK - 56.45%, EKPC - 9.21%	12/1/2021