Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AB2-179

“Townsend 138 kV”

May 2017

Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, 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 System Impact Study is performed.

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

General

Community Energy Solar Development LLC, the Interconnection Customer (IC), has proposed a 50 MW (37.6 MW Capacity) solar generating facility to be located in New Castle County, Delaware. PJM studied the AB2-179 project as an injection into the Delmarva Power and Light (DPL) system at the Townsend 138 kV Substation and evaluated it for compliance with reliability criteria for summer peak conditions in 2020. The planned in-service date, as requested by the IC during the project kick-off call, is October 31, 2017. This date is not attainable due to additional required studies and construction schedules.

Point of Interconnection

The AB2-179 project will connect with the DPL transmission system at the Townsend Substation (see Attachment 1).

Transmission Owner Scope of Attachment Facilities Work

Substation Interconnection Estimate

Scope: Build a new 7th position onto the 138 kV 6 position ring bus at Townsend Substation (the future arrangement of Townsend substation will have 6 positions after future construction projects). The new position will be connected to a generator. The

project will require the addition of a 138 kV breaker, 3 138 kV disconnect switches, 3 CT/VT combination units, and substation bus.

Estimate: $953,000
Construction Time: 24 months

Major Equipment Included in Estimate:

- Power Circuit Breaker, 138 kV, 2000A, 40kA, 3 cycle Qty. 1
- Disconnect Switch, 138 kV, 2000A, Manual Wormgear, Arcing Horns Qty. 3
- CT/VT Combination Units, 138 kV Qty. 3
- Disconnect Switch Stand, High, 138 kV, Steel Qty. 1
- Disconnect Switch Stand, Low, 138 kV, Steel Qty. 2
- CT/VT Stand, Single Phase, Low, 138 kV, Steel Qty. 3
- Relay Panel, Transmission Line, FL/BU (20") Qty. 1
- Control Panel, 138 kV Circuit Breaker (10") Qty. 1
- Bus Support Structure, 3 phase, 138 kV, Steel Qty. 3

Estimate Assumptions:

- Expansion of existing substation to be performed during previous projects.
- Control house is adequate for expansion.

Required Relaying and Communications

New protection relays are required for the new terminal. An SEL-487 will be required for primary protection and an SEL-387 will be required for back-up protection. One 20" relay panel for each line terminal will be required for front line and back-up protection.

An SEL-451 relay on a 20" breaker control panel will be required for the control and operation of each new 138 kV circuit breaker.

The project will require re-wiring and adjustment of existing relay schemes to accommodate the new 138 kV terminal.

The cost of the required relay and communications is included in the Substation Interconnection Estimate.

Metering

Three phase 138 kV revenue metering points will need to be established. DPL will purchase and install all metering instrument transformers as well as construct a metering structure. The secondary wiring connections at the instrument transformers will be completed by DPL's metering technicians. The metering control cable and meter cabinets will be supplied and installed by DPL. DPL will install conduit for the control cable between the instrument transformers and the metering enclosure. The location of the metering enclosure will be determined in the construction phase. DPL will provide both the Primary and the Backup meters. DPL's meter technicians will program and install the Primary & Backup solid state multi-function meters for each new metering position.

Each meter will be equipped with load profile, telemetry, and DNP outputs. The IC will be provided with one meter DNP output for each meter. DPL will own the metering equipment for the interconnection point, unless the IC asserts its right to install, own, and operate the metering system.

The Interconnection Customer will be required to make provisions for a voice quality phone line within approximately 3 feet of each Company metering position to facilitate remote interrogation and data collection.

It is the IC's responsibility to send the data that PJM and DPL requires directly to PJM. The IC will grant permission for PJM to send DPL the following telemetry that the IC sends to PJM: real time MW, MVAR, volts, amperes, generator status, and interval MWH and MVARH. The estimate for DPL to design, purchase, and install metering as specified in the aforementioned scope for metering is included in the Substation Interconnection Estimate.

Interconnection Customer Scope of Direct Connection Work

The Interconnection Customer is responsible for all design and construction related to activities on their side of the Point of Interconnection. Site preparation, including grading and an access road, as necessary, is assumed to be by the IC. Route selection, line design, and right-of-way acquisition of the direct connect facilities is not included in this report, and is the responsibility of the IC. The IC is also required to provide revenue metering and real-time telemetering data to PJM in conformance with the requirements contained in PJM Manuals M-01 and M-14 and the PJM Tariff.

DPL Interconnection Customer Scope of Direct Connection Work Requirements

- DPL requires that an IC circuit breaker is located within 500 feet of Townsend substation to facilitate the relay protection scheme between DPL and the IC at the Point of Interconnection (POI).

Special Operating Requirements

1. DPL will require the capability to remotely disconnect the generator from the grid by communication from its System Operations facility. Such disconnection may be facilitated by a generator breaker, or other method depending upon the specific circumstances and the evaluation by DPL.

2. DPL reserves the right to charge the Interconnection Customer operation and maintenance expenses to maintain the Interconnection Customer attachment facilities, including metering and telecommunications facilities, owned by DPL.

Summer Peak Analysis - 2020

Transmission Network Impacts

Potential transmission network impacts are as follows:

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

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)

1. (DP&L - DP&L) The MIDLTNTP-MT PLSNT 138 kV line (from bus 232106 to bus 232104 ckt 1) loads from 101.58% to 103.17% (AC power flow) of its emergency rating (348 MVA) for the tower line contingency outage of 'DBL_4NC'. This project contributes approximately 34.96 MW to the thermal violation.

   CONTINGENCY 'DBL_4NC'/* RED LION-CEDAR CREEK 230;RED LION-CARTANZA 230
   OPEN LINE FROM BUS 231004 TO BUS 232002 CKT 1
   OPEN LINE FROM BUS 231004 TO BUS 232003 CKT 1
   END

   Please refer to Appendix 1 for a table containing the generators having contribution to this flowgate.

2. (DP&L - DP&L) The TOWNSEND-MIDLTNTP 138 kV line (from bus 232107 to bus 232106 ckt 1) loads from 108.43% to 112.75% (AC power flow) of its emergency rating (348 MVA) for the tower line contingency outage of 'DBL_4NC'. This project contributes approximately 34.96 MW to the thermal violation.

   CONTINGENCY 'DBL_4NC'/* RED LION-CEDAR CREEK 230;RED LION-CARTANZA 230
   OPEN LINE FROM BUS 231004 TO BUS 232002 CKT 1
   OPEN LINE FROM BUS 231004 TO BUS 232003 CKT 1
   END

   Please refer to Appendix 2 for a table containing the generators having contribution to this flowgate.

Summer Peak Load Flow Analysis Reinforcements

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

None

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)

1. To mitigate the (DP&L) MIDLTNTP-MT PLSNT 138 kV line (from bus 232106 to bus 232104 ckt 1) overload will require reinforcements to increase the emergency rating of the Middletown Tap to Mount Pleasant 138 kV line. Those reinforcements include rebuilding a small section of the circuit and installing new poles and the re-mounting of 138 kV disconnect switches. The estimated cost to perform this work is **$800,000** and will take **18 months** to complete following a fully executed Interconnection Services Agreement (ISA) and Interconnection Construction Services Agreement (CSA). (PJM Network Upgrade Number n5300)

   Cost allocation is as follows:

Queue	MW contribution	Percentage of Cost	Cost($0.8M)	Contingency Name	Contingency Type
AB2-032	7.84	3.32%	$26,546	DBL_4NC'	tower
AB2-036	30.169	12.77%	$102,151	DBL_4NC'	tower
AB2-037	33.53	14.19%	$113,532	DBL_4NC'	tower
AB2-063	7.56	3.20%	$25,598	DBL_4NC'	tower
AB2-120	19.70	8.34%	$66,704	DBL_4NC'	tower
AB2-130	17.30	7.32%	$58,577	DBL_4NC'	tower
AB2-133	28.36	12.00%	$96,026	DBL_4NC'	tower
AB2-135	27.49	11.64%	$93,080	DBL_4NC'	tower
AB2-136	10.70	4.53%	$36,230	DBL_4NC'	tower
AB2-153	7.85	3.32%	$26,580	DBL_4NC'	tower
AB2-172	10.81	4.58%	$36,602	DBL_4NC'	tower
AB2-179	**34.96**	**14.80%**	**$118,374**	**DBL_4NC'**	**tower**

2. To mitigate the (DP&L) TOWNSEND-MIDLTNTP 138 kV line (from bus 232107 to bus 232106 ckt 1) overload will require reinforcements to increase the emergency rating of the Townsend to Middletown Tap 138 kV line. Those reinforcements include rebuilding a small section of the circuit and installing new poles and the re-mounting of 138 kV disconnect switches. The estimated cost to perform this work is **$800,000** and will take **18 months** to complete following a fully executed Interconnection Services Agreement (ISA) and Interconnection Construction Services Agreement (CSA). (PJM Network Upgrade Number n5301)

   Cost allocation is as follows:

Queue	MW contribution	Percentage of Cost	Cost($0.8M)	Contingency Name	Contingency Type
AB2-032	7.84	3.32%	$26,547.02	DBL_4NC'	tower
AB2-036	30.16	12.77%	$102,124.78	DBL_4NC'	tower
AB2-037	33.53	14.19%	$113,535.93	DBL_4NC'	tower
AB2-063	7.56	3.20%	$25,598.92	DBL_4NC'	tower
AB2-120	19.70	8.34%	$66,706.17	DBL_4NC'	tower
AB2-130	17.30	7.32%	$58,579.53	DBL_4NC'	tower
AB2-133	28.36	12.00%	$96,029.80	DBL_4NC'	tower
AB2-135	27.49	11.64%	$93,083.89	DBL_4NC'	tower
AB2-136	10.70	4.53%	$36,231.27	DBL_4NC'	tower
AB2-153	7.85	3.32%	$26,580.89	DBL_4NC'	tower
AB2-172	10.81	4.58%	$36,603.74	DBL_4NC'	tower
AB2-179	**34.96**	**14.80%**	**$118,378.06**	**DBL_4NC'**	**tower**

Steady-State Voltage Requirements

No issues identified.

Short Circuit

No issues identified.

Stability and Reactive Power Requirement

No issues identified. See Attachment 2 for full report.

Light Load Analysis - 2020

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

Delivery of Energy Portion of Interconnection Request

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 developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.

Only the most severely overloaded conditions are listed. 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 will study all overload conditions associated with the overloaded element(s) identified.

1. (DP&L - DP&L) The AB2-036 TAP-OIL_CITY 138 kV line (from bus 923950 to bus 232801 ckt 1) loads from 86.63% to 98.87% (AC power flow) of its emergency rating (159 MVA) for the single line contingency outage of 'CKT 13808'. This project contributes approximately 23.14 MW to the thermal violation.

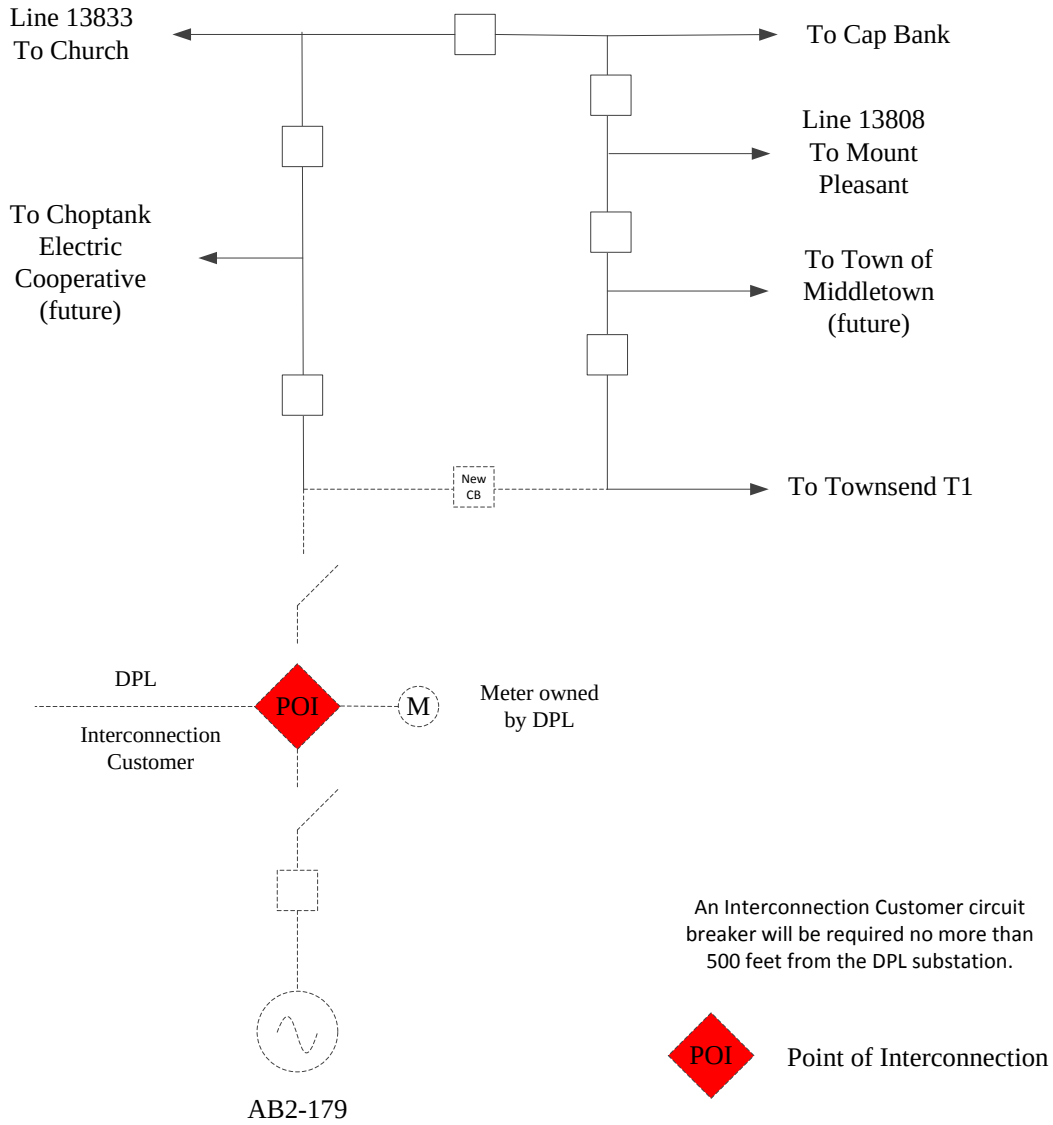
CONTINGENCY 'CKT 13808'
DISCONNECT BUS 232106/MOUNT PLEASANT - MIDDLETOWN - TOWNSEND 138
DISCONNECT BUS 232804/MIDDLETOWN 138
END

Delmarva Power and Light Costs

Cost estimates will further be refined as a part of the Facilities Study for this project. The Interconnection Customer will be responsible for all costs incurred by DPL in connection with the AB2-179 project. Such costs may include, but are not limited to, any transmission system assets currently in DPL's rate base that are prematurely retired due to the AB2-179 project. PJM shall work with DPL to identify these retirement costs and any additional expenses. DPL reserves the right to reassess issues presented in this document and, upon appropriate justification, submit additional costs related to the AB2-179 project.

Attachment 1

AB2-179
Townsend 138 kV
Townsend Substation



Attachment 2

AB2-179 System Impact Study

Dynamic Simulation Analysis

Prepared by	**Soma Soko** **PSC North America**
For	**PJM Interconnection, LLC**
Reference	**AB2-179-3-0**
Date	**March 20, 2017**

Proprietary & Confidential

Revision Table

Revision	Issue Date	Description
0	March 20, 2017	Initial Release

Reviewers

Name	Interest	Date
Kalyan Chilukuri	Peer Review	March 20, 2017

Approval

Name	Position	Date
Kalyan Chilukuri	Senior Power Systems Engineer	March 20, 2017

TABLE OF CONTENTS

Executive Summary **13**

1. Introduction **15**

2. Description of Project **16**

3. Loadflow and Dynamics Case Setup **19**

4. Fault Cases **20**

5. Evaluation Criteria **21**

6. Summary of Results **22**

7. Recommendations and Mitigations **23**

Executive Summary

Generator Interconnection Request AB2-179 is for a 50 MW Maximum Facility Output (MFO) solar powered generating facility with a Point of Interconnection (POI) at the Townsend 138kV Substation in the Delmarva Power and Light Company (DPL) system, New Castle County. This report describes a dynamic simulation analysis of AB2-179 as part of the overall system impact study.

The load flow scenarios for the analysis were based on the RTEP 2020 Peak Load case, modified to include applicable queue projects. AB2-179 was set to maximum power output.

AB2-179 was tested for compliance with NERC, PJM, Transmission Owner and other applicable criteria. 62 contingencies were studied, each with at least a 20 second simulation time period. Studied scenarios included:

a) Steady state operation (30 second simulation);

b) Three-phase faults with normal clearing time;

c) Single-phase faults with stuck breaker;

d) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from fault due to primary communications/relay failure.

No relevant Bus, Tower or High Speed Reclosing (HSR) contingencies were identified. For all simulations, the queue project under study along with the rest of the PJM system were required to maintain synchronism and with all states returning to an acceptable new condition following the disturbance.

For the all 62 fault contingencies tested on the 2020 peak load case:

a) AB2-179 is able to ride through the faults (except for faults where protective action trips a generator(s)),

b) The system with AB2-179 included is transiently stable and post-contingency oscillations are positively damped with a damping margin of at least 3%.

c) Following fault clearing, all bus voltages recover to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element trips, other than those either directly connected or designed to trip as a consequence of that fault.

No mitigations were found to be required.

1. Introduction

Generator Interconnection Request AB2-179 is for a 50 MW Maximum Facility Output (MFO) solar powered generating facility with a Point of Interconnection (POI) at the Townsend 138kV Substation in the Delmarva Power and Light Company (DPL) system, New Castle County, Delaware.

This analysis is effectively a screening study to determine whether the addition of AB2-179 will meet the dynamics requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AB2-179 project and how it is proposed to be connected to the grid are first described, followed by a description of how the project is modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided.

2. Description of Project

Generator Interconnection Request AB2-179 is for a 50 MW Maximum Facility Output (MFO) solar powered generating facility with a Point of Interconnection (POI) at the Townsend 138kV Substation in the Delmarva Power and Light Company (DPL) system, New Castle County, Delaware.
Figure 1 shows the simplified one-line diagram of the AB2-179 loadflow model. Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AB2-179 loadflow model.
Additional project details are provided in Attachments 1 through 4:

- Attachment 1 contains the Impact Study Data which details the proposed AB2-179 project.
- Attachment 2 shows the one line diagram of the DPL system in the vicinity of AB2-179.
- Attachment 3 provides a diagram of the PSS/E model in the vicinity of AB2-179.
- Attachment 4 gives the PSS/E loadflow and dynamic models of the AB2-179 plant.

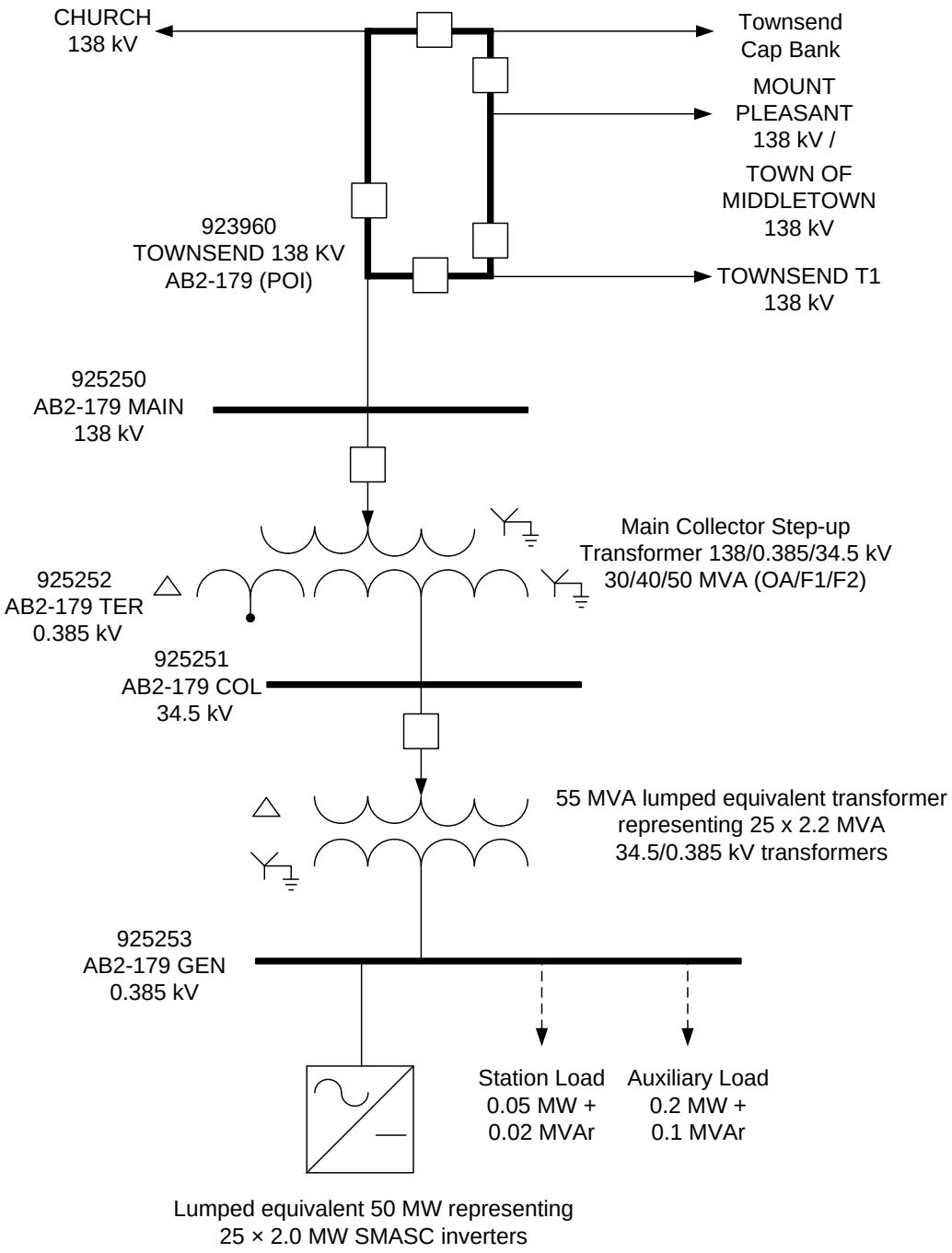


Figure 1: AB2-179 Plant Model

Table 1: AB2-179 Plant Model

	Impact Study Data	Model
Inverter Type	25 × 2.0 MW SMA Sunny Central 2200-US inverters MVA base = 2.2 MVA Vt = 0.385 kV Unsaturated sub-transient reactance = j10000 pu @ MVA base	Lumped equivalent representing 25 × 2.0 MW SMA Sunny Central 2200-US inverters Pgen 50 MW Pmax 50 MW Pmin 0 MW Qmax 16.5 MVAr Qmin -16.5 MVAr Mbase 55 MVA Zsorce j10000 pu @ Mbase
GSU transformer(s)	25 x 34.5/0.385 kV 2.2 MVA two winding transformers Dyn Transformer base = 2.2 MVA (OA) Rating = 2.2 MVA Impedance = 0.007 + j0.055 pu @ MVA base Number of taps = 5 Tap step size = 2.5%	Lumped equivalent representing 25 x 34.5/0.385 kV 2.2 MVA transformers Transformer base = 55 MVA Rating = 55 MVA Impedance = 0.007 + j0.055 pu @ MVA base Number of taps = 5 Tap step size = 2.5%
Main collector step-up transformer	1 x 138/0.385/34.5 kV Three winding transformer YN/d/yn Rating = 30/40/50 MVA (OA/F1/F2) Transformer base = 30 MVA Impedance @ MVA base High to Low = 0.003 + j0.085 pu High to Tertiary = 0.005 + j0.153 pu Low to Tertiary = 0.002 + j0.059 pu Number of taps = 5 Tap step size = 2.5%	1 x 138/0.385/34.5 kV Three winding transformer Rating = 30/40/50 MVA Transformer base = 30 MVA Impedance @ MVA base High to Low = 0.003 + j0.085 pu High to Tertiary = 0.005 + j0.153 pu Low to Tertiary = 0.002 + j0.059 pu Number of taps = 5 Tap step size = 2.5%
Station load	0.05 MW + 0.02 MVAr	0.05 MW + 0.02 MVAr (Switched off)
Auxiliary load	0.2 MW + 0.1 MVAr	0.2 MW + 0.1 MVAr (Switched off)
Transmission line	N/A	N/A

3. Loadflow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 33.7.0.
The load flow scenarios and fault cases for this study are based on PJM's Regional Transmission Planning Process[1] and discussions with PJM.
The selected load flow scenarios were the RTEP 2020 peak load case with the following modifications:

a) Addition of all applicable queue projects prior to AB2-179.

b) Addition of AB2-179 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AB2-179.

d) Dispatch of units in the PJM system in order to maintain slack generators within limits.

e) Merchant transmission projects X3-028 and S57/S58 set online and at maximum power import into PJM.

The AB2-179 initial conditions are listed in Table 2, indicating maximum power output.

Table 2: AB2-179 initial conditions

Bus	Name	Unit	PGEN (MW)	QGEN (MVar)	ETERM (pu)	POI Voltage (pu)
925253	AB2-179 GEN	1	50 MW	-2.6095	1	1.0170

Generation within the PJM500 system (area 225 in the PSS/E case) and within the vicinity of AB2-179 was dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AB2-179 is given in Attachment 5.

[1] Manual 14B: PJM Region Transmission Planning Process, Rev 33, May 5 2016, Attachment G : PJM Stability, Short Circuit, and Special RTEP Practices and Procedures.

4. Fault Cases

Table 3 to Table 6 list the contingencies that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over at least a 20 second simulation time interval.
The studied contingencies include:

a) Steady state operation (30 second);

b) Three phase faults with normal clearing time;

c) Single phase faults with stuck breaker;

d) Single-phase faults placed at 80% of the line with delayed (Zone 2) clearing at line end remote from the fault due to primary communications/relay failure.

No relevant bus, tower or high speed reclosing (HSR) contingencies were found.
Buses at which the faults listed above will be applied are:

- Townsend 138 kV (AB2-179 POI)
- Church 138 kV
- Mt Pleasant 138 kV

The one line diagram of the DPL network in the vicinity of AB2-179 is included in Attachment 2.
Clearing times listed in Tables 3 to 6 are as per revision 19 of "*2016 Revised Clearing times for each PJM company*" spreadsheet.
The positive sequence fault impedances for single line to ground faults were derived from the stability case directly by using the ASCC fault calculation method and zero/positive sequence impedance ratio provided by PJM.

5. Evaluation Criteria

This study is focused on AB2-179, along with the rest of the PJM system, maintaining synchronism and having all states return to an acceptable new condition following the disturbance. The recovery criteria applicable to this study are as per PJM's Regional Transmission Planning Process:

a) AB2-179 is able to ride through the faults (except for faults where protective action trips a generator(s)),

b) The system with AB2-179 included should be transiently stable and post-contingency oscillations are positively damped with a damping margin of at least 3%.

c) Following fault clearing, all bus voltages recover to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element trips, other than those either directly connected or designed to trip as a consequence of that fault.

6. Summary of Results

Plots from the dynamic simulations are provided in Attachment 6 with results summarized in Table 3 to Table 6.

All fault contingencies tested on the 2020 Peak Load case met the recovery criteria:

a) AB2-179 is able to ride through the faults (except for faults where protective action trips a generator(s)),

b) The system with AB2-179 included is transiently stable and post-contingency oscillations are positively damped with a damping margin of at least 3%.

c) Following fault clearing, all bus voltages recover to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element trips, other than those either directly connected or designed to trip as a consequence of that fault.

7. Recommendations and Mitigations

No adverse impacts attributable to the queue project under study were found and as such, no mitigations were found to be required.

Table 3: Steady State Operation

Fault ID	Duration	Result No mitigation
SS.01	Steady state 20 sec	Stable

Table 4: Three-phase Faults with Normal Clearing

Fault ID	Fault description	Clearing Time (Cycles)	Result No Mitigation
3N.01	Fault at Townsend 138 kV on AB2-179 circuit (trips AB2-179)	9	Stable
3N.02	Fault at Townsend 138 kV on Church circuit (13833)	9	Stable
3N.03	Fault at Townsend 138 kV on Townsend 43.2 MVAR capacitor bank	9	Stable
3N.04	Fault at Townsend 138 kV on Town of Middletown – Mt Pleasant circuit (13808) resulting in additional loss of all equipment at Town of Middletown	9	Stable
3N.05	Fault at Townsend 138 kV on Townsend 138/25 kV T1	9	Stable
3N.06	Fault at Church 138 kV on Townsend circuit (13833)	9	Stable
3N.07	Fault at Church 138 kV on Church 43.2 MVAR capacitor bank	9	Stable
3N.08	Fault at Church 138 kV on AB1-141 circuit (13723)	9	Stable
3N.09	Fault at Church 138 kV on AB2-036 circuit (13701)	9	Stable
3N.10	Fault at Church 138 kV on Church 138/69 kV AT1	9	Stable
3N.11	Fault at Church 138 kV on Church 138/69 kV AT2	9	Stable
3N.12	Fault at Mt Pleasant 138 kV on Town of Middletown – Townsend circuit (13808) resulting in additional loss of all equipment at Town of Middletown	9	Stable
3N.13	Fault at Mt Pleasant 138 kV on Glasgow circuit (13801)	9	Stable
3N.14	Fault at Mt Pleasant 138 kV on Mt Pleasant 138/25 kV T2[2]	9	Stable
3N.15	Fault at Mt Pleasant 138 kV on Lums Pond circuit (13842)	9	Stable
3N.16	Fault at Mt Pleasant 138 kV on Mt Pleasant 138/25 kV T1[1]	9	Stable
3N.17	Fault at Mt Pleasant 138 kV on Glasgow circuit (13844)	9	Stable
3N.18	Fault at Mt Pleasant 138 kV on Mt Pleasant 43.2 MVAR capacitor bank	9	Stable

[2] Only one 138/25 kV transformer at Mt Pleasant is modelled in PSSE, so faults are simulated by dropping half the load

Table 5: Single-Phase Faults With Stuck Breaker

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result No Mitigation
1B.01	Fault at Townsend 138 kV on AB2-179 circuit (trips AB2-179). Breaker stuck to Church circuit (13833). Fault cleared with loss of Church circuit (13833).	9 / 21	Stable
1B.02	Fault at Townsend 138 kV on AB2-179 circuit (trips AB2-179). Breaker stuck to Townsend 138/25 kV T1. Fault cleared with loss of Townsend 138/25 kV T1.	9 / 21	Stable
1B.03	Fault at Townsend 138 kV on Church circuit (13833). Breaker stuck to Townsend 43.2 MVAR capacitor bank. Fault cleared with loss of Townsend 43.2 MVAR capacitor bank.	9 / 21	Stable
1B.04	Fault at Townsend 138 kV on Church circuit (13833). Breaker stuck to AB2-179 circuit. Fault cleared with loss of AB2-179 circuit and AB2-179.	9 / 21	Stable
1B.05	Fault at Townsend 138 kV on Townsend 43.2 MVAR capacitor bank. Breaker stuck to Town of Middletown – Mt Pleasant circuit (13808). Fault cleared with loss of Town of Middletown – Mt Pleasant circuit (13808) and all equipment at Town of Middletown.	9 / 21	Stable
1B.06	Fault at Townsend 138 kV on Townsend 43.2 MVAR capacitor bank. Breaker stuck to Church circuit (13833). Fault cleared with loss of Church circuit (13833).	9 / 21	Stable
1B.07	Fault at Townsend 138 kV on Town of Middletown – Mt Pleasant circuit (13808). Breaker stuck to Townsend 138/25 kV T1. Fault cleared with loss Townsend 138/25 kV T1 and all equipment at Town of Middletown.	9 / 21	Stable
1B.08	Fault at Townsend 138 kV on Town of Middletown – Mt Pleasant circuit (13808). Breaker stuck to Townsend 43.2 MVAR capacitor bank. Fault cleared with loss Townsend 43.2 MVAR capacitor bank and all equipment at Town of Middletown.	9 / 21	Stable
1B.09	Fault at Townsend 138 kV on Townsend 138/25 kV T1. Breaker stuck to Town of Middletown – Mt Pleasant circuit (13808). Fault cleared with loss of Town of Middletown – Mt Pleasant circuit (13808) and all equipment at Town of Middletown.	9 / 21	Stable
1B.10	Fault at Townsend 138 kV on Townsend 138/25 kV T1. Breaker stuck to AB2-179 circuit. Fault cleared with loss of AB2-179 circuit and AB2-179.	9 / 21	Stable
1B.11	Fault at Church 138 kV on Townsend circuit (13833). Breaker stuck to Church 138/69 kV AT2. Fault cleared with loss of Church 138/69 kV AT2.	9 / 21	Stable
1B.12	Fault at Church 138 kV on Townsend circuit (13833). Breaker stuck to Church 43.2 MVAR capacitor bank. Fault cleared with loss of Church 43.2 MVAR capacitor bank.	9 / 21	Stable
1B.13	Fault at Church 138 kV on Church 138/69 kV AT2. Breaker stuck to Church 138/69 kV AT1. Fault cleared with loss of Church 138/69 kV AT1	9 / 21	Stable
1B.14	Fault at Church 138 kV on Church 138/69 kV AT2. Breaker stuck to Townsend circuit (13833). Fault cleared with loss of Townsend circuit (13833).	9 / 21	Stable

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result No Mitigation
1B.15	Fault at Church 138 kV on Church 138/69 kV AT1. Breaker stuck to Church 138/69 kV AT2. Fault cleared with loss of Church 138/69 kV AT2.	9 / 21	Stable
1B.16	Fault at Church 138 kV on Church 138/69 kV AT1. Breaker stuck to AB2-036 circuit (13701). Fault cleared with loss of AB2-036 circuit (13701).	9 / 21	Stable
1B.17	Fault at Church 138 kV on AB2-036 circuit (13701). Breaker stuck to Church 138/69 kV AT1. Fault cleared with loss of Church 138/69 kV AT1.	9 / 21	Stable
1B.18	Fault at Church 138 kV on AB2-036 circuit (13701). Breaker stuck to AB1-141 circuit (13723). Fault cleared with loss of AB1-141 circuit (13723).	9 / 21	Stable
1B.19	Fault at Church 138 kV on AB1-141 circuit (13723). Breaker stuck to AB2-036 circuit (13701). Fault cleared with loss of AB2-036 circuit (13701).	9 / 21	Stable
1B.20	Fault at Church 138 kV on AB1-141 circuit (13723). Breaker stuck to Church 43.2 MVAR capacitor bank. Fault cleared with loss of Church 43.2 MVAR capacitor bank.	9 / 21	Stable
1B.21	Fault at Church 138 kV on Church 43.2 MVAR capacitor bank. Breaker stuck to AB1-141 circuit (13723). Fault cleared with loss of AB1-141 circuit (13723).	9 / 21	Stable
1B.22	Fault at Church 138 kV on Church 43.2 MVAR capacitor bank. Breaker stuck to Townsend circuit (13833). Fault cleared with loss of Townsend circuit (13833).	9 / 21	Stable
1B.23	Fault at Mt Pleasant 138 kV on Town of Middletown – Townsend circuit (13808). Breaker stuck to Glasgow circuit (13801). Fault cleared with loss of Glasgow circuit (13801) and all equipment at Town of Middletown.	9 / 21	Stable
1B.24	Fault at Mt Pleasant 138 kV on Town of Middletown – Townsend circuit (13808). Breaker stuck to Mt Pleasant 43.2 MVAR capacitor bank. Fault cleared with loss of Mt Pleasant 43.2 MVAR capacitor bank and all equipment at Town of Middletown.	9 / 21	Stable
1B.25	Fault at Mt Pleasant 138 kV on Mt Pleasant 43.2 MVAR capacitor bank. Breaker stuck to Town of Middletown – Townsend circuit (13808). Fault cleared with loss of Town of Middletown – Townsend circuit (13808) and all equipment at Town of Middletown.	9 / 21	Stable
1B.26	Fault at Mt Pleasant 138 kV on Mt Pleasant 43.2 MVAR capacitor bank. Breaker stuck to Glasgow circuit (13844). Fault cleared with loss of Glasgow circuit (13844).	9 / 21	Stable
1B.27	Fault at Mt Pleasant 138 kV on Glasgow circuit (13844). Breaker stuck to Mt Pleasant 43.2 MVAR capacitor bank. Fault cleared with loss of Mt Pleasant 43.2 MVAR capacitor bank.	9 / 21	Stable
1B.28	Fault at Mt Pleasant 138 kV on Glasgow circuit (13844). Breaker stuck to Mt Pleasant 138/25 kV T1. Fault cleared with loss of Mt Pleasant 138/25 kV T1.	9 / 21	Stable
1B.29	Fault at Mt Pleasant 138 kV on Mt Pleasant 138/25 kV T1. Breaker stuck to Glasgow circuit (13844). Fault cleared with loss of Glasgow circuit (13844).	9 / 21	Stable
1B.30	Fault at Mt Pleasant 138 kV on Mt Pleasant 138/25 kV T1. Breaker stuck to Lums Pond circuit (13842). Fault cleared with loss of Lums Pond circuit (13842).	9 / 21	Stable

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result No Mitigation
1B.31	Fault at Mt Pleasant 138 kV on Lums Pond circuit (13842). Breaker stuck to Mt Pleasant 138/25 kV T1. Fault cleared with loss of Mt Pleasant 138/25 kV T1.	9 / 21	Stable
1B.32	Fault at Mt Pleasant 138 kV on Lums Pond circuit (13842). Breaker stuck to Mt Pleasant 138/25 kV T2. Fault cleared with loss of Mt Pleasant 138/25 kV T2.	9 / 21	Stable
1B.33	Fault at Mt Pleasant 138 kV on Mt Pleasant 138/25 kV T2. Breaker stuck to Lums Pond (13842). Fault cleared with loss of Lums Pond circuit (13842).	9 / 21	Stable
1B.34	Fault at Mt Pleasant 138 kV on Mt Pleasant 138/25 kV T2. Breaker stuck to Glasgow circuit (13801). Fault cleared with loss of Glasgow circuit (13801).	9 / 21	Stable
1B.35	Fault at Mt Pleasant 138 kV on Glasgow circuit (13801). Breaker stuck to Mt Pleasant 138/25 kV T2. Fault cleared with loss of Mt Pleasant 138/25 kV T2.	9 / 21	Stable
1B.36	Fault at Mt Pleasant 138 kV on Glasgow circuit (13801). Breaker stuck to Town of Middletown – Townsend circuit (13808). Fault cleared with loss of Town of Middletown – Townsend circuit (13808) and all equipment at Town of Middletown.	9 / 21	Stable

Table 6: Single-phase Faults With Delayed (Zone 2) Clearing at line end closest to AB2-179 POI

Fault ID	Fault description	Clearing Time Primary and Delayed (Cycles)	Result No Mitigation
1D.01	Fault at 80% of 138 kV line from Townsend to Church (13833). Delayed clearing at Townsend 138 kV.	9 / 37	Stable
1D.02	Fault at 80% of 138 kV line from Townsend to Town of Middletown – Mt Pleasant (13808). Delayed clearing at Townsend 138 kV. Fault cleared with loss of all equipment at Town of Middletown.	9 / 37	Stable
1D.03	Fault at 80% of 138 kV line from Church to AB2-036 (13701). Delayed clearing at Church 138 kV.	9 / 37	Stable
1D.04	Fault at 80% of 138 kV line from Church to AB1-141 (13723). Delayed clearing at Church 138 kV.	9 / 37	Stable
1D.05	Fault at 80% of 138 kV line from Mt Pleasant to Glasgow (13844). Delayed clearing at Mt Pleasant 138 kV.	9 / 37	Stable
1D.06	Fault at 80% of 138 kV line from Mt Pleasant to Lums Pond (13842). Delayed clearing at Mt Pleasant 138 kV.	9 / 37	Stable
1D.07	Fault at 80% of 138 kV line from Mt Pleasant to Glasgow (13801). Delayed clearing at Mt Pleasant 138 kV.	9 / 37	Stable

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.
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

(DP&L - DP&L) The MIDLTNTP-MT PLSNT 138 kV line (from bus 232106 to bus 232104 ckt 1) loads from 101.58% to 103.17% (AC power flow) of its emergency rating (348 MVA) for the tower line contingency outage of 'DBL_4NC'. This project contributes approximately 34.96 MW to the thermal violation.

CONTINGENCY 'DBL_4NC' /* RED LION-CEDAR CREEK 230;RED LION-CARTANZA 230
OPEN LINE FROM BUS 231004 TO BUS 232002 CKT 1
OPEN LINE FROM BUS 231004 TO BUS 232003 CKT 1
END

Bus Number	*Bus Name*	*Full Contribution*
232900	*DEMECSMY*	*2.25*
232851	*DUP-SFR1*	*0.43*
232902	*EASTMUNI*	*3.57*
232923	*MR1*	*3.36*
232924	*MR2*	*3.36*
232910	*NRG_G1*	*2.55*
232911	*NRG_G2*	*2.55*
297077	*V2-028 E*	*0.75*
904212	*V4-022E*	*0.61*
232813	*VAUGHN*	*0.16*
901004	*W1-003 E*	*0.89*
901014	*W1-004 E*	*0.89*
901024	*W1-005 E*	*0.89*
901034	*W1-006 E*	*0.89*
901411	*W1-062*	*2.39*
907052	*X1-032 E*	*0.79*
907324	*X1-096 E*	*18.27*
910571	*X3-008 C*	*0.34*
910572	*X3-008 E*	*2.68*
910591	*X3-015 C*	*0.32*
910592	*X3-015 E*	*2.51*

910821	*X3-066 C*	*0.18*
910822	*X3-066 E*	*1.41*
913361	*Y1-079 C*	*0.25*
913362	*Y1-079 E*	*1.96*
913411	*Y1-080 C*	*0.05*
913412	*Y1-080 E*	*0.43*
915751	*Y3-033*	*1.19*
915752	*Y3-033*	*7.92*
915542	*Y3-058 E*	*1.86*
920582	*Z1-076 C*	*1.05*
920583	*Z1-076 E*	*1.71*
920592	*Z1-077 C*	*0.75*
920593	*Z1-077 E*	*1.22*
916281	*Z1-081 C*	*0.21*
916282	*Z1-081 E*	*1.65*
917082	*Z2-012 E*	*2.44*
920763	*Z2-076 E*	*0.4*
920773	*Z2-077 E*	*0.4*
920812	*Z2-097 C*	*0.32*
920813	*Z2-097 E*	*0.65*
921123	*AA1-059 E*	*0.33*
921142	*AA1-061 C*	*2.87*
921143	*AA1-061 E*	*1.42*
921442	*AA1-110 C*	*0.36*
921443	*AA1-110 E*	*0.89*
921592	*AA1-140 C*	*1.51*
921593	*AA1-140 E*	*2.47*
921602	*AA1-141 C*	*1.13*
921603	*AA1-141 E*	*1.84*
921872	*AA2-069*	*104.83*
922213	*AA2-129 E*	*3.94*
922222	*AA2-130*	*0.39*
922752	*AB1-056 C OP*	*12.8*
922753	*AB1-056 E OP*	*36.44*
922762	*AB1-057 C*	*12.99*
922763	*AB1-057 E*	*37.04*
923282	*AB1-137 C*	*2.79*
923283	*AB1-137 E*	*1.2*
923322	*AB1-141 C OP*	*5.3*
923323	*AB1-141 E OP*	*2.47*
923332	*AB1-142 C OP*	*5.3*
923333	*AB1-142 E OP*	*2.47*
923452	*AB1-162 C OP*	*2.4*
923453	*AB1-162 E OP*	*3.92*
923602	*AB1-176 C*	*1.29*

923603	*AB1-176 E*	*2.12*
923902	*AB2-030 E*	*0.79*
923921	*AB2-032 C*	*5.34*
923922	*AB2-032 E*	*2.51*
923931	*AB2-033 C*	*1.41*
923932	*AB2-033 E*	*0.56*
923951	*AB2-036 C*	*11.45*
923952	*AB2-036 E*	*18.72*
923961	*AB2-037 C*	*12.73*
923962	*AB2-037 E*	*20.8*
924191	*AB2-063 C*	*2.87*
924192	*AB2-063 E*	*4.69*
924361	*AB2-084 C*	*0.75*
924362	*AB2-084 E*	*1.22*
924681	*AB2-120 C OP*	*7.49*
924682	*AB2-120 E OP*	*12.22*
924781	*AB2-130 C OP*	*6.58*
924782	*AB2-130 E OP*	*10.73*
924801	*AB2-133 C OP*	*14.2*
924802	*AB2-133 E OP*	*14.16*
924821	*AB2-135 C*	*12.84*
924822	*AB2-135 E*	*14.65*
924831	*AB2-136 C*	*1.07*
924832	*AB2-136 E*	*5.51*
924881	*AB2-142 C*	*1.14*
924882	*AB2-142 E*	*1.85*
924971	*AB2-153 C*	*2.98*
924972	*AB2-153 E*	*4.87*
925091	*AB2-166 C*	*0.4*
925092	*AB2-166 E*	*0.7*
925101	*AB2-167 C*	*1.05*
925102	*AB2-167 E*	*1.72*
925151	*AB2-172 C OP*	*4.11*
925152	*AB2-172 E OP*	*6.7*
925231	*AB2-177 C*	*0.49*
925232	*AB2-177 E*	*0.81*
925251	*AB2-179 C OP*	*26.29*
925252	*AB2-179 E OP*	*8.67*
925261	*AB2-180 C*	*2.8*
925262	*AB2-180 E*	*1.2*
925271	*AB2-185 C OP*	*4.42*
925272	*AB2-185 E OP*	*1.89*

Appendix 2

(DP&L - DP&L) The TOWNSEND-MIDLTNTP 138 kV line (from bus 232107 to bus 232106 ckt 1) loads from 108.43% to 112.75% (AC power flow) of its emergency rating (348 MVA) for the tower line contingency outage of 'DBL_4NC'. This project contributes approximately 34.96 MW to the thermal violation.

CONTINGENCY 'DBL_4NC' /* RED LION-CEDAR CREEK 230;RED LION-CARTANZA 230
OPEN LINE FROM BUS 231004 TO BUS 232002 CKT 1
OPEN LINE FROM BUS 231004 TO BUS 232003 CKT 1
END

Bus Number	*Bus Name*	*Full Contribution*
232900	*DEMECSMY*	*2.25*
232851	*DUP-SFR1*	*0.43*
232902	*EASTMUNI*	*3.57*
232923	*MR1*	*3.36*
232924	*MR2*	*3.36*
232910	*NRG_G1*	*2.55*
232911	*NRG_G2*	*2.55*
297077	*V2-028 E*	*0.75*
904212	*V4-022E*	*0.61*
232813	*VAUGHN*	*0.16*
901004	*W1-003 E*	*0.89*
901014	*W1-004 E*	*0.89*
901024	*W1-005 E*	*0.89*
901034	*W1-006 E*	*0.89*
901411	*W1-062*	*2.39*
907052	*X1-032 E*	*0.79*
907324	*X1-096 E*	*18.27*
910571	*X3-008 C*	*0.34*
910572	*X3-008 E*	*2.68*
910591	*X3-015 C*	*0.32*
910592	*X3-015 E*	*2.51*
910821	*X3-066 C*	*0.18*
910822	*X3-066 E*	*1.41*
913361	*Y1-079 C*	*0.25*
913362	*Y1-079 E*	*1.96*
913411	*Y1-080 C*	*0.05*
913412	*Y1-080 E*	*0.43*
915751	*Y3-033*	*1.19*
915752	*Y3-033*	*7.92*
915542	*Y3-058 E*	*1.86*
920582	*Z1-076 C*	*1.05*
920583	*Z1-076 E*	*1.71*

920592	*Z1-077 C*	*0.75*
920593	*Z1-077 E*	*1.22*
916281	*Z1-081 C*	*0.21*
916282	*Z1-081 E*	*1.65*
917082	*Z2-012 E*	*2.44*
920763	*Z2-076 E*	*0.4*
920773	*Z2-077 E*	*0.4*
920812	*Z2-097 C*	*0.32*
920813	*Z2-097 E*	*0.65*
921123	*AA1-059 E*	*0.33*
921142	*AA1-061 C*	*2.87*
921143	*AA1-061 E*	*1.42*
921442	*AA1-110 C*	*0.36*
921443	*AA1-110 E*	*0.89*
921592	*AA1-140 C*	*1.51*
921593	*AA1-140 E*	*2.47*
921602	*AA1-141 C*	*1.13*
921603	*AA1-141 E*	*1.84*
921872	*AA2-069*	*104.83*
922213	*AA2-129 E*	*3.94*
922222	*AA2-130*	*0.39*
922752	*AB1-056 C OP*	*12.8*
922753	*AB1-056 E OP*	*36.44*
922762	*AB1-057 C*	*12.99*
922763	*AB1-057 E*	*37.04*
923282	*AB1-137 C*	*2.79*
923283	*AB1-137 E*	*1.2*
923322	*AB1-141 C OP*	*5.3*
923323	*AB1-141 E OP*	*2.47*
923332	*AB1-142 C OP*	*5.3*
923333	*AB1-142 E OP*	*2.47*
923452	*AB1-162 C OP*	*2.4*
923453	*AB1-162 E OP*	*3.92*
923602	*AB1-176 C*	*1.29*
923603	*AB1-176 E*	*2.12*
923902	*AB2-030 E*	*0.79*
923921	*AB2-032 C*	*5.34*
923922	*AB2-032 E*	*2.51*
923931	*AB2-033 C*	*1.41*
923932	*AB2-033 E*	*0.56*
923951	*AB2-036 C*	*11.45*
923952	*AB2-036 E*	*18.72*
923961	*AB2-037 C*	*12.73*
923962	*AB2-037 E*	*20.8*
924191	*AB2-063 C*	*2.87*

924192	*AB2-063 E*	*4.69*
924361	*AB2-084 C*	*0.75*
924362	*AB2-084 E*	*1.22*
924681	*AB2-120 C OP*	*7.49*
924682	*AB2-120 E OP*	*12.22*
924781	*AB2-130 C OP*	*6.58*
924782	*AB2-130 E OP*	*10.73*
924801	*AB2-133 C OP*	*14.2*
924802	*AB2-133 E OP*	*14.16*
924821	*AB2-135 C*	*12.84*
924822	*AB2-135 E*	*14.65*
924831	*AB2-136 C*	*1.07*
924832	*AB2-136 E*	*5.51*
924881	*AB2-142 C*	*1.14*
924882	*AB2-142 E*	*1.85*
924971	*AB2-153 C*	*2.98*
924972	*AB2-153 E*	*4.87*
925091	*AB2-166 C*	*0.4*
925092	*AB2-166 E*	*0.7*
925101	*AB2-167 C*	*1.05*
925102	*AB2-167 E*	*1.72*
925151	*AB2-172 C OP*	*4.11*
925152	*AB2-172 E OP*	*6.7*
925231	*AB2-177 C*	*0.49*
925232	*AB2-177 E*	*0.81*
925251	*AB2-179 C OP*	*26.29*
925252	*AB2-179 E OP*	*8.67*
925261	*AB2-180 C*	*2.8*
925262	*AB2-180 E*	*1.2*
925271	*AB2-185 C OP*	*4.42*
925272	*AB2-185 E OP*	*1.89*