Generation Interconnection Feasibility Study Report

For

PJM Generation Interconnection Request Queue Position AC1-191

Elmont 230kV
53.4 MW Capacity / 80 MW Energy

May / 2017

Introduction

This Feasibility Study has been prepared in accordance with the PJM Open Access Transmission Tariff, 36.2, as well as the Feasibility Study Agreement between the Interconnection Customer (IC), and PJM Interconnection, LLC (PJM), Transmission Provider (TP). The Interconnected Transmission Owner (ITO) is Virginia Electric and Power Company (VEPCO).

Preface

The intent of the Feasibility Study is to determine a plan, with high level estimated cost and construction time estimates, to connect the subject generation to the PJM network at a location specified by the IC. The IC may request the interconnection of generation as a capacity resource or as an energy-only resource. As a requirement for interconnection, the IC may be responsible for the cost of constructing: (1) Direct Connections, which are new facilities and/or facilities upgrades needed to connect the generator to the PJM network, and (2) Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system.

In some instances a generator interconnection may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the Impact Study is performed.

The Feasibility Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The IC is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by ITO, the costs may be included in the study.

General

The IC has proposed a solar generating facility located in Hanover County, VA. The installed facilities will have a total capability of 80 MW with 53.4 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project is 12/31/2017. **This study does not imply an ITO commitment to this in-service date.**

Point of Interconnection

AC1-191 will interconnect with the ITO transmission system at one of the following points of interconnection:

Option 1 will connect via a breaker bay in the Elmont 115kV substation

Option 2 will connect via a new three breaker ring bus switching station that connects on the Elmont – Greenwood 115kV line #59.

Cost Summary

The AC1-191 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$6,100,000
Direct Connection Network Upgrades	$0
Non Direct Connection Network Upgrades	$1,500,000
Total Costs	**$7,600,000**

In addition, the AC1-191 project may be responsible for a contribution to the following costs:

Description	Total Cost
New System Upgrades	$50,000,000
Previously Identified Upgrades	$0
Total Costs	**$50,000,000**

Cost allocations for these upgrades will be provided in the System Impact Study Report.

Note: PJM Open Access Transmission Tariff (OATT) section 217.3A outline cost allocation rules. The rules are further clarified in PJM Manual 14A Attachment B. For New System Upgrades, the cost allocation rule differ depending on whether the minimum amount of upgrades to resolve a single reliability criteria violation will cost less than $5,000,000. For upgrades estimated to cost less than $5,000,000 the allocation of costs will not occur outside of the Queue in which the need for the Network Upgrade was identified. Cost allocation within the Queue will be contingent each Queue projects Distribution Factor on the overloaded facility. For upgrades estimated to cost $5,000,000 or greater the allocation of costs will start with the first Queue project to cause the need for the upgrade. Later queue projects will receive cost allocation contingent on their contribution to the violation and are allocated to the queues that have not closed less than 5 years following the execution of the first Interconnection Service Agreement which identifies the need for this upgrade.

Attachment Facilities

Generation Substation: Install metering and associated protection equipment. Estimated Cost $600,000.

Transmission: Build approximately 5.0 miles of 115 kV Line. Estimated Cost $5,500,000

The estimated total cost of the Attachment Facilities is $6,100,000. It is estimated to take 30-32 months to complete this work. These preliminary cost estimates are based on typical engineering costs. A more detailed engineering cost estimates are normally done when the IC provides an exact site plan location for the generation substation during the Facility Study phase. These costs do not include CIAC Tax Gross-up.

Non-Direct Connection Cost Estimate

Transmission: Re-arrange existing lines to accommodate new 115 kV Line. Estimated Cost $1,500,000.

The estimated total cost of the Direct Connection Facilities is $1,500,000. It is estimated to take 14-20 months to complete this work. These preliminary cost estimates are based on typical engineering costs. A more detailed engineering cost estimates are normally done when the IC provides an exact site plan location for the generation substation during the Facility Study phase.

Remote Terminal Work: During the Facilities Study, ITO's System Protection Engineering Department will review transmission line protection as well as anti-islanding required to accommodate the new generation and interconnection substation. System Protection Engineering will determine the minimal acceptable protection requirements to reliably interconnect the proposed generating facility with the transmission system. The review is based on maintaining system reliability by reviewing ITO's protection requirements with the known transmission system configuration which includes generating facilities in the area. This review may determine that transmission line protection and communication upgrades are required at remote substations.

New System Reinforcements

Reinforcement: Ladysmith – Chancellor 500kV line #581: Wreck and rebuild the existing line since overload exceeds conductor rating of 2913 MVA by 3.1% new line rating 4300 MVA. A Virginia CPCN is required. It is estimated to cost $50,000,000 and it is estimate to take 36-48 months to engineer, permit and construct.

Interconnection Customer Requirements

ITO's Facility Connection Requirements as posted on PJM's website
http://www.pjm.com/~/media/planning/plan-standards/private-dominion/facility-connection-requirements1.ashx

Voltage Ride Through Requirements - The Customer Facility shall be designed to remain in service (not trip) for voltages and times as specified for the Eastern Interconnection in Attachment 1 of NERC Reliability Standard PRC-024-1, and successor Reliability Standards, for both high and low voltage conditions, irrespective of generator size, subject to the permissive trip exceptions established in PRC-024-1 (and successor Reliability Standards).

Frequency Ride Through Requirements - The Customer Facility shall be designed to remain in service (not trip) for frequencies and times as specified in Attachment 2 of NERC Reliability Standard PRC-024-1, and successor Reliability Standards, for both high and low frequency condition, irrespective of generator size, subject to the permissive trip exceptions established in PRC-024-1 (and successor Reliability Standards).

Reactive Power - The Generation Interconnection Customer shall design its non-synchronous Customer Facility with the ability to maintain a power factor of at least 0.95 leading to 0.95 lagging measured at the generator's terminals.

Revenue Metering and SCADA Requirements

PJM Requirements

The IC will be required to install equipment necessary to provide Revenue Metering (KWH, KVARH) and real time data (KW, KVAR) for IC's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Sections 24.1 and 24.2.

Option One

Network Impacts

The Queue Project AC1-191 was evaluated as a 80.0 MW (Capacity 53.4 MW) injection at the Elmont 115kV substation in the ITO area. Project AC1-191 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC1-191 was studied with a commercial probability of 53%. Potential network impacts were as follows:

Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
57302	CONTINGENCY '57302' /*NORTH ANNA OPEN BRANCH FROM BUS 314934 TO BUS 314918 CKT 1 /*NORTH ANNA TO SPOTSYLVANIA (LINE 573) OPEN BRANCH FROM BUS 314918 TO BUS 314232 CKT 1 /*NORTH ANNA 500-230 (TX#5) END
LN 568	CONTINGENCY 'LN 568' OPEN BRANCH FROM BUS 314911 TO BUS 314922 CKT 1 /* 8LDYSMTH 500.00 - 8POSSUM 500.00 END
LN 574	CONTINGENCY 'LN 574' OPEN BRANCH FROM BUS 314908 TO BUS 314911 CKT 1 /* 8ELMONT 500.00 - 8LDYSMTH 500.00 END
LN 576	CONTINGENCY 'LN 576' OPEN BRANCH FROM BUS 314322 TO BUS 314914 CKT 1 /* 6MDLTHAN 230.00 - 8MDLTHAN 500.00 OPEN BRANCH FROM BUS 314914 TO BUS 314918 CKT 1 /* 8MDLTHAN 500.00 - 8NO ANNA 500.00 END
XT573	CONTINGENCY 'XT573' /*NORTH ANNA OPEN BRANCH FROM BUS 314934 TO BUS 314918 CKT 1 /*NORTH ANNA TO SPOTSYLVANIA (LINE 573) OPEN BRANCH FROM BUS 314918 TO BUS 314232 CKT 2 /*NORTH ANNA 500-230 (TX#6) END

Summer Peak Analysis - 2020

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion only of the interconnection)

#	Contingency Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution
1	N-1	LN 568	DVP - DVP	8LDYSMTH-8CHANCE 500 kV line	314911	314905	1	DC	99.7	100.08	ER	2738	10.66

Multiple Facility Contingency

(Double Circuit Tower Line, Fault with a Stuck Breaker, and Bus Fault contingencies for the full energy output)

#	Contingency Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Cir.	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Ref
2	LFFB	57302	DVP - DVP	8LDYSMTH-8CHANCE 500 kV line	314911	314905	1	DC	99.7	100.19		3351	16.55	1
3	LFFB	XT573	DVP - DVP	8LDYSMTH-8CHANCE 500 kV line	314911	314905	1	DC	99.7	100.19		3351	16.55	

Short Circuit

(Summary of impacted circuit breakers)

New circuit breakers found to be over-duty:

None

Contributions to previously identified circuit breakers found to be over-duty:

None

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

None

Steady-State Voltage Requirements

(Summary of the VAR requirements based upon the results of the steady-state voltage studies)

To be determined during Impact Study

Stability and Reactive Power Requirement for Low Voltage Ride Through

(Summary of the VAR requirements based upon the results of the dynamic studies)

To be determined during Impact Study

New System Reinforcements

(Upgrades required to mitigate reliability criteria violations, i.e. Network Impacts, initially caused by the addition of this project generation)

Violation #	Overloaded Facility	Upgrade Description	Network Upgrade Number	Upgrade Cost
# 1 - 3	8LDYSMTH-8CHANCE 500 kV line	Wreck and rebuild the existing line since overload exceeds conductor rating of 2913 MVA by 3.1% new line rating 4300 MVA. VA CPCN is required. Estimated time 36 – 48 months.	Pending	$50,000,000
			Total New Network Upgrades	**$50,000,000**

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the Impact Study)

None

Potential Congestion due to Local Energy Deliverability

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The IC can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which shall study all overload conditions associated with the overloaded element(s) identified.

	Contingency		Affected		Bus			Power	Loading %		Rating		MW
#	Type	Name	Area	Facility Description	From	To	Circuit	Flow	Initial	Final	Type	MVA	Contribution
5	N-1	LN 574	DVP - DVP	6FRRIVER-6STJOHN 230 kV line	314212	314150	1	DC	104.8	106.47	ER	749	12.48
6	N-1	LN 576	DVP - DVP	8ELMONT-8LDYSMTH 500 kV line	314908	314911	1	DC	168.9	170.01	ER	2442	27.44

Light Load Analysis

Light Load Studies to be conducted during later study phases (as required by PJM Manual 14B).

ITO Analysis

ITO assessed the impact of the proposed Queue Project #AC1-191 interconnection of a 80 MW Energy (53.4 MW Capacity) injection into the ITO's Transmission System at Elmont Substation at 115 kV, for compliance with NERC Reliability Criteria on ITO's Transmission System. The system was assessed using the summer 2020 RTEP case provided to ITO by PJM. When performing a generation analysis, ITO's main analysis will be load flow study results under single contingency (both normal and stressed system conditions). ITO Criteria considers a transmission facility overloaded if it exceeds 94% of its emergency rating under normal and stressed system conditions. A full listing of ITO's Planning Criteria and interconnection requirements can be found in the ITO's Facility Connection Requirements which are publicly available at: http://www.dom.com.

The results of these studies evaluate the system under a limited set of operating conditions and do not guarantee the full delivery of the capacity and associated energy of this proposed generation facility under all operating conditions. NERC Planning and Operating Reliability Criteria allow for the re-dispatch of generating units to resolve projected and actual deficiencies in real time and planning studies. Specifically NERC Category C

Contingency Conditions (Bus Fault, Tower Line, N-1-1, and Stuck Breaker scenarios) allow for re-dispatch of generating units to resolve potential reliability deficiencies. For ITO's Planning Criteria the re-dispatch of generating units for these contingency conditions is allowed as long as the projected loading does not exceed 100% of a facility Load Dump Rating.

As part of its generation impact analysis, the ITO routinely evaluates the impact that a proposed new generation resource will have under maximum generation conditions, stress system conditions and import/export system conditions (greater than 20 MW). The results of these studies are discussed in more detail below.

Category B Analysis (Single Contingency):

1. System Normal – Same as PJM identified deficiencies
2. Critical System Condition (No Surry 230 kV Unit) – Same as PJM identified deficiencies.

Category C Analysis: (Multiple Facility Analysis)

1. Bus Fault - No deficiencies identified
2. Line Stuck Breaker - No deficiencies identified
3. Tower Line – No deficiencies identified

The import and export conditions into and out of the ITO System are evaluated with any new interconnection greater than 20 MW, any new facility that is interconnected with the ITO System should not significantly decrement FCITC between utilities. These studies will be performed during the System Impact Study.

Affected System Analysis & Mitigation

Duke, Progress & TVA Impacts:

Duke Carolina, Progress, & TVA Impacts to be determined during later study phases (as applicable).

Option Two

Network Impacts

The Queue Project AC1-191 was evaluated as a 80.0 MW (Capacity 53.4 MW) injection tapping the Elmont-Greenwood 115kV line in the ITO area. Project AC1-191 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AC1-191 was studied with a commercial probability of 53%. Potential network impacts were as follows:

Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
H2T557	CONTINGENCY 'H2T557' /* ELMONT OPEN BRANCH FROM BUS 314908 TO BUS 314903 CKT 1 /*ELMONT TO CHICKAHOMINY (LINE 557) OPEN BRANCH FROM BUS 314903 TO BUS 314214 CKT 1 /*CHICKAHOMINY 500-230 (TX#1) OPEN BRANCH FROM BUS 314908 TO BUS 314218 CKT 2 /*ELMONT 500-230 (TX#2) END
LN 574	CONTINGENCY 'LN 574' OPEN BRANCH FROM BUS 314908 TO BUS 314911 CKT 1 /* 8ELMONT 500.00 - 8LDYSMTH 500.00 END
LN 576	CONTINGENCY 'LN 576' OPEN BRANCH FROM BUS 314322 TO BUS 314914 CKT 1 /* 6MDLTHAN 230.00 - 8MDLTHAN 500.00 OPEN BRANCH FROM BUS 314914 TO BUS 314918 CKT 1 /* 8MDLTHAN 500.00 - 8NO ANNA 500.00 END

Summer Peak Analysis - 2020

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion only of the interconnection)

None

Multiple Facility Contingency

(Double Circuit Tower Line, Fault with a Stuck Breaker, and Bus Fault contingencies for the full energy output)

None

Short Circuit

(Summary of impacted circuit breakers)

New circuit breakers found to be over-duty:

None

Contributions to previously identified circuit breakers found to be over-duty:

None

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

	Contingency		Affected		Bus			Power	Loading %		Rating		MW	
#	Type	Name	Area	Facility Description	From	To	Cir.	Flow	Initial	Final	Type	MVA	Contribution	Ref
1	LFFB	H2T557	DVP - DVP	8ELMONT 500/230 kV transformer	314218	314908	1	DC	101.75	104.26	LD	1051	26.4	2

Steady-State Voltage Requirements

(Summary of the VAR requirements based upon the results of the steady-state voltage studies)

To be determined during Impact Study

Stability and Reactive Power Requirement for Low Voltage Ride Through

(Summary of the VAR requirements based upon the results of the dynamic studies)

To be determined during Impact Study

Potential Congestion due to Local Energy Deliverability

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The IC can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which shall study all overload conditions associated with the overloaded element(s) identified.

	Contingency		Affected		Bus			Power	Loading %		Rating		MW
#	Type	Name	Area	Facility Description	From	To	Circuit	Flow	Initial	Final	Type	MVA	Contribution
2	N-1	LN 574	DVP - DVP	6FRRIVER-6STJOHN 230 kV line	314212	314150	1	DC	105.15	106.5	ER	749	10.11
3	N-1	LN 576	DVP - DVP	8ELMONT-8LDYSMTH 500 kV line	314908	314911	1	DC	162.8	163.26	ER	2442	24.66

Light Load Analysis

Light Load Studies to be conducted during later study phases (as required by PJM Manual 14B).

ITO Analysis

ITO assessed the impact of the proposed Queue Project #AC1-191 interconnection of a 80.0 MW Energy (53.4 MW Capacity) injection into the ITO's Transmission System at a new 115 kV Switching Station between the Elmont-Greenwood 115 kV section of Line #59, for compliance with NERC Reliability Criteria on ITO's Transmission System. The system was assessed using the summer 2020 RTEP case provided to ITO by PJM. When performing a generation analysis, ITO's main analysis will be load flow study results under single contingency (both normal and stressed system conditions). ITO Criteria considers a transmission facility overloaded if it exceeds 94% of its emergency rating under normal and stressed system conditions. A full listing of ITO's Planning Criteria and interconnection requirements can be found in the ITO's Facility Connection Requirements which are publicly available at: http://www.dom.com.

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As part of its generation impact analysis, the ITO routinely evaluates the impact that a proposed new generation resource will have under maximum generation conditions, stress system conditions and import/export system conditions (greater than 20 MW). The results of these studies are discussed in more detail below.

Category B Analysis (Single Contingency):

1. System Normal – No deficiencies identified
2. Critical System Condition (No Surry 230 kV Unit) – No deficiencies identified.

Category C Analysis: (Multiple Facility Analysis)

1. Bus Fault - No deficiencies identified
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3. Tower Line – No deficiencies identified

The import and export conditions into and out of the ITO System are evaluated with any new interconnection greater than 20 MW, any new facility that is interconnected with the ITO System should not significantly decrement FCITC between utilities. These studies will be performed during the System Impact Study.

Affected System Analysis & Mitigation

Duke, Progress & TVA Impacts:

Duke Carolina, Progress, & TVA Impacts to be determined during later study phases (as applicable).

Appendices

The following appendices contain additional information about each flowgate presented in the body of the report. For each appendix, a description of the flowgate and its contingency was included for convenience. However, the intent of the appendix section is to provide more information on which projects/generators have contributions to the flowgate in question. Although this information is not used "as is" for cost allocation purposes, it can be used to gage other generators impact. When a flowgate is identified in multiple analysis the appendix is presented for only the analysis with the greatest overload.

It should be noted the generator contributions presented in the appendices sections are full contributions, whereas in the body of the report, those contributions take into consideration the commercial probability of each project.

Appendix 1

(DVP - DVP) The 8LDYSMTH-8CHANCE 500 kV line (from bus 314911 to bus 314905 ckt 1) loads from 99.7% to 100.19% (**DC power flow**) of its load dump rating (3351 MVA) for the line fault with failed breaker contingency outage of '57302'. This project contributes approximately 16.55 MW to the thermal violation.

CONTINGENCY '57302' /*NORTH ANNA
OPEN BRANCH FROM BUS 314934 TO BUS 314918 CKT 1 /*NORTH ANNA TO SPOTSYLVANIA (LINE 573)
OPEN BRANCH FROM BUS 314918 TO BUS 314232 CKT 1 /*NORTH ANNA 500-230 (TX#5)
END

Bus Number	*Bus Name*	*Full Contribution*
315043	*1FRIVERA*	*4.42*
315044	*1FRIVERB*	*3.42*
315045	*1FRIVERC*	*4.42*
315046	*1FRIVERD*	*3.42*
315047	*1FRIVERE*	*3.42*
315048	*1FRIVERF*	*4.42*
315225	*1N ANNA1*	*49.76*
315226	*1N ANNA2*	*48.99*
315073	*1STONECA*	*7.57*
314784	*1WEYRHSB*	*2.09*
315091	*1YORKTN2*	*32.22*
314539	*3UNCAMP*	*2.5*
314541	*3WATKINS*	*0.7*
314229	*6MT R221*	*0.82*
314189	*6PAPERMILL*	*7.22*
292791	*U1-032 E*	*3.94*
292883	*U1-093 E*	*4.01*
292885	*U1-094 E*	*4.01*
292887	*U1-095 E*	*4.01*
297087	*V2-040*	*0.16*
900672	*V4-068 E*	*0.3*
901082	*W1-029E*	*48.36*
907092	*X1-038 E*	*6.25*
913392	*Y1-086 E*	*2.31*
916042	*Z1-036 E*	*47.36*
916192	*Z1-068 E*	*2.01*
916302	*Z1-086 E*	*9.15*
917122	*Z2-027 E*	*1.12*
917332	*Z2-043 E*	*0.97*

LTF	*Z2-067*	*16.97*
917592	*Z2-099 E*	*0.44*
921092	*AA1-049 C*	*2.57*
921093	*AA1-049 E*	*1.21*
LTF	*AA1-058*	*0.76*
921162	*AA1-063AC*	*8.39*
921163	*AA1-063AE*	*3.96*
921172	*AA1-064 C*	*8.36*
921173	*AA1-064 E*	*3.93*
918512	*AA1-065 E OP*	*4.43*
921182	*AA1-067 C*	*1.6*
921183	*AA1-067 E*	*0.69*
918562	*AA1-072 E*	*0.16*
921292	*AA1-083*	*4.11*
921532	*AA1-132 C*	*7.95*
921533	*AA1-132 E*	*3.41*
921542	*AA1-133 C*	*10.63*
921543	*AA1-133 E*	*4.55*
921552	*AA1-134 C*	*10.38*
921553	*AA1-134 E*	*4.45*
921562	*AA1-135 C*	*8.97*
921563	*AA1-135 E*	*3.85*
921572	*AA1-138 C*	*10.18*
921573	*AA1-138 E*	*4.36*
921582	*AA1-139 C*	*15.94*
921583	*AA1-139 E*	*6.83*
921622	*AA1-145*	*69.79*
921752	*AA2-053 C*	*8.49*
921753	*AA2-053 E*	*3.65*
921772	*AA2-059 C*	*2.46*
921773	*AA2-059 E*	*1.13*
921862	*AA2-068 C*	*2.11*
921863	*AA2-068 E*	*0.97*
LTF	*AA2-074*	*5.05*
920022	*AA2-086 E*	*0.24*
921982	*AA2-088 C*	*6.52*
921983	*AA2-088 E*	*10.63*
922512	*AA2-174 C*	*0.39*
922513	*AA2-174 E*	*0.42*
922522	*AA2-177 C*	*10.95*
922523	*AA2-177 E*	*4.69*
922532	*AA2-178 C*	*9.83*
922533	*AA2-178 E*	*4.21*
922602	*AB1-013 C*	*2.97*
922603	*AB1-013 E*	*19.84*

922672	*AB1-026 C*	*2.17*
922673	*AB1-026 E*	*0.93*
922682	*AB1-027 C*	*2.85*
922683	*AB1-027 E*	*1.22*
922722	*AB1-053 C*	*1.03*
922723	*AB1-053 E*	*0.58*
922732	*AB1-054 C*	*6.88*
922733	*AB1-054 E*	*3.39*
923262	*AB1-132 C OP*	*13.72*
923263	*AB1-132 E OP*	*5.88*
923272	*AB1-135 C OP*	*2.81*
923273	*AB1-135 E OP*	*1.21*
923572	*AB1-173 C OP*	*2.21*
923573	*AB1-173 E OP*	*1.03*
923582	*AB1-173AC OP*	*2.21*
923583	*AB1-173AE OP*	*1.03*
923801	*AB2-015 C OP*	*8.85*
923802	*AB2-015 E OP*	*7.26*
923831	*AB2-022 C*	*2.43*
923832	*AB2-022 E*	*1.31*
923841	*AB2-024 C*	*2.7*
923842	*AB2-024 E*	*1.21*
923851	*AB2-025 C*	*2.52*
923852	*AB2-025 E*	*1.13*
923861	*AB2-026 C*	*2.34*
923862	*AB2-026 E*	*1.05*
923911	*AB2-031 C OP*	*2.2*
923912	*AB2-031 E OP*	*1.08*
923981	*AB2-039 C OP*	*8.95*
923982	*AB2-039 E OP*	*7.24*
923991	*AB2-040 C OP*	*7.21*
923992	*AB2-040 E OP*	*5.9*
924061	*AB2-050*	*4.11*
924071	*AB2-051 C OP*	*146.91*
924072	*AB2-051 E OP*	*20.17*
924241	*AB2-068 OP*	*221.04*
924381	*AB2-087 C*	*0.56*
924382	*AB2-087 E*	*0.27*
924491	*AB2-098 C*	*0.53*
924492	*AB2-098 E*	*0.23*
924501	*AB2-099 C*	*0.58*
924502	*AB2-099 E*	*0.25*
924511	*AB2-100 C*	*11.28*
924512	*AB2-100 E*	*5.55*
924761	*AB2-128 C*	*9.66*

924762	*AB2-128 E*	*3.8*
924811	*AB2-134 C OP*	*14.04*
924812	*AB2-134 E OP*	*18.78*
924931	*AB2-147 C*	*2.52*
924932	*AB2-147 E*	*4.11*
924941	*AB2-149 C OP*	*3.6*
924942	*AB2-149 E OP*	*5.87*
924951	*AB2-150 C OP*	*2.52*
924952	*AB2-150 E OP*	*4.11*
924961	*AB2-152*	*2.96*
925051	*AB2-160 C OP*	*5.93*
925052	*AB2-160 E OP*	*9.68*
925061	*AB2-161 C OP*	*3.62*
925062	*AB2-161 E OP*	*5.9*
925121	*AB2-169 C OP*	*6.39*
925122	*AB2-169 E OP*	*5.74*
925141	*AB2-171 C OP*	*4.99*
925142	*AB2-171 E OP*	*8.14*
925171	*AB2-174 C OP*	*6.92*
925172	*AB2-174 E OP*	*6.26*
925281	*AB2-186 C*	*0.64*
925282	*AB2-186 E*	*0.27*
925291	*AB2-188 C OP*	*2.42*
925292	*AB2-188 E OP*	*1.09*
925331	*AB2-190 C*	*25.03*
925332	*AB2-190 E*	*6.26*
925361	*AC1-007 C OP*	*0.73*
925362	*AC1-007 E OP*	*1.2*
925521	*AC1-027 C*	*2.14*
925522	*AC1-027 E*	*1.23*
925691	*AC1-045 C*	*1.85*
925692	*AC1-045 E*	*1.01*
925701	*AC1-046 C*	*1.85*
925702	*AC1-046 E*	*1.01*
925711	*AC1-047 C*	*2.46*
925712	*AC1-047 E*	*1.35*
925811	*AC1-060*	*2.72*
925821	*AC1-061*	*0.04*
925841	*AC1-063*	*0.42*
925861	*AC1-065 C*	*3.66*
925862	*AC1-065 E*	*5.97*
926071	*AC1-086 C*	*20.21*
926072	*AC1-086 E*	*9.2*
926201	*AC1-098 C*	*5.88*
926202	*AC1-098 E*	*3.5*

926211	*AC1-099 C*	*1.97*
926212	*AC1-099 E*	*1.16*
926291	*AC1-107 OP*	*333.65*
926411	*AC1-112 C*	*2.22*
926412	*AC1-112 E*	*1.24*
926441	*AC1-115 C*	*1.15*
926442	*AC1-115 E*	*1.86*
926471	*AC1-118 C*	*2.05*
926472	*AC1-118 E*	*1.06*
926551	*AC1-134*	*10.26*
926591	*AC1-142 C*	*10.17*
926592	*AC1-142 E*	*7.67*
926661	*AC1-147 C*	*2.42*
926662	*AC1-147 E*	*1.42*
926741	*AC1-159 C*	*145.77*
926751	*AC1-161 C OP*	*32.66*
926752	*AC1-161 E OP*	*13.94*
926771	*AC1-163 C*	*2.1*
926772	*AC1-163 E*	*0.99*
926781	*AC1-164 C OP*	*46.04*
926782	*AC1-164 E OP*	*20.69*
927041	*AC1-191 C*	*11.05*
927042	*AC1-191 E*	*5.5*
927051	*AC1-193 C*	*3.66*
927052	*AC1-193 E*	*5.97*
927111	*AC1-206 C OP*	*11.77*
927112	*AC1-206 E OP*	*5.56*
927141	*AC1-208 C*	*8.46*
927142	*AC1-208 E*	*3.76*
927221	*AC1-216 C OP*	*10.72*
927222	*AC1-216 E OP*	*8.43*

Appendix 2

(DVP - DVP) The 8ELMONT 500/230 kV transformer (from bus 314218 to bus 314908 ckt 1) loads from 101.75% to 104.26% (**DC power flow**) of its load dump rating (1051 MVA) for the line fault with failed breaker contingency outage of 'H2T557'. This project contributes approximately 26.4 MW to the thermal violation.

CONTINGENCY 'H2T557' /* ELMONT
OPEN BRANCH FROM BUS 314908 TO BUS 314903 CKT 1 /*ELMONT TO CHICKAHOMINY (LINE 557)
OPEN BRANCH FROM BUS 314903 TO BUS 314214 CKT 1 /*CHICKAHOMINY 500-230 (TX#1)
OPEN BRANCH FROM BUS 314908 TO BUS 314218 CKT 2 /*ELMONT 500-230 (TX#2)
END

Bus Number	*Bus Name*	*Full Contribution*
315067	*1DARBY 1*	*4.87*
315068	*1DARBY 2*	*4.87*
315069	*1DARBY 3*	*4.93*
315070	*1DARBY 4*	*4.93*
315043	*1FRIVERA*	*6.55*
315044	*1FRIVERB*	*5.07*
315045	*1FRIVERC*	*6.55*
315046	*1FRIVERD*	*5.07*
315047	*1FRIVERE*	*5.07*
315048	*1FRIVERF*	*6.55*
315073	*1STONECA*	*9.14*
314784	*1WEYRHSB*	*1.71*
315091	*1YORKTN2*	*31.74*
314539	*3UNCAMP*	*2.15*
314541	*3WATKINS*	*0.6*
314229	*6MT R221*	*1.42*
314236	*6NRTHEST*	*0.36*
314189	*6PAPERMILL*	*8.79*
314251	*6S PUMP*	*1.65*
315074	*CIR_AB2-152*	*11.02*
315075	*CIR_AB2-152*	*10.88*
292791	*U1-032 E*	*4.76*
297087	*V2-040*	*0.27*
900672	*V4-068 E*	*0.25*
901082	*W1-029E*	*41.21*
907092	*X1-038 E*	*5.37*
913392	*Y1-086 E*	*1.96*

916042	*Z1-036 E*	*40.01*
916192	*Z1-068 E*	*1.73*
917122	*Z2-027 E*	*0.95*
917592	*Z2-099 E*	*0.37*
921092	*AA1-049 C*	*2.19*
921093	*AA1-049 E*	*1.03*
921162	*AA1-063AC*	*6.94*
921163	*AA1-063AE*	*3.27*
918512	*AA1-065 E OP*	*3.65*
921292	*AA1-083*	*6.*
921532	*AA1-132 C*	*6.77*
921533	*AA1-132 E*	*2.9*
921542	*AA1-133 C*	*9.06*
921543	*AA1-133 E*	*3.88*
921552	*AA1-134 C*	*8.84*
921553	*AA1-134 E*	*3.79*
921572	*AA1-138 C*	*8.66*
921573	*AA1-138 E*	*3.71*
921582	*AA1-139 C*	*13.6*
921583	*AA1-139 E*	*5.83*
921622	*AA1-145*	*102.06*
921772	*AA2-059 C*	*2.07*
921773	*AA2-059 E*	*0.95*
920022	*AA2-086 E*	*0.2*
921982	*AA2-088 C*	*5.49*
921983	*AA2-088 E*	*8.96*
922522	*AA2-177 C*	*12.12*
922523	*AA2-177 E*	*5.19*
922532	*AA2-178 C*	*8.21*
922533	*AA2-178 E*	*3.52*
922602	*AB1-013 C*	*2.48*
922603	*AB1-013 E*	*16.58*
922672	*AB1-026 C*	*2.22*
922673	*AB1-026 E*	*0.95*
922682	*AB1-027 C*	*4.44*
922683	*AB1-027 E*	*1.9*
922722	*AB1-053 C*	*0.85*
922723	*AB1-053 E*	*0.48*
922732	*AB1-054 C*	*5.79*
922733	*AB1-054 E*	*2.85*
923262	*AB1-132 C OP*	*11.47*
923263	*AB1-132 E OP*	*4.92*
923272	*AB1-135 C OP*	*3.7*
923273	*AB1-135 E OP*	*1.58*
923572	*AB1-173 C OP*	*1.85*

923573	*AB1-173 E OP*	*0.86*
923582	*AB1-173AC OP*	*1.85*
923583	*AB1-173AE OP*	*0.86*
923801	*AB2-015 C OP*	*7.57*
923802	*AB2-015 E OP*	*6.21*
923831	*AB2-022 C*	*2.07*
923832	*AB2-022 E*	*1.11*
923841	*AB2-024 C*	*3.3*
923842	*AB2-024 E*	*1.48*
923851	*AB2-025 C*	*2.36*
923852	*AB2-025 E*	*1.06*
923861	*AB2-026 C*	*1.94*
923862	*AB2-026 E*	*0.87*
923911	*AB2-031 C OP*	*1.84*
923912	*AB2-031 E OP*	*0.9*
923981	*AB2-039 C OP*	*8.77*
923982	*AB2-039 E OP*	*7.09*
923991	*AB2-040 C OP*	*6.03*
923992	*AB2-040 E OP*	*4.93*
924061	*AB2-050*	*6.*
924071	*AB2-051 C OP*	*126.81*
924072	*AB2-051 E OP*	*17.41*
924241	*AB2-068 OP*	*175.54*
924381	*AB2-087 C*	*0.47*
924382	*AB2-087 E*	*0.22*
924501	*AB2-099 C*	*0.48*
924502	*AB2-099 E*	*0.21*
924511	*AB2-100 C*	*9.74*
924512	*AB2-100 E*	*4.8*
924761	*AB2-128 C*	*8.34*
924762	*AB2-128 E*	*3.28*
924811	*AB2-134 C OP*	*15.54*
924812	*AB2-134 E OP*	*20.78*
924931	*AB2-147 C*	*2.13*
924932	*AB2-147 E*	*3.48*
924941	*AB2-149 C OP*	*3.35*
924942	*AB2-149 E OP*	*5.46*
924951	*AB2-150 C OP*	*2.13*
924952	*AB2-150 E OP*	*3.48*
924961	*AB2-152*	*3.57*
925051	*AB2-160 C OP*	*7.*
925052	*AB2-160 E OP*	*11.42*
925061	*AB2-161 C OP*	*3.55*
925062	*AB2-161 E OP*	*5.78*
925141	*AB2-171 C OP*	*4.24*

925142	*AB2-171 E OP*	*6.92*
925171	*AB2-174 C OP*	*5.82*
925172	*AB2-174 E OP*	*5.26*
925281	*AB2-186 C*	*0.53*
925282	*AB2-186 E*	*0.23*
925291	*AB2-188 C OP*	*2.02*
925292	*AB2-188 E OP*	*0.91*
925331	*AB2-190 C*	*27.7*
925332	*AB2-190 E*	*6.93*
925361	*AC1-007 C OP*	*0.68*
925362	*AC1-007 E OP*	*1.11*
925521	*AC1-027 C*	*1.84*
925522	*AC1-027 E*	*1.05*
925691	*AC1-045 C*	*1.65*
925692	*AC1-045 E*	*0.9*
925701	*AC1-046 C*	*1.58*
925702	*AC1-046 E*	*0.86*
925711	*AC1-047 C*	*2.1*
925712	*AC1-047 E*	*1.16*
925811	*AC1-060*	*3.44*
925821	*AC1-061*	*0.05*
925841	*AC1-063*	*0.5*
925861	*AC1-065 C*	*4.34*
925862	*AC1-065 E*	*7.08*
926071	*AC1-086 C*	*16.89*
926072	*AC1-086 E*	*7.69*
926291	*AC1-107 OP*	*422.4*
926411	*AC1-112 C*	*3.46*
926412	*AC1-112 E*	*1.94*
926441	*AC1-115 C*	*1.03*
926442	*AC1-115 E*	*1.66*
926471	*AC1-118 C*	*2.09*
926472	*AC1-118 E*	*1.08*
926551	*AC1-134*	*15.01*
926591	*AC1-142 C*	*11.37*
926592	*AC1-142 E*	*8.58*
926661	*AC1-147 C*	*2.09*
926662	*AC1-147 E*	*1.23*
926741	*AC1-159 C*	*125.84*
926751	*AC1-161 C OP*	*31.85*
926752	*AC1-161 E OP*	*13.59*
926771	*AC1-163 C*	*1.74*
926772	*AC1-163 E*	*0.81*
926781	*AC1-164 C OP*	*58.29*
926782	*AC1-164 E OP*	*26.19*

927041	*AC1-191 C*	*17.62*
927042	*AC1-191 E*	*8.78*
927051	*AC1-193 C*	*3.11*
927052	*AC1-193 E*	*5.08*
927111	*AC1-206 C OP*	*9.6*
927112	*AC1-206 E OP*	*4.54*
927221	*AC1-216 C OP*	*9.08*
927222	*AC1-216 E OP*	*7.14*