Transmission Expansion Advisory Committee
Market Efficiency Update

March 10, 2016
Market Efficiency 2014/15 Long Term Proposal Window Update
February PJM Board Approved Market Efficiency Projects

RPM project in ComEd Area
- Mitigate sag limitations on Loretto-Wilton Center line and replace station conductor at Wilton Center.

Optimal Capacitor configuration for ApSouth/AEP-DOM Reactive Interfaces
- Brambleton substation: 175 MVAR
- Ashburn substation: 175 MVAR
- Shelhorn substation: 300 MVAR
- Liberty substation: 150 MVAR
The Market Efficiency base case was updated to include:
- 2016 load forecast
- 2016 February Board approved projects

PJM performed additional Market Efficiency Analysis on transmission projects proposed to address ApSouth congestion.
- Included projects that passed the original B/C tests conducted in 2015 under multiple sensitivities.
- Ten projects qualified for additional analysis.
Project ID: 201415_1-6D Modified

Proposed by: Dominion
Proposed Solution: build a new 500 kV station (Palmyra) by connecting at the intersection of the North Anna – Midlothian 500 kV line and Cunningham – Elmont 500 kV line. Build five capacitor banks in Dominion Area.

kV Level: 500
Cost ($M): 28.7
IS Date: 2019
Target Zone: Dominion

Results: B/C=0.22
Notes: Minimal impact on congestion
Updated 1-7A

Project ID: 201415_1-7A Modified

Proposed by: Transource

Proposed Solution: Construct a double circuit 230 kV line between AEP's Axton Station to AEP's East Danville Station. Install breakers and a transformer at Axton and East Danville Station. A total of 1,550 MVARs of new capacitance will also be installed at Brambleton, Ashburn, Lexington, Dooms, Jackson’s Ferry and Broadford substations.

kV Level: 765
Cost ($M): 122
IS Date: 2020
Target Zone: AEP

Results: B/C=.02

Notes: Increases total PJM congestion
Proposed by: Transource

Proposed Solution: Construct a double circuit 230 kV line between Meadow Brook Station and Doubs Station. Additional upgrades in AEP will also be included in this proposal. A total of 1,550 MVARs of new capacitance will also be installed at Brambleton, Ashburn, Lexington, Dooms, Jackson’s Ferry and Broadford substations.

kV Level: 230
Cost ($M): 222
IS Date: 2021
Target Zone: AEP

Results: B/C=0.46

Notes: Increases total PJM congestion
**Project ID: 201415_1-7C Modified**

- **Proposed by:** Transource
- **Proposed Solution:** Construct a new 500 kV line from Meadow Brook to Doubs. Install a single 500 kV breaker in the existing ring arrangement at Meadow Brook Station. Additional upgrades in AEP will also be included in this proposal. 1,750 MVARs of new capacitance will also be installed with 350 MVAR of capacitor banks each at Brambleton, Loudoun, Lexington, Jackson’s Ferry and Broadford substations.

  - **kV Level:** 500
  - **Cost ($M):** 196
  - **IS Date:** 2021
  - **Target Zone:** AEP

**Results:** B/C = 0.46

**Notes:** Increases total PJM congestion
Project ID: 1-9A Modified

Proposed by: DOM High Voltage / Transource

Proposed Solution: Tap the Conemaugh - Hunterstown 500 kV line and build new 230 kV double circuit line between Rice and Ringgold. Build new 230 kV double circuit line between Furnace Run and Conastone. Rebuild the Conastone - Northwest 230 kV line. Add cap banks to Jackson's Ferry, Broadford, Lexington, Dooms, Ashburn and Brambleton stations. Additional upgrades required at Ringgold transformers.

kV Level: 230

Cost ($M): 292.1

IS Date: 2020

Target Zone: Multiple

Results: B/C = 2.66

Notes: Major congestion reductions on ApSouth and other PJM facilities
### Project ID: 1-9A-2

**Proposed by:** DOM High Voltage / Transource

**Proposed Solution:** Tap the Conemaugh - Hunterstown 500 kV line and build new 230 kV double circuit line between Rice and Ringgold. **Additional upgrades required at Ringgold transformers.**

- **kV Level:** 230
- **Cost ($M):** 143.6
- **IS Date:** 2020
- **Results:** B/C = 1.85
- **Notes:** Major congestion reductions on ApSouth and other PJM facilities. Increases congestion on eastern area constraints near Conastone.

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**Map showing project location**
Project ID: 1-9A-3

Proposed by: DOM High Voltage / Transource

Proposed Solution: Build new 230 kV double circuit line between Furnace Run and Conastone. Rebuild the Conastone - Northwest 230 kV line.

kV Level: 230

Cost ($M): 148.5

IS Date: 2020

Results: B/C = 1.05

Notes: Moderate congestion reductions on ApSouth. Increases congestion on Graceton-Bagley and Germantown-Straban
Project ID: 201415_1-18H Modified

Proposed by: FirstEnergy

Proposed Solution: Rebuild and reconductor the Lincoln - Carroll 115/138kV path.

Added: Path will be converted to 230kV operation. Rebuild Hunterstown-Lincoln.

kV Level: 138

Cost ($M): 72  (Does not include upgrade for TMI-Jackson 230 kV line)

IS Date: 2019

Target Zone: APS/Meted

Results: B/C= 2.11 (Does not include upgrade for TMI-Jackson 230 kV line)

Notes: Moderate congestion reduction on ApSouth. Increased congestion on TMI-Jackson 230 kV line would need to be addressed.
### Project ID: 201415_1-19B

**Proposed by:** Northeast Transmission Development  

**Proposed Solution:** Approximately 6-mile 138 kV Line from Grand Point to a new 500/138 kV substation on the Conemaugh-Hunterstown 500 kV Line ("Green Ridge").  
**Additional upgrades on Fayette-Grand Point-Guilford path.**

<table>
<thead>
<tr>
<th>kV Level: 138</th>
</tr>
</thead>
</table>

| Cost ($M): $50.3-$63.7 (Does not include upgrades at Otter Creek-Conastone and Peachbottom-Conastone) |

| IS Date: 2020 |

| Results: B/C= 2.92-3.69 (Does not include upgrades at Otter Creek-Conastone and Peachbottom-Conastone) |

| Notes: Increases congestion on eastern area constraints near Conastone. Additional upgrades would be required at Otter Creek-Conastone and Peachbottom-Conastone. Moderate congestion reduction on ApSouth. |

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[Map and diagrams showing project locations and connections]
Project ID: 201415_1-19D

Proposed by: Northeast Transmission Development

Proposed Solution: Approximately 26-mile 230 kV Line from Ringgold to a new 500/230 kV substation on the Conemaugh-Hunterstown 500 kV Line ("Green Ridge"). Additional upgrades required at Ringgold transformers.

kV Level: 230
Cost ($M): 115
IS Date: 2020
Target Zone: Meted/Penelec
Results: B/C= 2.0

Notes: Major congestion reductions on ApSouth and other PJM facilities. Increases congestion on eastern area constraints near Conastone.
Project ID: 201415_1-19F

Proposed by: Northeast Transmission Development

Proposed Solution: Approximately 99-mile 500 kV Line from Harrison to Bath County.

kV Level: 500

Cost ($M): 432.5

IS Date: 2019

Target Zone: APS/Dominion

Results: B/C=0.76

Notes: Significant congestion reduction on ApSouth
Project ID: 201415_1-19G

Proposed by: Northeast Transmission Development

Proposed Solution: Build 500/230 kV Substation (Keysers Run) Interconnecting Conastone-Brighton 500 kV Line to Northwest 230 kV Substation.

kV Level: 230

Cost ($M): 48.6

IS Date: 2020

Targeted Zone: Pepco/BGE

Results: B/C = 2.85

Notes: Minimal congestion reduction on ApSouth. Major increase in total PJM congestion.
<table>
<thead>
<tr>
<th></th>
<th>18H</th>
<th>19B</th>
<th>19D</th>
<th>19G</th>
<th>9A-2 West</th>
<th>9A-3 East</th>
<th>9A</th>
</tr>
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<tbody>
<tr>
<td><strong>Sponsor</strong></td>
<td>First Energy</td>
<td>Northeast Transmission Development</td>
<td>Northeast Transmission Development</td>
<td>Northeast Transmission Development</td>
<td>Transource /DOM HV</td>
<td>Transource /DOM HV</td>
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<td><strong>Project Cost</strong></td>
<td>$58.00</td>
<td>$38.90</td>
<td>$104.50</td>
<td>$48.60</td>
<td>$130.00</td>
<td>$152.00</td>
<td>$282.00</td>
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<tr>
<td><strong>Additional Upgrades Description</strong></td>
<td>Replace Germantown Transformer, Rebuild Hunterstown-Lincoln, Convert to 230 kV (Lincoln-Carrol)</td>
<td>Upgrade Fayette to Grand Point to Guilford Path</td>
<td>Ringgold Transformers</td>
<td>Ringgold Transformers</td>
<td>Ringgold Transformers</td>
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<td>-$2</td>
<td>-$7</td>
<td>-$1</td>
<td>-$4</td>
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<td><strong>Delta in AP SOUTH L/O BED-BLA</strong></td>
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<td><strong>Delta in Total Interfaces Cong</strong></td>
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<td>-$29</td>
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<td>$51</td>
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<td><strong>Delta in Production Cost</strong></td>
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<tr>
<td><strong>Comments</strong></td>
<td>Modified to tap into Hunterstown. Moderate congestion reduction on ApSouth. Increased congestion on the TMI-Jackson 230 kV line would need to be addressed.</td>
<td>Increases congestion on eastern area constraints near Conastone. Additional upgrades would be required at Otter Creek- Conastone and Peachbottom-Conastone.</td>
<td>Major congestion reductions on ApSouth and other PJM facilities. Increases congestion on eastern area constraints near Conastone.</td>
<td>Minimal congestion reduction on ApSouth. Major increase in total PJM congestion.</td>
<td>Major congestion reductions on ApSouth and other PJM facilities. Increases congestion on eastern area constraints near Conastone.</td>
<td>Moderate Congestion reductions on ApSouth. Increases congestion on Graceton-Bagley and Germantown-Straban</td>
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*Deltas represent totals of 2019 and 2022 study years*
<table>
<thead>
<tr>
<th>Sponsor</th>
<th>19F</th>
<th>6D</th>
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<td>2019</td>
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<td>Delta in AP SOUTH L/O BED-BLA</td>
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<td>-$6</td>
<td>-$2</td>
<td>$2</td>
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*Deltas represent totals of 2019 and 2022 study years*
The inclusion of the approved optimal capacitors reduces the benefits for the majority of projects.

Several projects that pass the B/C test increase PJM congestion or have minimal impacts on ApSouth congestion.

Several projects required additional upgrades because they caused additional congestion on existing facilities.

Most benefits provided by projects that diverted flow from ApSouth area to the central Pennsylvania area.

– Projects that tapped off the Conemaugh-Hunterstown 500 kV line provided larger benefits but increased congestion in eastern areas.

– Optimal solution requires multiple upgrades
  • Transmission line that taps the Conemaugh-Hunterstown 500 kV line
  • Transmission upgrades in Conastone area
## Combination Projects

<table>
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<tr>
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<td>Transource /DOM HV</td>
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<td>Upgrade Fayette to Grand Point to Guilford Path</td>
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<td>-$19</td>
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<td>Delta in Total Interfaces Cong</td>
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<td>-$24</td>
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<tr>
<td>Delta in Total PJM Cong</td>
<td>-$83</td>
<td>-$41</td>
<td>-$44</td>
<td>-$61</td>
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<tr>
<td>B/C Ratio</td>
<td>2.66</td>
<td>2.46</td>
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<td>Delta in Gross Load Payment</td>
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<td>-$9</td>
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<td>Delta in Production Cost</td>
<td>-$31</td>
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<td>Comments</td>
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<td>Additional congestion will require upgrade(s) in BGE Area</td>
<td>Additional congestion will require upgrade(s) in BGE Area</td>
<td></td>
</tr>
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*Deltas represent totals of 2019 and 2022 study years

PJM TEAC 03/10/2016

21
Each combination project provides significant market benefits
- Combinations with 18H, 19B, and 19D increase congestion in BGE area and additional upgrade(s) will be necessary.

9A project consistently ranked highest in most categories
- B/C ratio, ApSouth and PJM total congestion reduction, and production cost reduction

Project Combination of 9A-3 (East) + 19D is similar to project 9A
- 19D is a single circuit and 9A is a double circuit for western portion.
- Double circuit provides additional $22 million in PJM congestion reductions, $18 million in ApSouth congestion reductions, and higher B/C ratio.
Recommended Market Efficiency Project: 1-9A with upgrades

**Project ID: 1-9A**

Proposed by: DOM High Voltage / Transource

Proposed Solution:

Additional Upgrades: Replace the Ringgold #3 and #4 transformers with 230/138 kV autotransformers

**kV Level:** 230

**Cost ($M):** $292.1*

**IS Date:** 2020

**Notes:**
- Recommendation Pending Reliability Analysis and Sensitivity Analysis.
- Board recommendation in April 2016
- Constructability analysis complete
- Designated Entities: TBD

*Ringgold transformers estimate does not include work on the 230 kV side.
WebEx Session on Thursday, 3/17

- Reliability Analysis results on project 9A
- Sensitivity Analysis results on combination projects
- Identify Designated Entities

Recommendation to the PJM Board in April
Market Efficiency 2016/17 Long Term Proposal Window Update
**Market Efficiency Timeline**

<table>
<thead>
<tr>
<th>Year 0</th>
<th>Year 1</th>
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<tbody>
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<td>Jan</td>
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<td>Feb</td>
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<td>Nov</td>
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<tr>
<td>Dec</td>
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**Develop Assumptions (Y1, Y5)**

- Market Efficiency Analysis (Y1, Y6)
  - (Accelerations and Modifications)

**Identify and evaluate Solution Options (Accerlarations and Modifications)**

- Final Review with TEAC and approval by Board

**Develop Assumptions (Y1, Y5, Y6, Y11, Y15)**

- Market Efficiency Criteria Analysis (Y1, Y5, Y6, Y11, Y15)

**Market Efficiency Analysis (Y1, Y6, Y8, Y11, Y15)**

- Identify proposed solutions

**Update significant assumptions (Y0, Y4, Y7, Y10, Y14)**

- Independent Consultant reviews of buildability

- Adjustments to solution options by PJM on analysis

**Develop Assumptions (Y1, Y5)**

- Market Efficiency Analysis (Y1, Y5)
  - (Accelerations and Modifications)

- Identify and evaluate Solution Options (Accerlarations and Modifications)

- Final Review with TEAC and approval by Board

**12-month cycle**

**24-month cycle**
2016-2017  24-Month Market Efficiency Cycle Timeline

- Long Term proposal window: November 2016 - February 2017
- Analysis of proposed solutions: March 2017 - November 2017
- Determination of Final projects: December 2017
Market Simulation Input Data

• Study Years
  - 2017 and 2021 to study approved RTEP projects for accelerations and modifications
  - 2017, 2021, 2024, 2027, and 2031 to study new system enhancements
  - Underlying input data based on March 2016 PROMOD IV Data Release
    - 2016 update to loads, generation, demand resources, emissions, and fuels
    - Simulations performed using PROMOD IV v11.1 engine
• Powerflow Models

- 2016/2017 PJM and external world topology based on the 2017 summer peak case from the 2015 ERAG MMWG series
  - Any significant upgrades will be included/excluded based on simulation year
- 2021 and later PJM topology will be based on the 2016 RTEP 2021 Summer topology case
  - External World representation will be developed in coordination with the Interregional Planning group
  - PJM topology will include all upgrades through February 2016 PJM board approvals
Key Input Parameters

• Fuel Prices*
• Emissions Prices*
• Load and energy
• Demand resource
• Future generation
• Transmission constraints
• Carrying charge rate and discount rate

*Fuel and emissions prices to be presented at next TEAC, April 2016
PJM zonal peak and energy forecast from 2016 Load Forecast Report

### 2016 PJM Peak Load and Energy Forecast

<table>
<thead>
<tr>
<th>Load</th>
<th>2017</th>
<th>2021</th>
<th>2024</th>
<th>2027</th>
<th>2031</th>
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<tbody>
<tr>
<td>Peak (MW)</td>
<td>154,149</td>
<td>157,358</td>
<td>159,991</td>
<td>162,988</td>
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<tr>
<td>Energy (GWh)</td>
<td>821,812</td>
<td>843,262</td>
<td>862,838</td>
<td>879,605</td>
<td>906,168</td>
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</table>

Notes: 1.) Peak and energy values from PJM Load Forecast Report Table B-1 and Table E-1, respectively.

2.) Model inputs are at the zonal level, to the extent zonal load shapes create different diversity - modeled PJM peak load may vary.
Model zonal demand resources consistent with Table B-7 of the 2016 Load Forecast Report.

<table>
<thead>
<tr>
<th>Demand Resource (MW)</th>
<th>2017</th>
<th>2021</th>
<th>2024</th>
<th>2027</th>
<th>2031</th>
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<tr>
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<td>3,424</td>
<td>2,478</td>
<td>3,543</td>
<td>3,651</td>
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</table>
Future Generation

PJM Market Efficiency Reserve Margin - Preliminary

Note: Includes existing and projected PJM internal capacity resources

Year

Capacity MW


- Forecasted Summer Peak Net Internal Demand
- Reserve Requirement
- Existing + Not Suspended ISA Generation - Retirement
- Existing + ISA and FSA Queue Generation - Retirement

Capacity MW

130,000 140,000 150,000 160,000 170,000 180,000 190,000 200,000 210,000

130,000 140,000 150,000 160,000 170,000 180,000 190,000 200,000 210,000
• Generation included in Market Efficiency models include all ISAs and FSAs

• Machine list posted at February TEAC
  • http://www.pjm.com/~/media/committees-groups/committees/teac/20160211/20160211-2021-rtep-machine-list.ashx
Transmission Constraints

• Thermal Constraints
  ➢ NERC Book of Flowgates
  ➢ Planning study results for monitored facilities and monitored/contingency pair facilities
  ➢ Historical PJM congestion events

• Voltage Constraints
  ➢ PJM reactive interface limits
  ➢ MW limits based on historical values and voltage stability analysis
  ➢ RTEP upgrades impact future reactive interface limits
Carrying Charge Rate and Discount Rate

- Discount rate and levelized carrying charge rate developed using information contained in TO Formula Rate sheets (Attachment H) \(^1\)

- Discount rate based on weighted average after-tax embedded cost of capital
  \[
  \text{Discount rate} = 7.4\% 
  \]

- Levelized annual carrying charge rate based on weighted average net plant carrying charge levelized over an assumed 45 year life of project
  \[
  \text{Levelized Annual Carrying Charge Rate} = 15.3\% 
  \]

\(^1\) http://www.pjm.com/markets-and-operations/billing-settlements-and-credit/formula-rates.aspx
Market Efficiency Inputs:

- Fuel Prices  April
- Emissions Prices  April

Board Review of Market Efficiency Input Assumptions  May

Market Efficiency Preliminary Results:

- Stakeholder feedback on model:  June-September
- PJM review for acceleration candidates:  June-September
- Proposal window opens:  November
Questions?

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