PJM RTEP - Artificial Island Area

FIRSTENERGY'S PROPOSED SOLUTION AND REQUEST FOR CONSTRUCTION DESIGNATION

Part 1 – Report – REDACTED VERSION

FirstEnergy Corp.
Energy Delivery, Transmission Planning and Protection
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Foreword

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1.0 Executive Summary

This Proposal by FirstEnergy (FE) responds to the "PJM RTEP - Artificial Island Area Proposal Window Statement & Requirements Document" Request for Proposals (RFP) issued by PJM Interconnection, L.L.C. (PJM) on April 29, 2013. This Proposal considers several options as possible solutions for mitigating stability issues as defined by PJM in the RFP, identifies one option as the proposed solution and requests that Jersey Central Power & Light Company (JCP&L) and Trans-Allegheny Interstate Line Company (TrAILCo), both FE subsidiaries, be designated to construct the portion of the proposed solution that will be located in the JCP&L Transmission Zone.

PJM seeks a technical solution to improve operational performance in the Artificial Island area under a range of anticipated system conditions, and to eliminate potential planning criteria (PJM, NERC, RFC, and Local Transmission Owner criteria) violations. The Artificial Island (AI) under review here includes the Salem #1, Salem #2, and Hope Creek #1 nuclear generation facilities depicted in Figure 1.

FE's Proposal provides a cost effective solution that will:

1) allow maximum power to be generated (3,818 MW total) from all AI Units (Salem 1: 1,253MW, Salem 2: 1,245MW, Hope Creek: 1,320MW) without a minimum MVAr requirement. Full maximum power must be maintained under both the baseline and all N-1 outage conditions of 500 kV transmission lines in the AI area. For both the baseline and N-1 outage conditions, AI voltage must be maintained within operating limits and stable for all NERC Category B and C contingencies;

2) allow maximum MW output from AI to not be affected by the simultaneous outage of Power System Stabilizers (PSS) of Artificial Island units Hope Creek and Salem-2. The Salem-1 PSS is assumed to be on for all scenarios;

3) reduce operational complexity;

4) improve Artificial Island stability; and

5) maintain PJM System Operating Limits (SOLs).

Figure 1: Artificial Island One-line Diagram – Existing Configuration

Redacted Single Line

Results Overview

FE recommends construction of a new 500 kV line from New Freedom to Smithburg, supplemented with the construction of a second 500 kV line between Hope Creek and Red Lion (Option 1b discussed in Section 3.1). FE acknowledges that there are other options that could have been studied especially in the Hope Creek to Red Lion area, but considers this option as a viable solution and the best option.

Per the PJM Planning Committee meeting on June 6, 2013, it is FE's understanding that the solution chosen by PJM could be submitted by one stakeholder, multiple stakeholders, or multiple stakeholders with additional segments directed by PJM. FE has chosen to submit a complete solution to mitigate the issues outlined in the RFP with the potential for multiple stakeholders to be directed by PJM to build the complete solution. Consequently, as indicated in the Executive Summary, FE requests that PJM designate JCP&L and TrAILCo to construct the portion of the New Freedom to Smithburg line to be located within the JCP&L Transmission Zone with FE making the final determination as to which of its subsidiaries would finance, construct, own, operate and maintain the new line. To the extent possible, this portion of the line would be constructed on existing rights-of-way (ROW) controlled by JCP&L.

FE performed the stability study with the intent of finding solutions for all discovered stability issues in the study. FE also conducted a steady state analysis on the FE portion of the proposed solution (a new New Freedom to Smithburg 500 kV line). Based on previous PJM and FE analyses, the transmission system in the JCP&L Zone will need additional reinforcement due to the load growth in the JCP&L service area, announced generation retirements, and the possibility of the retirement of the Oyster Creek Generating Station. This proposed solution will provide the best alternative in addressing these anticipated system conditions.

In addition, FE's study included the possibility of providing a new 500/230 kV source at or near the Larrabee Substation for the long term planning horizon. FE has been evaluating potential solutions in this area for a long time and this solution is preferred. The proposed project will add a strong 500/230 kV source in the southern New Jersey/Oyster Creek area. From an operational perspective, the additional 500/230 kV source in the long term at or near Larrabee increases the operating flexibility during a breaker or path end outage of a 230 kV line out of Smithburg. The proposed project with the additional 500/230 kV source also provides an extra benefit to the existing RTEP Project #b2015 to build a 230 kV circuit from Larrabee to Oceanview to address NERC category C3 N-1-1 violations.

Also, the study results show the proposed project will eliminate the AI issues from a steady state standpoint. The proposed project does not create any adverse thermal or voltage impacts to the bulk system.

2.0 Description of the Proposed Solution

Phase 1:

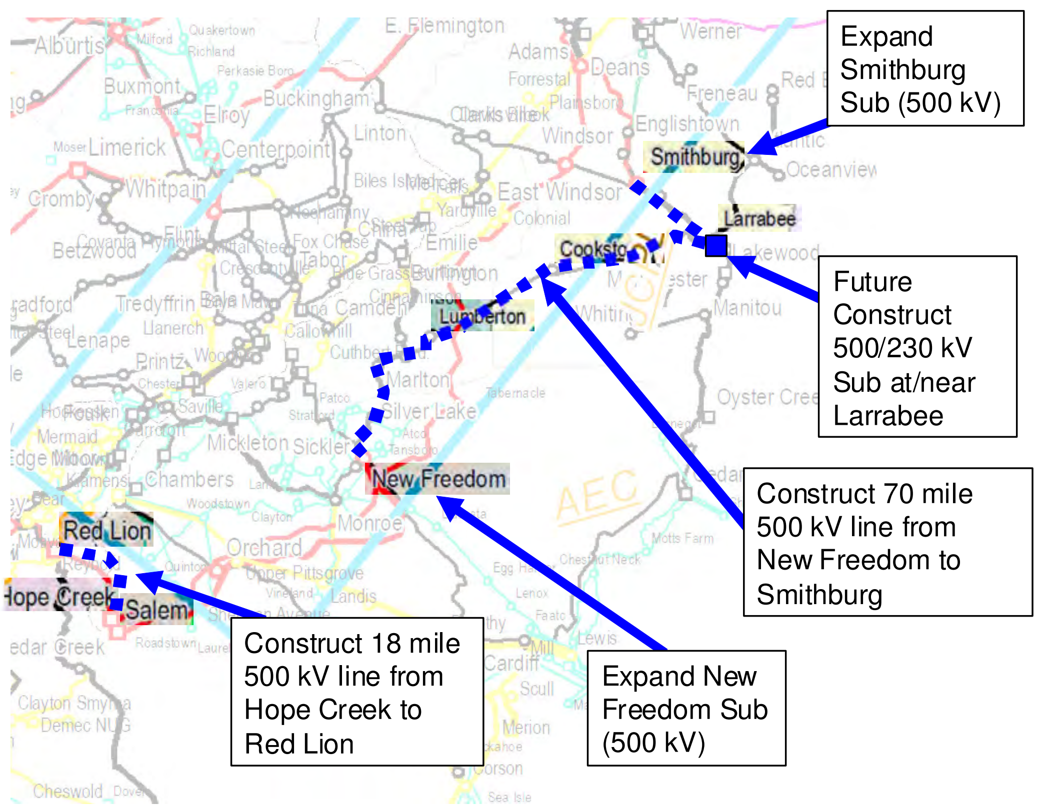
1. Construct approximately 43 miles of 500 kV line in the JCP&L Zone and an additional 27 miles of 500 kV line in the PSEG and AEC Zones from New Freedom (PSEG/AEC) substation to Smithburg (FE) substation.
2. Construct approximately 18 miles of 500 kV line from Hope Creek to Red Lion in the AEC and DPL Zones.
3. Expand, as necessary, the New Freedom and Smithburg Substations.
4. Expand, as necessary, the Hope Creek and Red Lion Substations.

Phase 2 (Future):

1. In addition to Phase 1, loop the proposed New Freedom-Smithburg 500 kV line and install two 500/230 kV transformers in a ring bus configuration at or near the existing Larrabee Substation.

Figure 2: Phase 1 & 2 Project Summary Sketch (See Appendix D for detailed one-line)

FE Proposed Solution



3.0 Detailed Analysis

3.1 Transient Analysis

FE uses the GE PSLF program for load flow studies and transient stability studies. FE also uses CAPE for its relay coordination and short circuit studies, which generated the fault impedances for this analysis using the short circuit data PJM provided in Appendix C. The following assumptions were made for the conversion of the PSS/E dynamics data to PSLF dynamics data and for the study:

Assumptions:

1. The Hope Creek to Salem 500 kV line impedance was set above jumper threshold reactance at X = j0.0002 pu.
2. The voltage regulator for the Hope Creek and Salem Nuclear Units is set to regulate the high side (500 kV) voltage.
3. The exciter User Written model for the Hope Creek and Salem Nuclear Units was converted and modeled as a GE PSLF ESAC6A by GE in a PSS/E to PSLF case conversion process.
4. FE did not numerically apply the 3% damping criteria, but rather used engineering judgment by visually inspecting the curves to see if they were well sampled as the GE PSLF program does not have that capability.
5. Plots of the rotor angles were chosen for display in the report.
6. Power System Stabilizers for Hope Creek and Salem Units were on in all scenarios.
7. Any scenario yielding a rotor angle swing greater than 120 degrees and not slipping poles will be classified as Marginally Stable (MS), but for purposes of this analysis, FE considers it as Unstable and requiring mitigation.
8. A fault at a bus is the same as a fault on a transmission line at 1% of the distance of the line away from the bus (close in fault equals the bus fault).

Existing System:

FE ran the PJM fault contingencies defined in the PJM AI request against the ‘as is’ transmission system to determine which faults cause instabilities on the system. In addition to the existing system, two system initial conditions were studied: one condition was to have the Hope Creek to Red Lion 500 kV 5015 line out of service before applying any of the faults. The second condition was to have the New Freedom to East Windsor 500 kV 5038 line out of service before applying any of the faults. When the faults were applied, it was discovered that the Hope Creek to Red Lion 500 kV line out of service case was by far the worst in yielding 21 out of 27 of the faults being unstable. In contrast, the New Freedom to East Winsdor 500 kV line out of service case, only three instabilities were observed. The results can be seen in Table 1 and Table 2.

Option 1 (New Freedom to Smithburg 500 kV line):

In observing the existing transmission system, it becomes apparent that when the Hope Creek to Red Lion 500 kV 5015 line is out of service and there is a loss of the New Freedom to East Windsor 500 kV 5038 line (or vice versa), the system will be unstable due to the fact that all of the power output from the Hope Creek and Salem units is forced into the New Freedom substation down to the 230 kV system across a higher Thevenin impedance. As a result, an obvious solution is to have a new line in parallel with the New Freedom to East Windsor to Deans 500 kV path. The parallel path chosen by FE is a new 500 kV path between New Freedom and Smithburg going by the Larrabee 230 kV substation (anticipating a connection at or near Larrabee 230 kV in the future). This was an option studied by FE to try to alleviate the stability issues found in the existing system. FE found that in the Hope Creek to Red Lion 500 kV 5015 line out of service case, 13 of the 21 instabilities became stable. As a result, FE considered additional projects for solving the eight remaining instabilities, which are described in Options 1a and 1b.

Option 1a: (New Freedom to Smithburg 500 kV line and a 2nd New Freedom to Hope Creek 500 kV line):

FE added a second 500 kV line between the New Freedom and Hope Creek Substations (Option 1a is a full 500 kV path between the Hope Creek and Smithburg Substations). This scenario eliminated five of the eight remaining instabilities, leaving three instabilities. Critical clearing times were found for those remaining three instabilities, which imply that faster stuck breaker clearing times might be achievable. All of these observations can be seen in Table 1 and Table 2. In the New Freedom to East Windsor 500 kV 5038 line out of service case (Table 2), the proposed New Freedom to Smithburg 500 kV path (Option 1) eliminated two (2) of the three (3) instabilities; the instability that remained (even after adding the second New Freedom to Hope Creek 500 kV line to form Option 1a) was the single-line-to-ground fault that results in the loss of the Hope Creek to Red Lion 500 kV 5015 line. If the stuck breaker clearing time is reduced from 9.5 cycles to 9 cycles for the remaining contingency, it becomes stable.

Option 1b: New Freedom to Smithburg 500 kV line and a 2nd Hope Creek to Red Lion 500 kV line

In place of the New Freedom to Hope Creek proposed 500 kV path (Option 1a), a second 500 kV line from Hope Creek to Red Lion was considered as an option in the analysis (Option 1b). FE observed that this option is better than the second New Freedom to Hope Creek 500 kV line option. The analysis showed that all 27 PJM-defined faults were stable, which can be seen in Table 1 and Table 2. Two additional contingencies (a three-phase and single-line-to-ground fault causing the loss of the Keeney to Red Lion 500 kV line) were run against this case to determine what would happen if the path toward the Peach Bottom nuclear station (i.e. Red Lion 500 kV path towards Keeney) was lost. The application of the two additional fault contingencies involving the Keeney to Red Lion 500 kV line were also found to be stable.

3.2 Breaker one-line diagrams FE Proposed Solution

Redacted Single Line

3.3 Transient Results

Table 1: Transient Results Condition 1

Artificial Island Study Initial System Condition 1: Hope Creek to Red Lion 500 kV 5015 Out of Service				
Fault ID	**Existing System (Base)**	**Add New Freedom to Smithburg 500 kV line (Option 1)**	**Add New Freedom to Smithburg and 2nd New Freedom to Hope Creek 500 kV lines (Option 1a)**	**Add New Freedom to Smithburg and 2nd Hope Creek to Red Lion 500 kV lines (Option 1b)**
1a	U	S	S	S
1b	U	S	S	S
1c	U	S	S	S
2a	N/A	N/A	N/A	S
2b	N/A	N/A	N/A	S
3a	U	S	S	S
3b	U	U	S	S
4	U	S	S	S
5a	MS (> 120 deg)	S	S	S
5b	U	S	S	S
6a	U	U	S	S
6b	U	U	S	S
7a	U	U	S	S
7b	U	U	U	S
7c* (mod 7b)	Not Studied	Not Studied	S	N/A

8	U	S	S	S
9a	S	S	S	S
9b	U	S	S	S
9c	U	U	S	S
10a	S	S	S	S
10b	S	S	S	S
11a	S	S	S	S
11b	U	S	S	S
11c	U	S	S	S
12a	U	S	S	S
12b	U	U	U	S
12c	U	U	U	S
12d	U	S	S	S
12e* (mod 12b)	Not Studied	Not Studied	S	N/A
12f* (mod 12c)	Not Studied	Not Studied	S	N/A
13a** (RL-KE)	N/A	N/A	N/A	S
13b** (RL-KE)	N/A	N/A	N/A	S

U = Unstable, MS = Marginally Stable, S = Stable, N/A = Not Applicable

* Faults 7c, 12e, and 12f added to determine the critical times for the possibility of shortening breaker failure times (see fault definitions).

** Faults 13a and 13b added to see if the new 2nd Hope Creek to Red Lion line solution can sustain the initial condition outage of one of the Hope Creek to Red Lion 500 kV lines and a three-phase or single-line-to-ground fault on the Red Lion to Keeney 500 kV line.

Table 2: Transient Results Condition 2

Artificial Island Study Initial System Condition 2: New Freedom to East Windsor 500 kV 5038 Out of Service				
Fault ID	**Existing System (Base)**	**Add New Freedom to Smithburg 500 kV line (Option 1)**	**Add New Freedom to Smithburg and 2nd New Freedom to Hope Creek 500 kV lines (Option 1a)**	**Add New Freedom to Smithburg and 2nd Hope Creek to Red Lion 500 kV lines (Option 1b)**
1a	S	S	S	S
1b	S	S	S	S
1c	S	S	S	S
2a	U	S	S	S
2b	U	U	U	S
2c* (mod 2b)	Not Studied	Not Studied	S	N/A
3a	S	S	S	S
3b	S	S	S	S
4	S	S	S	S
5a	S	S	S	S
5b	S	S	S	S
6a	S	S	S	S
6b	S	S	S	S
7a	S	S	S	S
7b	S	S	S	S

8	S	S	S	S
9a	S	S	S	S
9b	S	S	S	S
9c	S	S	S	S
10a	S	S	S	S
10b	U	S	S	S
11a	S	S	S	S
11b	S	S	S	S
11c	S	S	S	S
12a	N/A	N/A	N/A	N/A
12b	N/A	N/A	N/A	N/A
12c	N/A	N/A	N/A	N/A
12d	N/A	N/A	N/A	N/A
13a** (RL-KE)	N/A	N/A	N/A	S
13b** (RL-KE)	N/A	N/A	N/A	S

U = Unstable, MS = Marginally Stable S = Stable, N/A = Not Applicable

* Fault 2c added to determine the critical times for the possibility of shortening breaker failure times (see fault definitions).

** Faults 13a and 13b added to determine whether the new second Hope Creek to Red Lion line solution can sustain the initial condition outage of one of the Hope Creek to Red Lion 500 kV lines and a three-phase or single-line-to-ground fault on the Red Lion to Keeney 500 kV line.

3.4 Response Plots

Attached in Appendix A are the response plots, related to the following contingencies and solutions studied.

Existing System with Hope Creek-Red Lion 500 kV 5015 line Out of Service (OOS).

Proposed New Freedom-Smithburg 500 kV line with Hope Creek-Red Lion 500 kV 5015 line OOS.

Proposed New Freedom-Smithburg 500 kV line with second Hope Creek-New Freedom 500 kV line and Hope Creek-Red Lion 500 kV 5015 line OOS.

Proposed New Freedom-Smithburg 500 kV line with second Hope Creek-Red Lion 500 kV line and Hope Creek-Red Lion 500 kV 5015 line OOS.

Existing System with New Freedom-East Windsor 500 kV 5038 line OOS.

Proposed New Freedom-Smithburg 500 kV line with New Freedom-East Windsor 500 kV 5038 line OOS.

Proposed New Freedom-Smithburg 500 kV line with second Hope Creek-New Freedom 500 kV line and New Freedom-East Windsor 500 kV 5038 line OOS.

Proposed New Freedom-Smithburg 500 kV line with second Hope Creek-Red Lion 500 kV line and New Freedom-East Windsor 500 kV 5038 line OOS.

3.5 Project Scope, Construction Schedule and Cost Estimate

<u>Project Scope (Phase 1):</u>

Smithburg – New Freedom Transmission Line Scope

Smithburg (FE) – New Freedom (PSEG) 500 kV line – JCP&L Zone only

- Construct a new 500 kV line from Smithburg to Larrabee to New Freedom.
- Construct approximately 43 miles of 500 kV line traversing the JCP&L Zone.
- Construction includes rebuilding an existing 230 kV line to double-circuit 500/230 kV line.
- A field visit was conducted of the proposed route to assist in the estimating process.
- Cost estimate and construction schedule assumes no siting/permitting issues or ROW acquisition issues.
- New structures will be located and constructed to minimize outages to the existing 230 kV line.
- Cost estimate and construction schedule are based on PJM authorizing FE to begin engineering and construction activities prior to January 1, 2014.
- Construction schedule will be impacted by availability of outages required to complete the work.

Smithburg Substation Scope

- Eliminate the 500 kV equipment at Smithburg Substation.
- Remove transformer bank #1 and replace with new 500/138 kV open air transformer.
- Install 230 kV transition bushing and connect low side of new transformer to same bus position as former bank #1 transformer.
- Install new 500 kV four position ring bus.
- Re-terminate existing 500 kV Deans line, add one new 500 kV line exit.
- Expand existing substation yard to the north and east.

<u>Project Scope (Phase 2 - Future):</u>

Larrabee Substation Scope

- Install 11 new 230 kV breakers and reconfigure existing yard to six bays of 230 kV to a breaker-and-a-half configuration.
- Install two new 500/230 kV transformers.
- Install four position ring buss (set up for future breaker-and-a-half configuration).
- Install two new 500 kV exits.

<u>Construction Schedule:</u>

Transmission Line (Phase 1):

The construction schedule is based on PJM authorizing FE to begin engineering and construction activities prior to January 1, 2014.

Engineering	1/1/2014 through 7/31/2015
Additional ROW Acquisition	5/1/2014 through 6/30/2016
Siting Studies and Siting Authorization	1/1/2014 through 11/30/2015
Construction	1/1/2016 through 11/30/2018
In Service Date	12/31/2018

Smithburg Substation Expansion (Phase 1):

The construction schedule is based on PJM authorizing FE to begin engineering and construction activities prior to January 1, 2014.

Engineering	1/1/2016 through 6/30/2017
Below Grade Construction	9/1/2017 through 1/30/2018
Above Grade Construction	12/1/2017 through 5/30/2018
Major Equipment Delivery	12/1/2017
In Service Date	6/1/2018

Larrabee Substation Expansion (Phase 2 - Future):

The construction schedule will be based on a three-year construction timeline once the project is authorized.

Cost Estimate:

Redacted Direct Costs and Overheads

Description ($ millions)	Total Cost
Create a new 500kV line from Smithburg to Larrabee to New Freedom (PSEG). This estimate is only for the 43 miles that is in JCPL territory. The scope includes rebuilding an existing 230kV line to a double-circuit 500/230kV line. @ Smithburg-New Freedom 500kV, New Line	392.4
Replace 500kV GIS. Install one new 500/230kV transformer and 500kV four position ring bus (one existing and one new 500kV line exit). @ Smithburg	18.3
Subtotal Phase 1	410.7
Phase 2: Install 11 new 230kV breakers and convert existing yard to 6 bays of 230kV breaker and a half. Install two new 500/230kV transformers, four position 500kV ring bus, and two new 500kV line exits. @ Larrabee	41.6
Grand Total of All Phases	452.3

Redacted Direct Costs and Overheads

[redacted]

Transmission Line Assumptions:

Engineering Assumptions:

- Double circuit 500 kV towers are insulated to 500 kV on both sides.
- 500 kV conductor is three 1113 kcmil ACSS.
- 230 kV conductor is one 1113 kcmil ACSS (230 kV occupies 230 kV side of double circuit 500 kV towers.
- One shieldwire will be OPGW and the other will be alumoweld.
- Cost estimate includes structure for structure replacement on existing corridor.
- Cost estimates for foundations assume 25% rock.

Siting Assumptions:

- Outside consultant will perform all siting and permitting activities.

Right-of-Way Assumptions:

- Route will utilize an existing transmission corridor to the extent possible.
- Some additional ROW will be required to widen the corridor and is included in the estimate.
- Schedule assumes that the additional ROW can be obtained in a timely manner.
- A sampling review of existing easements was conducted to determine availability for use with this project.
- Certain existing ROW restrictions may have to be re-negotiated with current property owners.
- A portion of the line route will require negotiating with the appropriate governmental authority for authorization to construct the line through a New Jersey state park.

Major Equipment Lead Times (beyond 6 weeks delivery):

- Approximately 275 steel poles with concrete foundations.
- Approximately 470 miles of 1113 ACSS conductor.

Substation Assumptions:

Smithburg Substation

- Assumes the fenceline on the northeast side of substation can be expanded.
- Relocation of at least two nearby transmission lines will be required.
- Assumes existing 500 kV air insulated circuit breaker will be relocated and re-used in new ring bus.
- Assumes new relay panels will fit inside existing control building.
- No detailed protection requirements were used in the estimates.
- No site visit performed on the 230 kV bus estimate and scope preparation.
- Bank #4 transformer to remain in place. Bank #1 transformer along with all 500 kV gas insulated bus and equipment will be replaced with air bus and gas to air transition bushing.
- Bank #1 transformer protective relaying to be replaced. New relaying to be placed in pre-wired panel.
- Transition bushing will be custom designed to interface with existing 230 kV GIS.

Larrabee Substation

- Existing fence line can be expanded to the south and west.
- Approximately eight acres of new substation yard will be added.
- Site expansion will require permitting, siting, environmental, and grading work and is included in the estimate.
- Site expansion will require some transmission line relocations and is included in the estimate.
- Assumes a new control building since there is not enough space in the existing control building.
- 500 kV yard set up as four breaker ring bus with option for breaker and a half expansion in future.

3.6 *Steady State Analysis*

3.6.1 Base Case Description

The base case utilized for this study was provided by PJM and has all lines in service with AI units at maximum real power output. This analysis used the 2017 summer model from the 2011 series Multiregional Model Working Group case.

Description of Power Flow Cases

Three additional load flow cases were developed to examine each of the proposed FE solutions. Table 3 details the analysis performed on each of the cases. A description of each case follows the table.

Table 3: Base Cases

Case	*Cat A*	*Cat B*	*Cat C*	*Cat C3*
Pjm 2017 RTEP Base Case	Y	Y	Y	Y
Phase 1	Y	Y	Y	Y
Phase 2	Y	Y	Y	Y

Base Case

The 50/50 summer peak case represents a forecasted load level for which there is a 50% chance that the actual summer peak load will be higher than the forecasted load, and a 50% chance that the actual peak will be lower.

Phase 1: (Appendix D)

This phase installs a new 500 kV line from Smithburg to New Freedom.

Phase 2: (Appendix D)

This plan includes looping the 500 kV line between New Freedom and Smithburg into the existing Larrabee Substation or a new substation near Larrabee Substation with a 500 kV four position ring bus and two 870 MVA, 500/230 kV transformers.

3.6.2 Thermal and Voltage Screening Criteria

PJM AI Screening Criteria

The Stability Performance Criteria outlined in PJM's proposal document included the following steady state voltage screening criteria.

(a) *Steady state voltage*: pre-fault voltages at selected 500 kV buses should be within operating range in Table 4. This pre-fault voltage must be noted for the following buses:

Table 4 Bus Numbers Redacted

Table 4 – Steady State Voltage Limits

Bus Name	Bus Voltage	Bus # Identifier	Steady state pre-fault Voltage
Branchburg	500 kV		1.0 – 1.1 p.u.
Deans	500 kV		1.0 – 1.1 p.u.
Keeney	500 kV		1.0 – 1.1 p.u.
New Freedom	500 kV		1.0 – 1.1 p.u.
Peach Bottom	500 kV		1.0 – 1.1 p.u.
Salem	500 kV		1.0 – 1.1 p.u.
Red Lion	500 kV		1.0 – 1.1 p.u.
East Windsor	500 kV		1.0 – 1.1 p.u.
Hope Creek	500 kV		1.0 – 1.1 p.u.
Orchard	500 kV		1.0 – 1.1 p.u.

1. Post-fault steady state voltage shall not be below 0.986 pu at the Salem and Hope Creek 500 kV buses.
2. The voltage drop magnitude from pre-trip to post-trip conditions for any of the Artificial Island Units shall not exceed:
    a) 2% - Salem Unit 1 and Unit 2
    b) 2.5% - Hope Creek
3. The operating voltage range of AI generator terminal (25 kV bus) is from 0.95 pu to 1.05 pu.

FE Screening Criteria

In addition to the above criteria, while conducting the load flow analysis, all transmission lines (including tie-lines) and transmission transformers within the study area were monitored for violation of FE Transmission Planning Criteria. This analysis was conducted to determine the impacts each option listed above would have on the transmission system. Table 5 summarizes the additional thermal loading, voltage magnitude, and voltage change screening criteria used in for the steady state analysis.

Table 5: FE Screening Criteria

System Condition	*Transmission Line & Transformer Thermal Loading*	*kV*	*Bus Voltage Magnitude*	*Voltage Change*
Normal System (N-0) – NERC Category A	Greater than 95% of Summer Normal Rating (SN)	500 345 230 138 115	1.00 < Vbus < 1.10 0.95 < Vbus < 1.05 0.95 < Vbus < 1.05 0.95 < Vbus < 1.05 0.95 < Vbus < 1.05	N/A
Single Contingency (N-1) – NERC Category B	Greater than 95% of Summer Emergency Rating (SE)	500 345 230 138 115	0.97 < Vbus < 1.10 0.92 < Vbus < 1.05 0.92 < Vbus < 1.05 0.92 < Vbus < 1.05 0.92 < Vbus < 1.05	5% 8% 8% 10% 10%
Multiple Contingency – NERC Category C	Greater than 100% of Summer Emergency Rating (SE)	500 345 230 138 115	0.97 < Vbus < 1.10 0.92 < Vbus < 1.05 0.92 < Vbus < 1.05 0.92 < Vbus < 1.05 0.92 < Vbus < 1.05	5% 8% 8% 10% 10%

Voltage Control

For voltage magnitude violations, all contingencies were solved with voltage-controlled capacitor banks operable and automatic transformer load tap changers (LTCs) enabled. During the next set of tests to identify potential voltage collapse (voltage less than 0.85 per unit) and to screen for voltage drop violations, switch capacitors and LTCs were locked at the pre-contingency position.

3.6.3 Contingency Testing

NERC Category B Testing

A single contingency analysis (N-1) of all FE transmission lines (34.5 kV and above), transformers, and generating units was performed on all base cases summarized in Table 3. All FE transmission tie-lines were included in the single contingency analysis.

NERC Category C1, C2 & C5 Contingency Testing

All bus (C1), breaker failure (C2), and common structure (C5) contingencies were analyzed on the base cases summarized in Table 3.

NERC Category C3 Contingency Testing
The purpose of the N-1-1 analysis is to determine if all monitored facilities can be operated within normal thermal and voltage limits after an actual N-1 contingency and within the applicable emergency thermal and voltage limits after an additional simulated contingency. The outage of NERC Category B contingencies (N-1-1) was considered for all combinations of FE 500, 345, 230, 138, and 115 kV facilities. This includes FE transmission transformers, single unit generator outages, transmission capacitor banks, and all neighboring utility BES facilities, including generators, located within two buses of FE.

3.6.4 Steady State Load Flow Results

Results using PJM AI Screening Criteria
(a) Steady state pre-fault voltages at selected 500 kV buses

All of the pre-fault voltages at the selected 500 kV buses are within the operating range specified in Table 4 (1.0 -1.1 p.u.) and are summarized in Table 6.

Table 6: Pre-fault voltages at PJM selected 500 kV buses

Redacted Table

1. *Post-fault steady state voltage at Salem and Hope Creek 500 kV buses*
The post-fault steady state voltage at the Salem and Hope Creek 500 kV buses did not drop below [redacted] p.u. in any of the power flow cases for any of the studied faults.

2. *Voltage drop magnitude (pre-trip to post-trip) for the Artificial Island units*
The voltage drop magnitude did not exceed 2% at the Salem units or 2.5% at the Hope Creek unit in any of the power flow cases for any of the studied faults.

3. Operating voltage at the AI generator terminals

The operating voltage at the Artificial Island generator terminals was between 0.95 p.u. and 1.05 p.u. in all of the power flow cases for all of the studied faults.

Results using additional FE Screening Criteria

Normal System Results (N-0) – NERC Category A

JCP&L Category A Thermal Violations

There were no Category A bulk thermal violations.

JCP&L Category A Voltage Violations

There were no new Category A bulk voltage violations to report.

Single Contingency Results (N-1) – NERC Category B

JCP&L Category B Thermal Violations

There were no Category B bulk thermal violations.

JCP&L Category B Voltage Violations

There were no Category B bulk voltage violations.

Multiple Contingency Results – NERC Category C1, C2, C5

JCP&L Category C1, C2, C5 Thermal Violations

There were no Category C1, C2, C5 bulk thermal violations.

JCP&L Category C1, C2, C5 Voltage Violations

There were no new Category C1, C2, C5 bulk voltage violations.

Double Contingency Results (N-1-1) – NERC Category C3

Table 7 lists the thermal violations in the JCP&L region for NERC Category C3 contingencies.

Table 7: JCP&L Category C3 Thermal Violations

Table 7 Results redacted

Index	*Overloaded Element*	*Contingency Description*	*Base Case*	*Phase 1*	*Phase 2*

JCP&L Category C3 Voltage Violations

There were no new Category C3 bulk voltage violations.

4.0 Equipment Parameters and Assumptions

Table 8: 500 kV Line Parameters

Table 8 Line Parameters Redacted

Table 9: 500/230 kV XMFR Parameters

Table 9 Transformer Parameters Redacted

5.0 Other Supporting Information

Future Benefit to EHV System

- Reduces facility loadings.
- Eliminates the AI operating constraints/complexity.
- Improves performance and Artificial Island stability margin under N-0 and N-1 (forced or unforced) conditions.
- Complies with the Artificial Island Operating Guide (AIOG) and eliminates need for the AI trip scheme.
- Minimizes impact to property owners by using, to the extent possible, ROW currently owned by utilities.
- Helps in the continued reliance on transmission to meet load deliverability requirements, and to obtain additional sources of power when generation is being retired.
- Minimizes 500 kV double circuit line construction.
- Has the potential to reduce system congestion.
- Eliminates Smithburg 500 kV substation from being radially feed.

Future Benefit to support JC&PL (Phase 2)

– Construction of a 500/230 kV substation at/near Larrabee.

  - Provide regional operational flexibility.
  - Improves load serving capability in southern New Jersey/Oyster Creek area for future load growth.
  - Provide additional support for the continued reliance on transmission to meet load deliverability requirements and to obtain additional sources of power when generation is retired.

Appendix 6.0 Totally Redacted