Reliability Analysis Update

Transmission Expansion Advisory Committee
March 9, 2017
2016/17 RTEP Long Term Proposal Window
2016/17 RTEP Long Term Proposal Window

• Timeline
  – Window Opened: 11/1/2016
    – Window Closed: 2/28/2017
      • All documents and fees due

  – Scope
    • Market Efficiency Congestion
    • 15 Year Reliability Analysis
• 96 Proposals received from 20 entities/combinations addressing 19 target zones/combinations
  
  – 52 Greenfield
    • 5 of which are interregional
  – 44 Upgrades
    • 3 of which are interregional

• Additional detail and updates will be provided at future TEAC meetings
2016 RTEP Proposal Window #3/3A Update
The Avon Lake – Black River – Beaver area had several flowgates identified as part of 2016 RTEP Window 3.

One of the flowgates found to be invalid due to incorrect modeling and as a result PJM posted and addendum to the 2016 RTEP Window 3.

There were several projects proposed to solve the flowgates listed below during the Window 3 and Window 3 Addendum.

- Window 2 (Summer Analysis) → FG # 915
- Window 3 (Winter Analysis) → FG # 392, 393, 489, 490, 400, 493, 407 and 504
- Window 3 Addendum (Winter Analysis) → FG # 386

PJM evaluated 13 stakeholder proposals.
• **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.

• **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
  - 2016_3-5B
  - 2016_3-5D
  - 2016_3-5F
  - 2016_3-6B/
    2016_3A-3B
  - 2016_3-6C
  - 2016_3-6D/
    2016_3A-2C
  - 2016_3A-3A
  - 2016_3A-1B
  - 2016_3A-2A
### Reliability Analysis Result Summary

<table>
<thead>
<tr>
<th>Project ID</th>
<th>Cost Estimate ($ Million)</th>
<th>FG #</th>
<th>FG #</th>
<th>FG #</th>
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<th>FG #</th>
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<td>2016_3-2C</td>
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<td>New 345 kV circuit overload. Beaver - Carlisle 345 kV (118%) for tower outage</td>
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<td>2016_3-5D</td>
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<td>O</td>
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<td>X</td>
<td>X</td>
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</table>

**Note:**
- Blue shaded cells indicate the flowgates that were claimed to be solved by the Proposing Entity
- ‘O’ means yes, the proposed project solves the flowgate violation
- ‘X’ means no, the proposed project doesn't solve the flowgate violation
# Proposals Comparison and Cost Summary

<table>
<thead>
<tr>
<th>Project ID</th>
<th>Entity</th>
<th>Cost Estimate ($ Million)</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Additional upgrade</th>
<th>Additional Cost ($ Million)</th>
<th>Total Cost ($ Million)</th>
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<tbody>
<tr>
<td>2016_3-2C</td>
<td>Transource (Greenfield)</td>
<td>44.58</td>
<td>Solves all Flowgates</td>
<td>Causes a new violation. Requires a new ROW</td>
<td>Replace terminal equipments at the Beaver and Carlisle 345 kV stations</td>
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<td>45.58</td>
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<td>2016_3A-1A</td>
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<td>2016-3-5B</td>
<td>NTD (Greenfield)</td>
<td>19</td>
<td>Solves 8 Flowgates</td>
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<td>Upgrade FG # 386 and 915</td>
<td>Cost from 2016-3A-3A</td>
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<td>2016-3-5D</td>
<td>NTD (Greenfield)</td>
<td>35.4</td>
<td>Solves all Flowgates</td>
<td>Causes a new violation. Requires a new ROW</td>
<td>Replace terminal equipments at the Beaver and Carlisle 345 kV stations</td>
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<td>36.4</td>
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<td>2016-3-5F</td>
<td>NTD (Greenfield)</td>
<td>12.4</td>
<td>Solves one flowgate</td>
<td>9 unsolved flowgates</td>
<td>Upgrade FG # 386, 392, 393, 489 and 490, 400, 493, 407 and 504</td>
<td>Cost from 2016-3A-3A, 2016_3A-3B and 2016_3A-3C</td>
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<tr>
<td>2016-3-6B</td>
<td>First Energy (Upgrade)</td>
<td>13.46</td>
<td>Solves 4 Flowgates</td>
<td>6 unsolved flowgates</td>
<td>Upgrade FG # 386, 915, 392, 393, 489 and 490</td>
<td>Cost from 2016-3A-3A and 2016-3A-3C</td>
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<td>2016-3-6C</td>
<td>First Energy (Greenfield)</td>
<td>30.3</td>
<td>Solves 4 Flowgates</td>
<td>6 unsolved flowgates</td>
<td>Upgrade FG # 386, 915, 392, 393, 489 and 490</td>
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<tr>
<td>2016-3-6D</td>
<td>First Energy (Upgrade)</td>
<td>3.2</td>
<td>Solves 4 Flowgates</td>
<td>6 unsolved flowgates</td>
<td>Upgrade FG # 386, 915, 400, 493, 407 and 504</td>
<td>Cost from 2016-3A-3A and 2016_3A-3B</td>
<td>36.63</td>
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<tr>
<td>2016_3A-3C</td>
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</tbody>
</table>
The First Energy Combined proposals (2016_3A-3A, 2016_3A-3B and 2016_3A-3C) total cost is the lowest of any of the proposed solutions, with the exception of the 2016-3-5D,

First Energy projects (2016_3A-3A, 2016_3A-3B and 2016_3A-3C) are upgrade to an existing facilities and therefore no risk for siting or permitting.

**Preliminary Recommendation:**
- Reconduct the Avon – Lorain 138 kV section and (2016_3A-3C)
- Reconductor the Beaver - Black River 138kV) with 954Kcmil ACSS conductor and upgrade terminal equipment on both stations. (2016_3A-3A)

**Estimated Project Cost:**
- 2016_3A-3B $3.2M
- 2016_3A-3C $13.46M
- 2016_3A-3A $19.97M

**Required IS Date:** 6/1/2021
PSE&G End Of Life Assessment
Newark Switch Review
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
Newark Switch

- 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)
Newark Switch – Existing Station Layout

- 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
Newark Switch – Existing Station Age and Condition

• 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
Newark Switch – Current Property

- Distribution feeds below transformer vaults
Newark Switch – Existing Equipment and Transformers

- Transformers located below the 138 kV rooftop switchyard.

- A transformer fire would be significant and result in catastrophic loss.
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
Design Concept Alternative #1A  
January 2017

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

Previous 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
Existing Newark Switch Footprint
PSE&G Transmission Zone
Newark Switch New Design Concept

- Proposed Control Room
- Proposed GIS
- 138 kV Switchgear
- Proposed Cable Vault
- Proposed Retention Basin
• 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
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

Recommended 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)
Short Circuit
Problem: Short Circuit
- The Sickler 69kV breakers “H,” “M,” and “A” are overstressed

Immediate Need:
- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:
- Replace the Sickler 69kV breakers “H,” “M,” and “A” with 63kA breakers (b2839-2841)

Estimated Project Cost: $321.67 K (per breaker)

Required IS Date: June 1, 2019
Problem: Short Circuit
- Eleven Kammer 138kV breakers are overstressed

Significant Driver: George Washington Area Project (b2753)
- Build double circuit 138 kV line from Dilles Bottom - Holloway 138 kV and a George Washington - Holloway 138 kV.

Immediate Need:
- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:
- Remove/Open Kammer 345/138 kV transformer #301 (b2753.9)
- Convert s1197 to a baseline upgrade (b2753.10)
  - S1197: Complete sag study mitigation on the Muskingum – Natrium 138 kV line

Estimated Project Cost: $2.8 M
Required IS Date: January 1, 2019
Problem: Short Circuit
• The Crossland 138kV breaker “B-16” is overstressed

Immediate Need:
• Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:
• Due to the immediate need of the project no alternatives were considered

Proposed Solution:
• Replace the Crossland 138kV breaker “B-16” with 40 kA breaker (B2869)

Estimated Project Cost: $250 K

Required IS Date: June 1, 2019
Problem: Short Circuit
• Seven of the Mt. Storm 500kV breakers are overstressed

Immediate Need:
• Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:
• Due to the immediate need of the project no alternatives were considered

Proposed Solution:
• Upgrade and replace the seven Mt. Storm 500kV with 50kA breakers (b2842-2848)

Estimated Project Cost: $2.708 M (total)

Required IS Date: June 1, 2019
Problem: Short Circuit

- Sixteen breakers at Parrish, Plymouth Meeting, Grays Ferry, Eddystone, Waneeta, Chichester, and North Philadelphia 230kV substations are overstressed

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

- Due to the immediate need of the project no alternatives were considered

Proposed Solution:

- Replace the Sixteen breakers at Parrish, Plymouth Meeting, Grays Ferry, Eddystone, Waneeta, Chichester, and North Philadelphia 230kV substations with 63kA breakers (b2849-2864)

Estimated Project Cost: $375 K (per breaker)

Required IS Date: June 1, 2019
Problem: Short Circuit
- The Seward 138kV breakers “Jackson Road,” “Conemaugh N,” “Conemaugh S,” and “No. 8 XFMR” are overstressed

Immediate Need:
- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:
- Due to the immediate need of the project no alternatives were considered

Proposed Solution:
- Replace the Seward 138kV breakers “Jackson Road,” “Conemaugh N,” “Conemaugh S” and “No. 8 XFMR” with 63kA breakers (b2865-2868)

Estimated Project Cost: $302.1 K (per breaker)

Required IS Date: June 1, 2019
Problem: Short Circuit

- The six of the Keystone 500kV breakers are overstressed

Significant Driver: Market Efficiency Project 9A - West (b2743)

- Tap the Conemaugh - Hunterstown 500 kV line and tie in new Rice 500 kV station
- Build new 230 kV double circuit line between Rice and Ringgold 230 kV

Proposed Solution:

- Replace six of the Keystone 500kV breakers with 50kA breakers (b2743.9-b2743.14)

Estimated Project Cost: $7.4625 M (total)

Required IS Date: June 1, 2020
Supplemental Projects
Problem Statement:

- 765 kV line 11215 from Wilton Center to Dumont has a 150 MVAR shunt inductor at Wilton Center and a 300 MVAR shunt inductor at Dumont in AEP. The AEP inductor will have a circuit breaker installed under b2231 (Install 765 kV reactor breaker at Dumont 765 kV substation on the Dumont - Wilton Center line).
- The Wilton Center inductor is bolted to the line with no switching device.
- This line has a large impact on the PJM market.
- The inductor is removed in summer months for voltage support and returned to service in the fall. Each time it is switched requires a day long outage to bolt or unbolt the connections.
- Installing a CB on the inductor will have several benefits:
  - No more line outages required for seasonal switching.
  - The inductor can be switched in and out as conditions change instead of being switched seasonally.
  - The inductor will automatically close in the event of a high voltage condition.
  - Line will stay in service for inductor faults

Selected Solution:
Install 765 kV CB at Wilton Center 765kV substation on line 11215 (Wilton Center – Dumont 765kV line) shunt inductor (S1204)

Estimated Project Cost: $5.8M
Projected IS Date: 6/1/2018
Project Status: Engineering & Procurement
Supplemental Project
Previously Presented: Dec. 15, 2016

Problem Statement:
• Presently Pontiac transformer 82 shares a 345 kV ring bus position with 345 kV line 8014 (Pontiac – Dresden).
  – There is no high-side circuit breaker on transformer 82, so any transformer fault trips line 8014.
  – The line must be switched out of service to switch the transformer off.
  – A line fault on 8014 trips transformer 82.

Selected Solution:
At Pontiac 345kV station, install 345 kV bus tie 6-7 to separate the transformer and line onto their own bus sections and Install a high side circuit breaker on transformer 82 to bring it up to current standards. (S1205)

Estimated Project Cost: $4.1M

Projected IS Date: 12/31/2018

Project Status: Engineering & Procurement
RTEP Anticipated Schedule
Preliminary 2017 RTEP 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
RTEP Next Steps

- 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?

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Revision History

- V1 – 3/6/2017 – Original Version Posted to PJM.com
- V2 – 3/7/2017
  - Updated Table on slide #9 – Cosmetic only
  - Updated Slides #10 and #11
  - Added slide #31 – AEP transmission zone short circuit
  - Added slides #37-#39 – 2 ComEd Supplemental Projects
- V3 – 3/8/2017
  - Updated map on Slide #8
  - Added map to Slide #31
  - Updates to Slides #38 and #39 including formatting, status and IS date