Artificial Island Area Proposal 2

New 500 kV 3000 MVA line from Salem to Delaware

Dominion Virginia Power

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Contact Information

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Purpose of Proposal

This solution proposal is being made in response to PJM's Request For Proposal (RFP) on April 29, 2013 in which PJM seeks technical solution alternatives (hereinafter referred to as "Proposals") to improve PJM 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 in the Artificial Island area.

The objectives as stated in the RFP include

1. Generate maximum power (3818 MW total) from all AI Units (Salem1: 1253MW, Salem-2: 1245MW, Hope Creek: 1320MW) without a minimum MVAR requirement from the AI. Full maximum power must be maintained under both the baseline and all N-1 outage conditions of 500kV 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. NERC Category C3 contingencies "N-1-1 contingencies" do not need to be run on top of the N-1 outage condition.
2. Maximum MW output from AI should 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.
5. Maintain PJM System Operating Limits (SOLs).

Proposals

Dominion is submitting this proposal as the Entity to construct, own and operate should PJM select and approve as a baseline upgrade. As demonstrated in the Pre-Qualification package for Virginia Electric and Power Company (Dominion Virginia Power), Dominion has demonstrated its qualifications to construct, own, and operate electric facilities.

Because of the potential for the route for this new line to vary, Dominion has studied two options labeled Long Line and Short Line options. The proposal has the following major components:

Short Line Option

- Construct a new 6 mile 500 kV 3000 MVA line from Salem to Delaware and associated breakers, controls and protection to a new substation that would connect into the two existing 230 kV lines Cedar Creek to Red Lion and Catanza to Red Lion
- Install two parallel 500 – 230 kV 840 MVA transformers, 8 – 230 kV and 2 – 500 kV breakers at the New Substation
- Add one 500 kV breaker at East Windsor Substation
- Add two 500 kV breakers at New Freedom Substation
- Add two 500 kV breakers at Salem Substation
- Add one 500 kV breaker at Red Lion Substation

Long Line Option

- Construct a new 18 mile 500 kV 3000 MVA line from Hope Creek to Delaware and connect into the existing substation Red Lion.
- Construct a new 0.5 mile 500 kV 3000 MVA line from Salem to Hope Creek
- Add four 500 kV breaker at Red Lion Substation
- Add two 500 kV breakers at Hope Creek Substation
- Add one 500 kV breaker at East Windsor Substation
- Add two 500 kV breakers at New Freedom Substation
- Add one 500 kV breakers at Salem Substation

Description of the proposed solution

A 500-kV line is proposed emanating from Salem station to a new station in Delaware across the Delaware River. Through two 500/230 kV transformers, the proposed line connects to two 230-kV lines that originate from Cedar Creek station to Red Lion station. One of the 230-kV lines does not terminate at Cedar Creek station but passes by. Both 230-kV lines are on the same right-of-way.

Depending on the availability of the right-of-way, the length of the new line can vary from 6 miles to 18 miles. The maximum length is when the new line follows the existing right-of-way from Salem to Red Lion. Since Red Lion is a 500-kV station, 500/230 kV transformers are not required. Please refer to the breaker one-line diagrams for illustration of the proposed solutions. The proposed line and all related system updates are highlighted in red.

In addition to the 500-kV line, the following circuit breakers need to be doubled to eliminate delayed clearing due to stuck breaker events:

- Red Lion 505
- New Freedom 2-10, 9-10
- East Windsor B16

Detailed analysis report on proposed solutions

1. Response plots (Voltages and Machine angles over time)

PJM specified 27 normally cleared and stuck breaker contingencies to be applied on 13 line outage cases. The combination of the contingencies and the thirteen power flow cases resulted in 351 contingencies. In addition, the contingencies associated with the new line are included as well. All these contingencies are studied with the PSSs of Salem unit 2 and Hope Creek unit out of service.

The response plots in Appendix A display the simulation results with the proposed solutions of Short and Long 500-kV lines respectively. On each page, there are four plots. The plot on the lower left shows the rotor angles of the three Artificial Island units. The plot on the upper left shows the terminal voltages of the three Artificial Island units. The two plots on the right display the voltages of the ten 500-kV Artificial

Island buses. To show the damping ratio of rotor angle is above 3%, in addition to the plots, SSAT analysis results are attached in Appendix B. SSAT Results. Both the SSAT results and the PSS/e plots show good damping ratios above 3%. The naming convention of the raw files used for SSAT analysis is explained as below in an example:

AI_L5014-3new-5022-5038-ETx12.raw
5014 outage Elements out due to contingency, line 5022, line 5038, and transformers 1 and 2 at East Windsor (E represents the first letter of the station name)

2. Breaker one-line diagrams to illustrate system topology

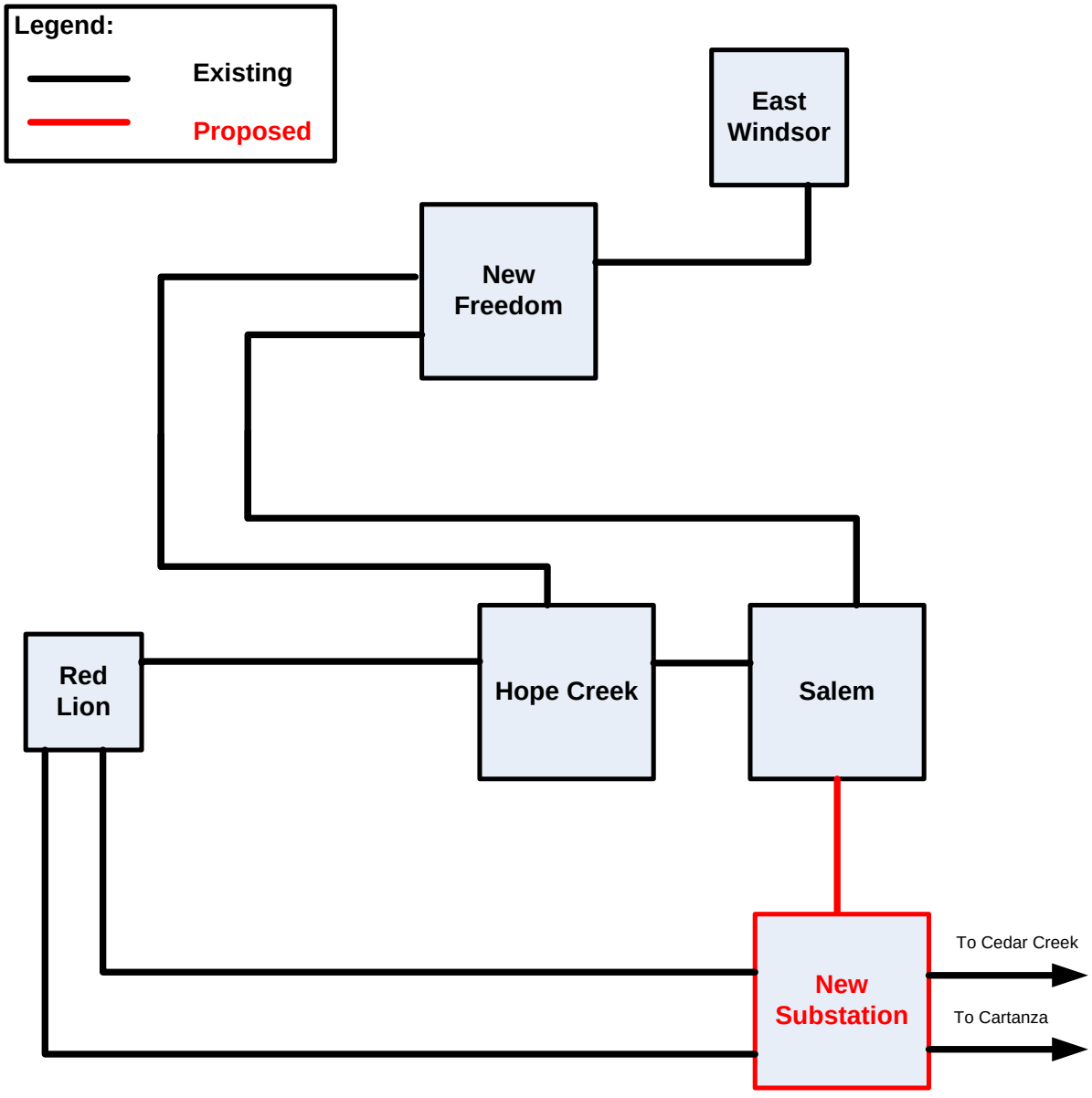

Fig. 1. One Line Diagram of Short 500-kV Line Solution

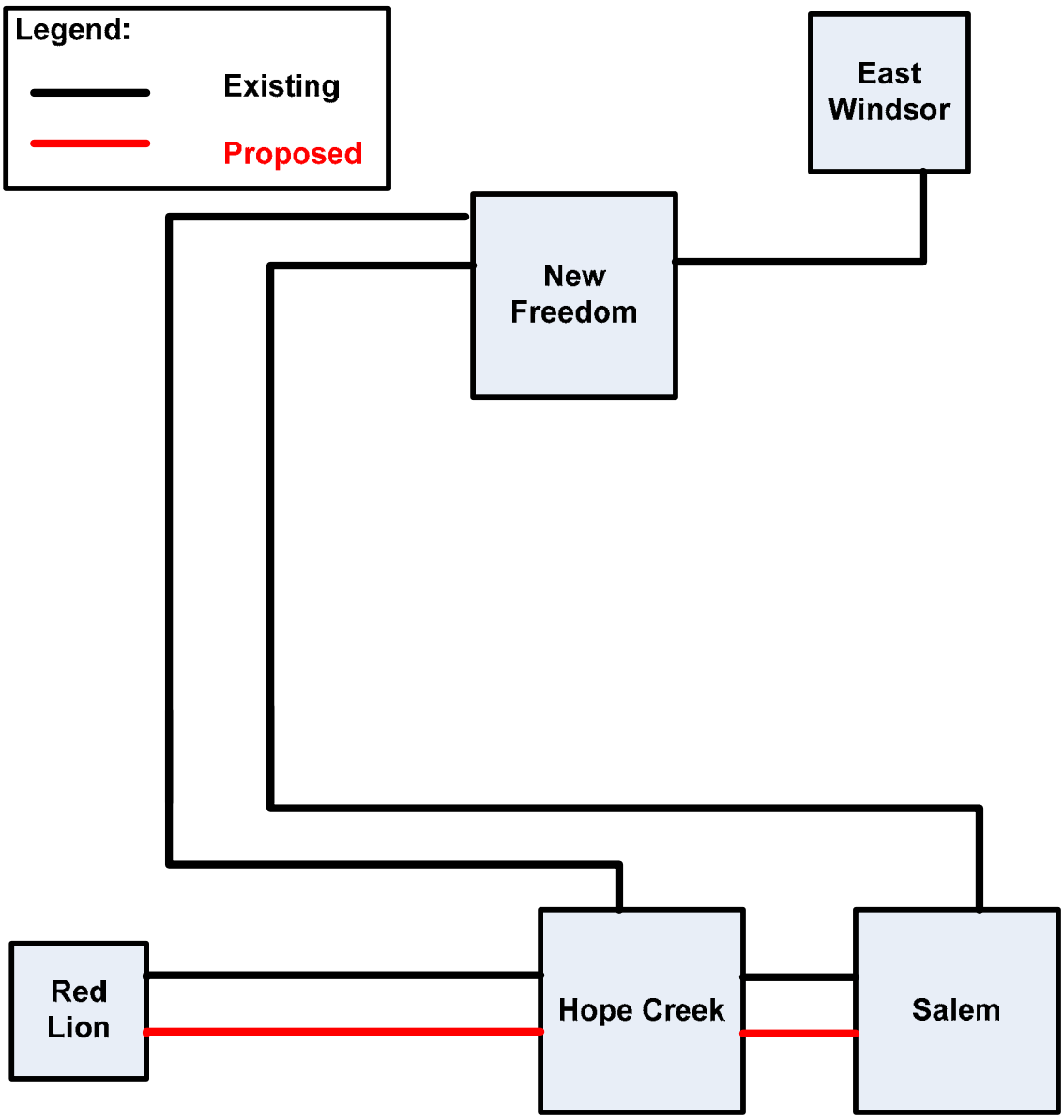

Fig. 2. One Line Diagram of Long 500-kV Line Solution

The breaker one-line diagrams for illustration of the proposed solutions are displayed as above. The proposed line and all related system updates are highlighted in red.

3. Spreadsheets (Table of system voltages)

The two Excel files in Appendix C tabulate the terminal voltages of the three Artificial Island units, pre-fault, post-fault, and voltage drop magnitude from pre-fault to post-fault conditions. In addition, the files tabulate the steady state pre-fault and post-fault voltages for ten 500-kV buses listed in the Artificial Island Proposal. The results show that

1. The pre-fault and post-fault steady state voltages at selected 500-kV buses are within operating range of 1.0-1.1 p.u.
2. The post-fault steady state voltages are above 0.986 p.u. at the Salem and Hope Creek 500-kV buses.
3. The voltage drop magnitude from pre-fault to post-fault steady state conditions do not exceed 2% and 2.5% respectively for Salem units and Hope Creek unit.
4. The AI generator terminal voltages are within the operating voltage range, from 0.95 p.u. to 1.05 p.u.

In Appendix D. Maximum Angle Deviations, two more spreadsheets list the largest angle deviation for each contingency. The system with solution is stable for all outages and contingencies considered. With respect to a reference machine, Sea Brook unit 1, the maximum angle swing of any unit is smaller than 120 degrees. The out files including all the required monitored facilities and data channels for all required contingencies are also contained in the data package as Appendix E. The naming convention of the out files are described as below in an example.

AI-AI_L5014-3new-2017SLL0-10A.out
Power flow Dynamic Contingency
Line 5014 outage

For contingency 10B, 12B, 12C, and 12D, the contingency names are updated to 10B2, 12B2, 12C2, and 12D2. The name change reflects the system upgrades of double circuit breakers.

Fault ID	**Fault Description**
13a-short	3 phase fault on new line from Salem to new substation near Salem bus section 1. Normal clearing in 4.13 cycles. (Short line solution)
13b-short	SLG fault on new line from Salem to new substation near Salem bus section 1, 3 SB at new substation. Clearing in 10.26 cycles. (Short line solution)
13c-short	SLG fault on new line from Salem to new substation near Salem bus section 1, 1 SB at new substation. Clearing in 10.26 cycles. (Short line solution)
13b1-short	SLG fault on new line from Salem to new substation near Salem bus section 1, 3 SB at new substation. Clearing in 8.75 cycles. (Short line solution)
13c1-short	SLG fault on new line from Salem to new substation near Salem bus section 1, 1 SB at new substation. Clearing in 8.75 cycles. (Short line solution)
13b-long	SLG fault on new line 50371 from Salem to Hope Creek near Salem bus section 1, 3-8 SB at Salem. Clearing in 10.26 cycles. (Long line solution)
13c-long	SLG fault on new line 50371 from Salem to Hope Creek near Salem bus section 1, 3-4 SB at Salem. Clearing in 10.26 cycles. (Long line solution)
14b-long	SLG fault on new line 5015 from Salem to Hope Creek near Hope Creek bus section 1, 3-4 SB at Hope Creek. Clearing in 10.26 cycles. (Long line solution)

More contingencies due to the addition of the new lines are also studied. The contingency descriptions are listed above in the table.

Equipment parameters and assumptions

1. All parameters (Ratings, impedances, mileage, etc.)

1. For the short line solution, the parameters of 500-kV transmission line and the two 230/500 kV transformers are listed below:

   – Line :
   - Ratings: Rate A-3464 MVA; Rate B-3741 MVA;
   - Impedances: R-0.000068 p.u.; X-0.001346 p.u.; B-0.12357 p.u.;
   - Mileage: 6.2 miles

   – Transformer 1:
   - Ratings: Rate A-957 MVA; Rate B-1009.2 MVA; Rate C-1060.7 MVA;
   - Impedances: R-0.00016 p.u.; X-0.0152 p.u.;

   – Transformer 2:
   - Ratings: Rate A-957 MVA; Rate B-1009.2 MVA; Rate C-1060.7 MVA;
   - Impedances: R-0.00016 p.u.; X-0.0152 p.u.;

2. For the long line solution, the parameters of 500-kV transmission line segments are listed below:

   – Line Segment 1 from Salem to Hope Creek:
   - Ratings: Rate A-2940 MVA; Rate B-3733 MVA;
   - Impedances: R-0.000010 p.u.; X-0.000100 p.u.; B-0.0065 p.u.;
   - Mileage: 0.5 miles

   – Line Segment 2 from Red Lion to Hope Creek:
   - Ratings: Rate A-2654 MVA; Rate B-3014 MVA;
   - Impedances: R-0.00020 p.u.; X-0.004200 p.u.; B-0.300290 p.u.;
   - Mileage: 18 miles

   The Load Flow Model data are attached in Appendix F.

2. For synchronous machines, MW and MVAR output assumptions

The Artificial Island units are dispatched according to the base case from PJM. The reactive power was fixed at a reasonable value. The unit terminal voltage is easy to be lower than 0.95 p.u. if the reactive power output is reduced a little. Due to the operating voltage restrictions on AI generator terminal, the reactive power is fixed at the original value.

	Salem1	Salem2	Hope Creek
Gross power output (MW)	1253	1245	1320
Reactive power output (MVARs)	265	265	265

Case Data

The complete set of power flow and dynamic cases containing proposed solutions along with the PSAS files for contingencies are provided in Appendix G. Also PSS/E IDEV files are provided in Appendix H, so that the modeling of the proposal may be easily applied to other models. All cases and data files for dynamic simulations are in PSS/E ver. 32 format.

Right of Ways

Dominion has performed a high level review of routing in this proposal. For the short line, it is estimated the line would be along new right of way spanning the Delaware River for approximately 6 miles to the existing 230 kV corridor.

For the long line, there appears to be right of way that would parallel the existing Hope Creek to Red Lion 500 kV line 5015. The path is nearly 100% wetlands and includes a Delaware River crossing. Property is available at Red Lion Substation to connect the new line to DPL facilities. The line would be approximately 18 miles in length.

For either of these two options or any options in between, Dominion would have to further explore routing options but due to the short window, that was not fully addressed in this alternative.

Permitting and Construction Schedule

Permitting would be required from federal, state, and local jurisdictions. State and local permits would be required in both Delaware and New Jersey.

- Examples of federal would be Corp of Engineers permits.
- Examples of both state and local permitting would be Erosion and Sediment Plan permits and site construction permits.
- A Certificate of Public Convenience and Need (CPCN) would be required in both Delaware and New Jersey.

It is estimated that 60 to 72 months after project approval will be needed to complete this project.

Cost Estimates

Short Line Option

500 kV 3000 MVA 6 mile long line and New Substation	
500 kV Line	$70 Million
New Substation which includes two 500 – 230 kV transformers and associated breakers	$35 Million
Substation Land and Development	$9 Million
Total	$114 Million

East Windsor Substation – Existing	
Install one additional 500 kV breakers	$2 Million
Total	$2 Million

New Freedom Substation – Existing	
Install two additional 500 kV breakers	$4 Million
Total	$4 Million

Salem Substation – Existing	
Install two additional 500 kV breakers	$4 Million
Total	$4 Million

Red Lion Substation – Existing	
Install one additional 500 kV breakers	$2 Million
Total	$2 Million

** System protection costs are embedded in the figures above*

The total estimated cost for Short 6 mile Line Option Proposal = $126 M

Long Line Option

500 kV 3000 MVA 18 mile long line to Red Lion	
500 kV Line	$180 Million
Total	$180 Million

500 kV 3000 MVA 0.5 mile long line from Salem to Hope Creek	
500 kV Line	$2 Million
Total	$2 Million

Salem Substation – Existing	
Install one additional 500 kV breakers	$2 Million
Total	$2 Million

Hope Creek – Existing	
Install two additional 500 kV breakers	$4 Million
Total	$4 Million

New Freedom – Existing	
Install two additional 500 kV breakers	$4 Million
Total	$4 Million

East Windsor – Existing	
Install one additional 500 kV breakers	$2 Million
Total	$2 Million

Red Lion Substation – Existing	
Install four additional 500 kV breakers	$8 Million
Total	$8 Million

** System protection costs are embedded in the figures above*

The total estimated cost for Long 18 mile Line Option Proposal = $202 M

APPENDIX A

Response Plots–PDF files for Short and Long Line Solutions are included in the data package

500 kV line solution/App A Response Plots long.pdf

500 kV line solution/App A Response Plots short.pdf

APPENDIX B

SSAT Results–Input and output files of SSAT for Short and Long Line Solutions are included in the data package

500 kV line solution/App B SSAT Results long/..

500 kV line solution/App B SSAT Results short/..

APPENDIX C

System Voltages–Spreadsheets for Short and Long Line Solutions are included in the data package

500 kV line solution/App C System Voltages long.xlsx

500 kV line solution/App C System Voltages short.xlsx

APPENDIX D

Maximum Angle Deviations–Spreadsheets for Short and Long Line Solutions are included in the data package

500 kV line solution/App D Maximum Angle Deviations long.xlsx

500 kV line solution/App D Maximum Angle Deviations short.xlsx

APPENDIX E

Out Files–Out files for Short and Long Line Solutions are included in the data package

500 kV line solution/App E Out Files long/..

500 kV line solution/App E Out Files short/..

APPENDIX F

Load Flow Model Data–Raw files for Short and Long Line Solutions are included in the data package

500 kV line solution/App F Load Flow Model Data long.raw

500 kV line solution/App F Load Flow Model Data short.raw

APPENDIX H

IDV Files–IDV files for Short and Long Line Solutions are included in the data package

500 kV line solution/App H long.idv

500 kV line solution/App H short.idv