Generation Interconnection System Impact Study Report

For

TP Generation Interconnection Request Queue Position Z1-086

Carson – Heritage 500kV

November 2014

Introduction

This System Impact Study (SIS) has been prepared in accordance with the TP Open Access Transmission Tariff, Section 205, as well as the System Impact Study Agreement between Virginia Electric and Power Company (Interconnection Customer (IC)) and TP Interconnection, LLC (Transmission Provider (TP)). The Interconnected Transmission Owner (ITO) is Virginia Electric and Power Company.

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 TP network at a location specified by the IC. As a requirement for interconnection, the IC 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 TP system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on TP web site) for the appropriate transmission owner.

In some instances an IC 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 project developer 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

Virginia Electric and Power Company, the IC, has proposed a natural gas generating facility located at Greensville County, Virginia. The installed facilities will have a total capability of 1681 MW with 1630 MW of this output being recognized by TP as capacity. The proposed in-service date for this project is December 1, 2018. **This study does not imply an ITO commitment to this in-service date.**

Point of Interconnection

Z1-086 will interconnect with the ITO system via a new three breaker ring bus switching station that connects to the Carson – Heritage 500kV line.

Cost Summary

The Z1-086 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$2,600,000
Direct Connection Network Upgrades	$6,000,000
Non Direct Connection Network Upgrades	$22,000,000
Allocation for New System Upgrades	$0
Contribution for Previously Identified Upgrades	$TBD
Total Costs	**$30,600,000**

Attachment Facilities

Generation Substation: Install metering and associated Protection Equipment. Estimated Cost $600,000.

Transmission Line: Construct approximately one span of 500 kV Attachment line between the generation substation and Z1086 Switching Substation. The estimated cost for this work is $2,000,000.

The estimated total cost of the Attachment Facilities is $2,600,000. It is estimated to take 18-24 months to complete this work after execution of Interconnection Service Agreement (ISA) and Interconnection Construction Service Agreement (ICSA). 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. The single line is shown below in Attachment 1.

Direct Connection Cost Estimate

Substation: TP network upgrade # n4300 to establish the new 500 kV Z1086 Switching Substation (interconnection substation). The arrangement in the substation will be as shown below on Attachment 1: One–Line Diagram. The estimated cost of this facility is $6,000,000. It is estimated to take 24-36 months to complete this work after execution of ISA and ICSA.

Non-Direct Connection Cost Estimate

TP network upgrade # n4258 to uprate the Carson to Rawlings 500 kV line to approximately 4300 MVA. The estimated cost is $22,000,000. It is estimated to take 20 months to complete. The time line to complete is based on being able to obtain outages to uprate line.

Interconnection Customer Requirements

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

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 TP Manuals M-01 and M-14D, and TP Tariff Sections 24.1 and 24.2.

Network Impacts

The Queue Project Z1-086 was studied as a 1630.0 MW (Capacity 1630.0 MW) injection tapping the Carson – Brunswick 500 kV line in the ITO area. Project Z1-086 was evaluated for compliance with applicable reliability planning criteria (TP, NERC, NERC Regional Reliability Councils, and Transmission Owners) for summer peak conditions in 2017. The stability analysis used a 2019 model and 1681MW injection. Queue project Z1-086 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
1127_B2_A	CONTINGENCY '1127_B2_A' OPEN BRANCH FROM BUS 314902 TO BUS 916370 CKT 1 / 314902 8CARSON 500 916370 Z1-086 500 1 END
8MORRSVL _8NO ANNA _033	CONTINGENCY '8MORRSVL _8NO ANNA _033' DISCONNECT BRANCH FROM BUS 314916 TO BUS 314918 CKT 1 /* 500/500KV, AREA 345/345. END

Generator Deliverability

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

Overload Number	Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Flowgate Appendix
1	N-1	1127_B2_A	CPLE - DVP	6PERSON230 T-6HALIFAX 230 kV line	304070	314697	1	DC	97.42	131.8	ER	712	244.79	1
2	N-1	1127_B2_A	DVP - DVP	6HALIFAX-6CLOVER 230 kV line	314697	314686	1	AC	82.18	112.47	ER	749	226.93	2

TP network upgrades n3289, n3290, and n3292 to build a 14 mile Heritage to Rawlings 500kV Line to approximately 3402 MVA. Work includes the Rawlings switching substation and re-arrangement at Carson substation. Included in this is a portion of the network upgrade n3287 to connect the new line into Heritage. These network upgrades were previously identified in TP Queue X2-076 due to the violations identified in Duke Progress. The cost allocation for $85,000,000 between the X2-076 project and the Z1-086 project will be determined during the facility study while performing a joint study with Duke Progress.

a. Install three breaker ring bus substation (Rawlings) on line 556 (n3289). The estimated cost is $8,626,657.
b. Construct new 500 kV 591 line between line 570 and 556 (n3290.2). The estimated cost is $31,382,028.
c. Rearrange the Carson 500 kV substation configuration to separate line 556 and 570 from the same breaker bay (n3292). The estimated cost is $4,832,288.
d. Construct one bay of the four bay switching substation (Heritage) for the new 591 line (assume one quarter of n3287). The estimated cost is one quarter of $13,315,148.

With the network upgrades above added to the study an additional thermal violation was identified.

Overload Number	Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution
3	N-1	1127_B2_A	DVP - DVP	556BKRSTA-8CARSON 500 kV line	314995	314902	1	AC	75.69	102.55	ER	3402	923.75

TP network upgrade n4258 to uprate the Carson to Rawlings 500 kV Line to approximately 4300 MVA. The estimated cost is $22,000,000. It is estimated to take 20 months to complete. The time line to complete is based on being able to obtain outages to uprate line.

Queue	MW contribution	Percentage of Cost	Cost($M)
Z1-086	86.75	100.00%	22.0000

Multiple Facility Contingency

(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)

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 TP Queue)

Overload		Contingency			Bus				Loading %		Rating		MW	Flowgate
Number	Type	Name	Affected Area	Facility Description	From	To	Circuit	Power Flow	Initial	Final	Type	MVA	Contribution	Appendix
4	N-1	8MORRSVL _8NO ANNA _033	DVP - DVP	8NO ANNA-8LDYSMTH 500 kV line	314918	314911	1	DC	103.7	112.61	ER	3219	291.53	4

TP network upgrade n0718.1 to build a 15-mile long North Anna – Lady Smith 2nd 500 kV line and install 500 kV breakers at North Anna and Ladysmith Stations. The estimated cost is $44,000,000. It is estimated to take 30 months to complete. Previously identified in PJM Queue Q65.

Queue	MW contribution	Percentage of Cost	Cost($44M)
Q65	400.00	43.57%	19.1697
X2-076	226.59	24.68%	10.8590
Z1-086	291.53	31.75%	13.9713

Steady-State Voltage Requirements

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

None

Stability and Reactive Power Requirement for Low Voltage Ride Through

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

Requirements

The following actions are required for Z1-086:

1. **Operating Restrictions**: There are N-1-1 operating conditions (such as maintenance outage) that result in transient instability with the addition of the Greensville units (Z1-086). Specifically, the following N-1 system conditions (pre-contingency) result in transient instability and/or poorly damped oscillations for the next contingency:
    - Brunswick-Rawlings 500kV line O/S
    - Z1-086-Carson 500kV line O/S
    - Rawlings-Carson 500kV line O/S

    To mitigate this instability, immediate operating restrictions must be enforced following an N-1 (planned or forced). For any of the system conditions defined above, without further study, generation at this location (Brunswick/Greensville) must be limited to:

Operating Restriction Recommendation Table

Online Generation	Brunswick Max Output [MW]	Z1-086 Max Output [MW]
If Brunswick is Offline…	N/A	<1200
If Z1-086 is Offline…	1376 (max)	N/A
If both Plants are Online…*	1376 (max)*	0*
*This assumes Brunswick is dispatched to full capacity. Z1-086 must be restricted to below its Pmin output of 862 MW. This assumes that the unit is normally operated with all combustion turbines running and the steam running at Pmin quantity.		

It is noted that Z1-086 is less stable than the Brunswick plant based on the parameters provided. Therefore, it must be restricted to a lower MW limit than Brunswick. These operating restrictions likely will require additional studies and possible further restriction on the units' output. This also is studied under 2019 light load and summer peak

conditions, and does not cover all possible system conditions. Therefore, system conditions could arise in the operational timeframe that could further limit the units' output.

2. **Installation of out-of-step protection**: This study was made using a certain set of operating conditions. There may be other operating conditions, although less probable, that can create stability problems either during high transfer or high voltage conditions. It is the Customer's responsibility to protect their own equipment from damage due to disturbances on the transmission system by installing out-of-step protection on their generators.

Recommendations

The following actions are recommended for Z1-086:

1. **Additional PSS Tuning Studies**: It is strongly recommended that additional PSS tuning studies be performed to ensure that the power system stabilizer is sufficiently damping out the oscillations of interest. The model provided uses the PSS2B model in PSS/e, whereas similar plants such as Warren County Power Station use the PSS2A model. Parameters are slightly modified between the two and should be investigated further. This could help lessen the restrictions identified above.

2. **Construction of Z1-086-Carson #2 500kV line**: For N-1-1 operating conditions (such as maintenance outage), the combination of Z1-086 and the existing Brunswick generating facility results in transient instability for a number of contingencies. These operating conditions can occur during times of maintenance and forced outage. Specifically, generation remaining connected to the grid solely through Brunswick-Wake 500kV line results in insufficient synchronizing torque to maintain stability. To mitigate this potentially unstable condition, and also to maintain voltage stability in the Clover area, the addition of Z1-086-Carson #2 500kV line provides a sufficiently strong connection to the grid at a low cost relative to other transmission infrastructure solutions.

3. **Coordinated Study with Duke / Progress Energy:** It is recommended that TP coordinate with Progress to ensure there are no negative impacts by the proposed Z1-086 project on their network. A study comprising both ITO and Duke / Progress Energy systems to develop comprehensive Operating Restrictions may be warranted.

   For more details see Attachment 2.

Light Load Analysis

(Study to determine that the Transmission System is capable of delivering the system generating capacity at light load)

Not required

Potential Congestion due to Local Energy Deliverability

TP 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.

Not applicable

ITO Analysis

ITO assessed the impact of the proposed Queue Project #Z1-086 interconnection as 1681MW of energy (Capacity 1630.0 MW) for compliance with reliability criteria on ITO's Transmission System. The system was assessed using the summer 2017 RTEP case provided to ITO by TP. 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's 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 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. The results of these studies are discussed in more detail below.

A. Category B Analysis (Single Contingency):

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

B. 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

C. 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 First Contingency Incremental Transfer Capacity between utilities. The results of these studies can be found in Tables A and B for both with and without Z1-086.

Table A: Import Study Results

Import Study Results			
Area	**Summer 2017**	**Summer 2017 with Z1-086**	**Limiting Element**
AEP	2000+	2000+	None
APS	2000+	2000+	None
CPL	2000+	-411	None
TP	2000+	2000+	None

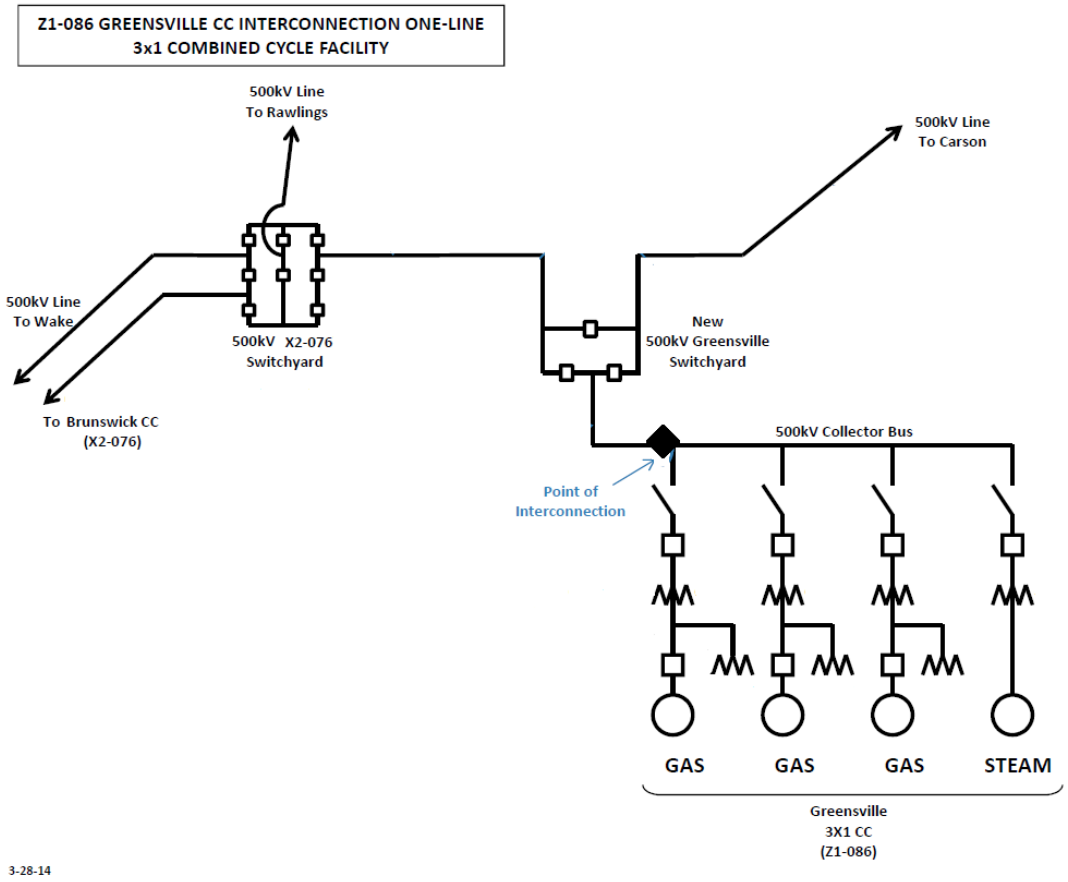
Table B: Export Study Results

Export Study Results			
Area	**Summer 2017**	**Summer 2017 with Z1-036**	**Limiting Element**
AEP	2000+	2000+	None
APS	2000+	2000+	None
CPL	2000+	2000+	None
TP	2000+	2000+	None

ITO's Planning Criteria indicates a need to have approximately 2000 MW of import and export capability. The results of these import and export studies indicate that the proposed generation facility will impact ITO's import or export capability. Upgrades required to reliably interconnect the proposed generating facility with ITO's Transmission Facilities will resolve the identified deficiencies.

Attachment 1. Z1-086

Single Line



Attachment 2.

Z1-086 Stability Study Report

Introduction

This study evaluates the stability and dynamics for TP queue project Z1-086 on the ITO transmission system facilities only. The Z1-086 project is a combined cycle comprising of one steam turbine generator (ST) and three combustion turbine generators (C1, C2, C3) connecting to a new facility located approximately 0.5 miles from the new Brunswick 500kV switching station along the new Brunswick-Carson 500kV line. This new Brunswick 500kV substation is a new switching station added to the existing Carson-Wake 500kV line approximately 30 miles from Carson and 90 miles from Wake. Z1-086 queue project requests 1630 MW capacity / 1681 MW energy at the point of interconnection.

For this stability study, the Z1-086 project was studied with total net generating output of 1681 MW delivered to the grid (combustion and steam units modeled with 12.5 MW and 5.0 MW stations service, respectively).

Note: This study by ITO does not evaluate the stability and dynamic impacts for the above mentioned queue project for faults on the Duke / Progress Energy system.

Analysis

The stability study for Z1-086 was performed using the 2019 heavy summer base case and 2019 light load base case conditions. The most severe contingencies were studied for this particular generating resource to ensure transient stability during and immediately after faults on the transmission system. Three phase faults with normal clearing and single-line-to-ground faults with delayed clearing were studied. For the purposes of this study, fault clearing time is:

- 500kV normal clearing: 3 cycle and 4 cycle for near and far side, respectively.
- 500kV delayed clearing: 12 cycle near side (delayed clearing with backup) and 4 cycle far side.

Queue project Z1-086 was modeled as one 23 kV steam generator and three 20 kV combustion generators (see Appendix 4). The generators were dispatched into leading power factor region as required by ITO Planning criteria. In general, the units were dispatched at approximately 50% under-excitation (about 50% of Qmin) for each N-0 base case condition studied. The generators have the following MW and MVAR output characteristics.

Table 1. Generator Output Characteristics

	ST	C1	C2	C3
Pmax [MW]	629	365	365	365
Station Load	5	12.5	12.5	12.5

[MW]				
Qmax [MVAR]	368	169	169	169
Qmin [MVAR]	-262	-160	-160	-160
50% Qmin [MVAR]	-131	-80	-80	-80

Note: N-1-1 transient stability analysis did not consider redispatch of the units' MW output prior to applying the next N-1 contingency in dynamics (time step integration); however, the units were set with 50% under-excitation in all cases (unless terminal voltage below 0.95 pu). The terminal voltage in each of the cases is shown in the table below:

Table 2. Base Case Conditions

Root Case	Operating Cond	Condition	500kV	C1/C2/C3	ST
2019SLL		N-0 Base	1.0349	0.9539	0.9626
		BRUNS-RAWL O/S	1.0341	0.9531	0.9618
		Z1-086-CARS O/S	1.0360	0.9550	0.9637
		RAWL-CARS O/S	1.0348	0.9538	0.9625
		Z1-086-CARS O/S	1.0349	0.9539	0.9626
	CARS #2 Add	N-0 Base	1.0349	0.9539	0.9626
	CARS #2 Add	BRUNS-RAWL O/S	1.036	0.9550	0.9637
2019SUM		N-0 Base	1.0341	0.9531	0.9618
	BRUNS ONLY – No Z1-086	N-0 Base			
	BRUNS ONLY – No Z1-086	BRUNS-RAWL O/S			
	BRUNS ONLY – No Z1-086	RAWL-CARS O/S			

	Z1-086 ONLY – No BRUNS	N-0 Base	1.0254	0.9509	0.9566
				-60MVAR	-110 MVAR
		BRUNS-RAWL O/S	1.0327	0.9517	0.9604
		BRUNS-WAKE O/S	1.0339	0.9529	0.9617
		RAWL-CLOV O/S	1.0908	0.9498	0.9586
		Z1-086-CARS O/S	1.0339	0.9529	0.9617
	CARS #2 Add	RAWL-CARS O/S	1.0351	0.9541	0.9628
	CARS #2 Add	BRUNS-RAWL O/S	1.0401	0.9591	0.9678
	CARS #2 Add	RAWL-CARS O/S	1.0385	0.9575	0.9575
	CARS #2 Add	Z1-086-CARS O/S	1.0341	0.9531	0.9618

Results

Results – 2019 Heavy Summer and Light Load

Stability results in tabular form regarding transient swing angle are provided in Appendix 5. Absolute angle is shown, and very large absolute angle is indication of out-of-step conditions. Further analysis is performed for oscillation damping analysis of concern. Observations regarding transient stability performance for Z1-086 and the Brunswick generating facility are as follows:

1. Z1-086 (and Brunswick plant) maintains transient stability with acceptable swing angle for all N-1 three-phase (3P) fault conditions and breaker failure single-line-to-ground (SLG) fault conditions. Oscillation damping for these contingencies is acceptable according to ITO Planning criteria.
2. N-1 maintenance outages pose a stability restriction on safe and reliable operation of the Z1-086 project as well as Brunswick generating facility. Complete simulation results are included in the Appendix 5 and 6.

- Loss of Carson-Z1-086 500kV line with Rawlings-Brunswick 500kV line out-of-service (O/S) results in instability.
- Loss of Rawlings-Brunswick 500kV line with Carson-Z1-086 line O/S is unstable.
- Loss of Z1-086-Carson 500kV line with Rawlings-Carson 500kV O/S results in severe transient instability at Brunswick, Z1-086, and Clover generating plants.

3. Transient stability results demonstrate that if Brunswick generating facility is generating at full capacity, Z1-086 will be forced to shut down due to operating restriction and minimum output (Pmin) requirements (as modeled in the case).
4. Stability results demonstrate a lower frequency oscillation in the 0.02-0.05 Hz range that is an indication that further PSS tuning studies should be performed to improve stability for these conditions.

Results – Operating Restrictions

To understand how generation in this area must be dispatched for an N-1 pre-contingency outage (forced or planned), three distinct conditions are considered:

1. Brunswick Generation Online Only – Z1-086 is offline.
2. Z1-086 Generation Online Only – Brunswick is offline.
3. Combined output of Brunswick & Z1-086 – Brunswick is assumed to have full capacity rights and priority is given to dispatching Brunswick for this analysis.

Results from this analysis in terms of maximum absolute angle are shown in Appendix 6.

Oscillation damping results for restricted output conditions are also considered by analyzing transient ringdown. Results for oscillation ringdown analysis are shown in the table below.

Table 3. Restricted Output Modal Analysis

BRUNSWICK ONLY

Window 1	Freq [Hz]	1.053	0.282	0.718
	Real	-0.180646	-1.3404	-0.432645
	Imaginary	6.61367	1.77036	4.51225
	Energy	16.156	5.5723	3.0951
	Damping %	2.730385	60.363397	9.5444593
Window 2	Freq [Hz]	1.05	0.862	0.688
	Real	-0.220996	-0.327488	-1.05016
	Imaginary	6.59975	5.41622	4.32335
	Energy	9.7463	3.3758	3.093
	Damping %	3.3466753	6.0354084	23.604054

1376 MW Reduction

Window 1	Freq [Hz]	0.977	0.859	0.634
	Real	-0.1129	-0.121443	-0.3231

	Imaginary	6.13923	5.39799	3.98401
	Energy	9.699	3.9317	2.0939
	Damping %	1.838682	2.2492127	8.0833805
Window 2	Freq [Hz]	0.565	0.829	0.982
	Real	-1.9465	-1.59522	-0.11907
	Imaginary	3.55038	5.20645	6.16739
	Energy	8.8779	8.385	7.2901
	Damping %	48.074098	29.295081	1.9302787

1207 MW Reduction

Window 1	Freq [Hz]	0.999	0.865	0.642
	Real	-0.270063	-0.17618	-0.242455
	Imaginary	6.27381	5.43487	4.03451
	Energy	12.882	4.658	1.7077
	Damping %	4.3006265	3.239958	5.9987056

The following observations are made:

1. Brunswick Generation Only – Brunswick experiences relatively low damping ratio for the system conditions used. This is a separate issue that will need to be addressed. However, this is used as a baseline for this analysis in terms of oscillatory and transient stability.
2. Z1-086 Generation Only – At full output, Z1-086 is transient unstable for N-1-1 contingencies.
    a. Therefore, MW output is restricted first to 1376 MW (to match Brunswick output) in the 2019SUM heavy summer case (which is more stable). Although the unit maintains synchronism, oscillation damping is insufficient.
    b. Generating output is set to 1207, which is approximately 70% of maximum generating capability. The unit maintains synchronism with measured oscillation damping for the predominant mode of 0.999 Hz of 4.3% with a secondary mode of 0.865 Hz with 3.24% damping ration. This is considered sufficient for the purposes of this study, and the primary oscillation frequency is above the 4% criteria in the ITO Planning Manual.
3. Combined Brunswick & Z1-086 – For this analysis, Brunswick is dispatched at full output and Z1-086 is studied as variable scheduled generation. Results show that even with Z1-086 set to minimum output power, Pmin, oscillation damping remains negative. Therefore, it is determined that Z1-086 must remain offline when Brunswick is scheduled near full output for certain N-1 system conditions identified.

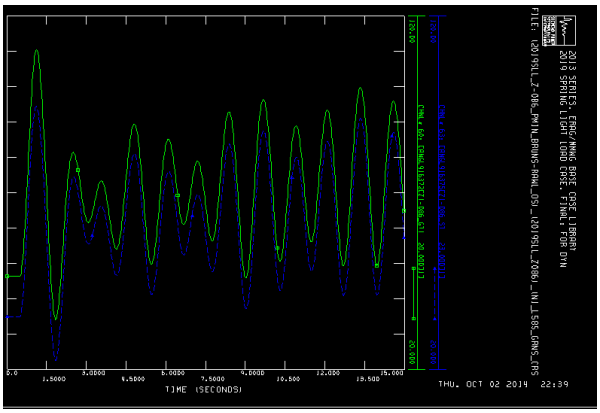


Figure 1. Undamped oscillation frequency for Brunswick + Z1-086 at Pmin.

Results – 2019 Heavy Summer with Modified PSS Settings

The tables below show oscillation ringdown analysis results for various perturbations of the PSS settings. These studies were performed on the base case with Brunswick-Rawlings 500 out of service pre-contingency and then the Z1-086-Carson contingency is applied, with the Brunswick unit offline and Z1-086 at 1376 MW output (to match maximum Brunswick output). Legend of case names is as follows:

- PSS0 – Data as Provided
- PSS1 – Change Washout Filters to 10 sec
- PSS2 – Change Gain to 10
- PSS3 – Change Gain to 2
- PSS4 – Change to PSS2A Model (Match Warren County Power Station)

The modal information contained below is generated from PSS/e modal analysis using Least Squares / Eigenvector Fit by Initial Points, and ensuring that small error ratio and high signal to noise ratio is achieved. Energy is ranked left to right in the table below.

Table 4. PSS Tuning Modal Analysis Results

BRUNSWICK ONLY

Window 1	Freq [Hz]	1.053	0.282	0.718
	Real	-0.180646	-1.3404	-0.432645
	Imaginary	6.61367	1.77036	4.51225
	Energy	16.156	5.5723	3.0951
	Damping %	2.730385	60.363397	9.5444593
Window 2	Freq [Hz]	1.05	0.862	0.688
	Real	-0.220996	-0.327488	-1.05016
	Imaginary	6.59975	5.41622	4.32335
	Energy	9.7463	3.3758	3.093
	Damping %	3.3466753	6.0354084	23.604054

PSS0

Window 1	Freq [Hz]	0.953	0.925	0.563
	Real	-0.161419	-0.188842	0.0058838
	Imaginary	5.98723	5.80938	3.53445
	Energy	28.083	22.819	0.54607
	Damping %	2.6950755	3.2489234	-0.166471
Window 2	Freq [Hz]	0.981	0.873	0.68
	Real	-0.114955	-0.155767	-1.32441
	Imaginary	6.1636	5.48389	4.27027
	Energy	6.4491	3.5218	2.1548
	Damping %	1.8647383	2.839302	29.622657

PSS1

Window 1	Freq [Hz]	0.96	0.916	1.41
	Real	-0.102707	-0.281596	-0.36387
	Imaginary	6.03318	5.758	8.8533
	Energy	15.41	14.566	0.2621
	Damping %	1.7021226	4.8846796	4.106526
Window 2	Freq [Hz]	0.982	0.874	0.679
	Real	-0.0993	-0.143068	-1.18524
	Imaginary	6.16873	5.48918	4.26742
	Energy	6.7119	3.2217	1.9723
	Damping %	1.6095231	2.605479	26.761149

PSS2

Window 1	Freq [Hz]	0.898	0.947	1.325
	Real	-0.392178	-0.160423	-1.10344
	Imaginary	5.6453	5.94978	8.32253
	Energy	15.196	11.004	0.25627
	Damping %	6.9302796	2.695305	13.143449
Window 2	Freq [Hz]	0.976	0.866	0.646
	Real	-0.221911	-0.152419	-0.98247
	Imaginary	6.13361	5.44092	4.05989
	Energy	3.8846	3.2778	1.0529
	Damping %	3.6155854	2.8002476	23.520527

PSS3

Window 1	Freq [Hz]	0.971	0.905	1.431
	Real	-0.046875	-0.286146	-1.12292
	Imaginary	6.1014	5.68323	8.98932
	Energy	13.018	9.9402	0.40152

	Damping %	0.7682436	5.0285488	12.395376
Window 2	Freq [Hz]	0.982	0.874	0.701
	Real	-0.044479	-0.123643	-1.02159
	Imaginary	6.17307	5.49178	4.40707
	Energy	8.8839	3.0369	1.8017
	Damping %	0.7205142	2.250849	22.581931

PSS4

Window 1	Freq [Hz]	0.763	0.828	0.954
	Real	-1.06275	-0.046525	-0.103629
	Imaginary	4.79232	5.20437	5.99106
	Energy	5.0499	3.7681	1.8523
	Damping %	21.650141	0.8939188	1.7294686
Window 2	Freq [Hz]	0.847	0.937	0.88
	Real	-0.179459	-0.393072	-1.24357
	Imaginary	5.31872	5.88474	5.52795
	Energy	7.0207	4.7917	2.4065
	Damping %	3.3721823	6.6646625	21.947545

The results show no major improvement by increasing the washout filter time constants. Oscillation damping is moderately improved for an increase in PSS Gain from 5 to 10, and conversely negatively impacted by a reduction in PSS Gain from 5 to 2. Mirroring the Warren County Power Station units' PSS settings on the Z1-086 model does not produce sufficient damping, leading to the conclusion that it may not necessarily be an issue with the PSS. But further study is required.

Results – 2019 Heavy Summer and Light Load w/ Added Z1-086-Carson #2 500kV Line

Stability results in tabular form regarding transient swing angle are provided in Appendix 5. Observations regarding transient stability performance for Z1-086 and the Brunswick generating facility are as follows:

1. Z1-086 (and Brunswick plant) maintains transient stability with acceptable swing angle for all identified transient unstable conditions in the 2019SUM and 2019SLL discussed above. Oscillation damping is also improved for this addition.
2. In the N-1-1 conditions, all credible contingencies result in transient stability with the additional Z1-086-Carson #2 line.

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

CONTINGENCY '1127_B2_A'
OPEN BRANCH FROM BUS 314902 TO BUS 916370 CKT 1 / 314902 8CARSON 500 916370 Z1-086 500 1
END

Bus Number	Bus Name	Full Contribution
242750	05PHILPO	0.03
315131	1EDGECMA	0.14
315132	1EDGECMB	0.14
LTF	W4-049	7.98
LTF	X2-042	34.53
909841	X2-076 C	6.51
LTF	X4-041	8.48
LTF	Y1-002	33.95
LTF	Y1-004	43.79
LTF	Y1-007	30.42
LTF	Y2-004	17.09
LTF	Y2-005	6.84
LTF	Y2-006	17.55
LTF	Y2-033	6.19
LTF	Y2-034	20.04
LTF	Y2-035	22.9
LTF	Y2-114	5.61
LTF	Y2-115	6.16
LTF	Y3-028	10.83
LTF	Y3-069	17.06
LTF	Y3-072	17.06
LTF	Y3-094	27.46
LTF	Z1-025	12.45
LTF	Z1-027	7.22
LTF	Z1-046	13.64
LTF	Z1-067	5.36
LTF	Z1-071	4.31
916371	Z1-086 C	244.79

Appendix 2

CONTINGENCY '1127_B2_A'
OPEN BRANCH FROM BUS 314902 TO BUS 916370 CKT 1 / 314902 8CARSON 500 916370 Z1-086 500 1
END

Bus Number	Bus Name	Full Contribution
242701	05LEESVI	0.17
242750	05PHILPO	0.04
246843	05SMG1	0.2
246844	05SMG2	0.54
246845	05SMG3	0.31
246846	05SMG4	0.55
246847	05SMG5	0.21
315150	1BUGGS 1	0.51
315151	1BUGGS 2	0.51
315131	1EDGECMA	0.15
315132	1EDGECMB	0.15
315165	1HURT 1	0.18
315166	1HURT 2	0.18
315158	1KERR 1	0.08
315159	1KERR 2	0.23
315160	1KERR 3	0.23
315161	1KERR 4	0.23
315162	1KERR 5	0.23
315163	1KERR 6	0.23
315164	1KERR 7	0.23
244221	INDDRVL	0.08
315167	O06_DP01	0.02
315419	Q-070	0.03
242889	REUSENS	0.01
297087	V2-040	0.05
902621	W2-049	0.51
LTF	W4-049	7.4
907491	X1-084	0.54
LTF	X2-042	34.7
909841	X2-076 C	6.03
LTF	X4-041	8.49
LTF	Y1-002	33.98
LTF	Y1-004	43.91
LTF	Y1-007	30.5
LTF	Y2-004	17.12
LTF	Y2-005	6.84

LTF	Y2-006	17.55
LTF	Y2-033	6.17
LTF	Y2-034	19.96
LTF	Y2-035	21.66
LTF	Y2-114	5.61
LTF	Y2-115	6.16
LTF	Y3-028	10.92
LTF	Y3-069	17.13
LTF	Y3-072	17.13
LTF	Y3-094	27.66
915731	Y3-119 C	0.44
LTF	Z1-025	12.45
LTF	Z1-027	7.25
LTF	Z1-046	13.77
LTF	Z1-067	5.11
LTF	Z1-071	4.4
916371	Z1-086 C	226.93

Appendix 3

CONTINGENCY '8MORRSVL _8NO ANNA _033'
DISCONNECT BRANCH FROM BUS 314916 TO BUS 314918 CKT 1 /* 500/500KV, AREA 345/345.
END

Bus Number	Bus Name	Full Contribution
315170	1BREMO 3	0.31
315171	1BREMO 4	0.68
315150	1BUGGS 1	0.3
315151	1BUGGS 2	0.3
315094	1CHESPK1	16.3
315095	1CHESPK2	16.3
315096	1CHESPK3	22.17
315097	1CHESPK4	31.71
315098	1CHESPKA	0.07
315099	1CHESPKB	0.18
315153	1CLOVER1	2.42
315154	1CLOVER2	2.45
315131	1EDGECMA	0.24
315132	1EDGECMB	0.24
315108	1ELIZAR1	0.57
315109	1ELIZAR2	0.5
315110	1ELIZAR3	0.53
315139	1GASTONA	0.5
315141	1GASTONB	0.5
315260	1GOSPRTA	0.01
315261	1GOSPRTB	0.02
315262	1GOSPRTC	0.01
315158	1KERR 1	0.06
315159	1KERR 2	0.18
315160	1KERR 3	0.18
315161	1KERR 4	0.18
315162	1KERR 5	0.18
315163	1KERR 6	0.18
315164	1KERR 7	0.18
315111	1LKKINGA	0.26
315112	1LKKINGB	0.26
315172	1LOISA A	0.89
315173	1LOISA B	0.89
315174	1LOISA C	0.89
315175	1LOISA D	0.89
315176	1LOISA E	1.82
315225	1N ANNA1	21.88

315226	1N ANNA2	21.54
315126	1ROARAP2	0.23
315128	1ROARAP4	0.21
315134	1ROAVALA	0.75
315135	1ROAVALB	0.2
315136	1ROSEMG1	0.35
315138	1ROSEMG2	0.17
315137	1ROSEMS1	0.22
315177	1SANNAG1	0.84
315179	1SANNAG2	0.84
315178	1SANNAS1	0.43
315180	1SANNAS2	0.43
315115	1SHAMPT1	0.29
315083	1SPRUNCA	0.24
315084	1SPRUNCB	0.24
315085	1SPRUNCC	0.18
315086	1SPRUNCD	0.18
315073	1STONECA	4.35
315090	1YORKTN1	18.66
315091	1YORKTN2	19.36
314643	3O INLET	0.08
314539	3UNCAMP	2.03
314621	3WEYERH	0.13
315446	Q-065	1096.9
315419	Q-070	0.05
297087	V2-040	0.02
900671	V4-068 C	0.01
901081	W1-029 C	5.7
902241	W2-022 C OP1	1.3
902621	W2-049	0.21
903530	W3-066 C1OP1	2.87
903531	W3-066 C2OP1	2.87
LTF	W4-049	6.16
909841	X2-076 C	7.5
913391	Y1-086 C	0.03
914001	Y2-001 C	< 0.01
914181	Y2-066	0.04
914221	Y2-076	0.08
916051	Z1-036 C	5.64
916241	Z1-068 C	0.22
916371	Z1-086 C	291.53

Appendix 4

Generator Model Parameters

Combustion Turbine Generator Models:

Generator Model: GENROU
Excitation Model: EXST1
Governor Model: GAST
Power System Stabilizer Model: PSS2B

Steam Turbine Generator Models:

Generator Model: GENROU
Excitation Model: EXST1
Governor Model: N/A
Power System Stabilizer Model: PSS2B

```
/ ******  Z1-086  ******
916372  'GENROU'  1         7.8         0.045        0.87        0.074
          4.34       0.0         2.02         1.97        0.289
          0.468       0.226       0.158       0.16        0.7    /
916372  'GAST'    1          0.04        0.1          1           5.0
          1.0         3           1.0         0.05        0.1    /
916372  'EXST1'   1          0.008       999         -999        0.5
          1.90        171.5       0.029       4.52        -1.82
          0.11        0.0         1                       /
916372  'PSS2B'   1          2          0        3          0          4          1
          2          2          0.0      2          1000        2
          0.22        1.0         0.4      0.1         5
          0.28        0.02        0.28     0.02        0.25
          1.5         999         -999     999         -999
          0.05        -0.05 /
916373  'GENROU'  1         7.8         0.045        0.87        0.074
          4.34       0.0         2.02         1.97        0.289
          0.468       0.226       0.158       0.16        0.7    /
916373  'GAST'    1          0.04        0.1          1           5.0
          1.0         3           1.0         0.05        0.1    /
916373  'EXST1'   1          0.008       999         -999        0.5
          1.90        171.5       0.029       4.52        -1.82
          0.11        0.0         1                       /
916373  'PSS2B'   1          2          0        3          0          4          1
          2          2          0.0      2          1000        2
          0.22        1.0         0.4      0.1         5
          0.28        0.02        0.28     0.02        0.25
          1.5         999         -999     999         -999
          0.05        -0.05 /
```

```
916374  'GENROU'  1         7.8         0.045        0.87        0.074
          4.34       0.0         2.02         1.97        0.289
          0.468       0.226       0.158       0.16        0.7    /
916374  'GAST'    1          0.04        0.1          1           5.0
          1.0         3           1.0         0.05        0.1    /
916374  'EXST1'   1          0.008       999         -999        0.5
          1.90        171.5       0.029       4.52        -1.82
          0.11        0.0         1                       /
916374  'PSS2B'   1          2          0        3          0          4          1
          2          2          0.0      2          1000        2
          0.22        1.0         0.4      0.1         5
          0.28        0.02        0.28     0.02        0.25
```

```
            1.5         999         -999        999         -999
            0.05        -0.05 /
916375  'GENROU'  1         6.7         0.017       0.74        0.029
            4.05        0.0         1.60        1.57        0.258
            0.422       0.226       0.161       0.16        0.68    /
916375  'EXST1'   1         0.008       999         -999        0.48
            1.72        137.8       0.029       5.21        -1.93
            0.19        0.0         1                       /
916375  'PSS2B'   1         2         0       3         0         4         1
            2         2         0.0       2         1000        2
            0.247       1.0         0.4       0.1         5
            0.30        0.03        0.30      0.03        0.3
            1.5         999         -999        999         -999
            0.05        -0.05 /
```

Appendix 5

Case Name	Stable?	Max Angle	Element
(2019SLL_1207_NoBruns_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	87.08	
(2019SLL_1207_NoBruns_RAWL-CARS_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	80.9	
(2019SLL_1207_NoBruns_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	61.04	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(FB_BRUN1).txt	No	1.47E+05	ANGL315105[1BRUNSWICKS119.000]S1 0.1467E+06
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(FB_BRUN2).txt	No	8.74E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(FB_RAWL1).txt	Yes	82.13	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	89.55	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	77.45	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	92.46	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	97.02	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	94.06	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	97.77	
(2019SLL_2013Series_Z-086_BRUNS-RAWL_OS)_(2019SLL_PSS2A)_(N1_L585_GRNS_CRSN).txt	No	5.18E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_2013Series_Z-086_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	No	6.66E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_2013Series_Z-086_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	No	6.66E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_N11_CARS2_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	92.11	
(2019SLL_N11_CARS2_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	91.31	
(2019SLL_NoBruns_Z-086_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	No	1.48E+05	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_NoBruns_Z-086_RAWL-CARS_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	132.5	
(2019SLL_NoBruns_Z-086_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	No	7.90E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_Z-086_PMIN_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	110.4	
(2019SUM_1207_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	58.52	
(2019SUM_1376_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_1376_NoBruns_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	79.05	
(2019SUM_1376_NoBruns_Z086-CARS_OS)_(19SUM_Z086_Ed1)_(N1_L591_BRUN_RAWL).txt	Yes	79.05	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS0)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS1)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS2)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS2A)_(N1_L585_GRNS_CRSN).txt	Yes	80.23	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS3)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	

(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(FB_BRUN1).txt	No	1.47E+05	ANGL315105[1BRUNSWICKS119.000]S1 0.1467E+06
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(FB_BRUN2).txt	No	8.74E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(FB_RAWL1).txt	Yes	43.22	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L511_RAWL_CRSN).txt	Yes	51.63	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L556_CLOV_RAWL).txt	Yes	46.57	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L570_BRUN_WAKE).txt	Yes	50.48	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L585_GRNS_CRSN).txt	Yes	59.55	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L591_BRUN_RAWL).txt	Yes	55.17	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L595_BRUN_GRNS).txt	Yes	57.57	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(P2_BRUN_GNSVL_Sim).txt	No	1.51E+05	ANGL315105[1BRUNSWICKS119.000]S1 0.1506E+06
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	48.53	
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	47.23	
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	55.58	
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	No	6.63E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	53.31	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	58.34	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	45.89	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	68.15	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	63.09	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	59.36	
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	45.02	
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	54.01	
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	No	6.30E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	49.49	
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	51.76	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	48.8	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	46.4	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	56.65	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	51.82	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	54.49	
(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	130.5	
(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	46.02	
(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	60.4	

(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	No	6.61E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	No	8.89E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_BrunsOn_BRUNS-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	57.01	
(2019SUM_BrunsOn_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L595_BRUN_CARS).txt	Yes	55.98	
(2019SUM_BrunsOn_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_CARS).txt	Yes	53.21	
(2019SUM_N11_CARS2_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	55.47	
(2019SUM_N11_CARS2_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	47.04	
(2019SUM_N11_CARS2_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	54.98	
(2019SUM_N11_CARS2_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	55.34	
(2019SUM_N11_CARS2_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	55.17	
(2019SUM_PSS1_1376_BR_OS)_(2019SUM_PSS)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_Z-086_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	No	1.47E+05	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_Z-086_NoBruns_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	91.61	
(2019SUM_Z-086_NoBruns_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	43.83	
(2019SUM_Z-086_NoBruns_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	No	1.47E+05	ANGL916375[Z1-086_ST 23.000]1

Appendix 6

Description	Case Name	Stable?	Max Angle	Element
SLL Case - Z1-086 & Brunswick @ Pmax	(2019SLL_2013Series_Z-086_BRUNS-RAWL_OS)_(2019SLL_PSS2A)_(N1_L585_GRNS_CRSN).txt	No	5.18E+04	ANGL916375[Z1-086_ST 23.000]1
	(2019SLL_2013Series_Z-086_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	No	6.66E+04	ANGL916375[Z1-086_ST 23.000]1
	(2019SLL_2013Series_Z-086_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	No	6.66E+04	ANGL916375[Z1-086_ST 23.000]1
SLL Case - Z1-086 Dispatched to 1207 MW	(2019SLL_1207_NoBruns_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	87.08	
	(2019SLL_1207_NoBruns_RAWL-CARS_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	80.9	
	(2019SLL_1207_NoBruns_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	61.04	
SUM Case - Z1-086 Dispatched to 1207 MW	(2019SUM_1207_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	58.52	
SUM Case - Z1-086 Dispatched to 1376 MW	(2019SUM_1376_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
	(2019SUM_1376_NoBruns_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	79.05	
	(2019SUM_1376_NoBruns_Z086-CARS_OS)_(19SUM_Z086_Ed1)_(N1_L591_BRUN_RAWL).txt	Yes	79.05	
SUM Case - Z1-086 Dispatched to Pmax	(2019SUM_Z-086_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	No	1.47E+05	ANGL916375[Z1-086_ST 23.000]1
	(2019SUM_Z-086_NoBruns_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	91.61	
	(2019SUM_Z-086_NoBruns_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	43.83	
	(2019SUM_Z-086_NoBruns_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	No	1.47E+05	ANGL916375[Z1-086_ST 23.000]1

Generation Interconnection System Impact Study Report

For

TP Generation Interconnection Request Queue Position Z1-086

Carson – Heritage 500kV

October 2014

Introduction

This System Impact Study (SIS) has been prepared in accordance with the TP Open Access Transmission Tariff, Section 205, as well as the System Impact Study Agreement between Virginia Electric and Power Company (Interconnection Customer (IC)) and TP Interconnection, LLC (Transmission Provider (TP)). The Interconnected Transmission Owner (ITO) is Virginia Electric and Power Company.

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 TP network at a location specified by the IC. As a requirement for interconnection, the IC 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 TP system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on TP web site) for the appropriate transmission owner.

In some instances an IC 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 project developer 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

Virginia Electric and Power Company, the IC, has proposed a natural gas generating facility located at Greensville County, Virginia. The installed facilities will have a total capability of 1681 MW with 1630 MW of this output being recognized by TP as capacity. The proposed in-service date for this project is December 1, 2018. **This study does not imply an ITO commitment to this in-service date.**

Point of Interconnection

Z1-086 will interconnect with the ITO system via a new three breaker ring bus switching station that connects to the Carson – Heritage 500kV line.

Cost Summary

The Z1-086 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$2,600,000
Direct Connection Network Upgrades	$6,000,000
Non Direct Connection Network Upgrades	$22,000,000
Allocation for New System Upgrades	$0
Contribution for Previously Identified Upgrades	$TBD
Total Costs	**$30,600,000**

Attachment Facilities

Generation Substation: Install metering and associated Protection Equipment. Estimated Cost $600,000.

Transmission Line: Construct approximately one span of 500 kV Attachment line between the generation substation and Z1086 Switching Substation. The estimated cost for this work is $2,000,000.

The estimated total cost of the Attachment Facilities is $2,600,000. It is estimated to take 18-24 months to complete this work after execution of Interconnection Service Agreement (ISA) and Interconnection Construction Service Agreement (ICSA). 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. The single line is shown below in Attachment 1.

Direct Connection Cost Estimate

Substation: TP network upgrade # n4300 to establish the new 500 kV Z1086 Switching Substation (interconnection substation). The arrangement in the substation will be as shown below on Attachment 1: One–Line Diagram. The estimated cost of this facility is $6,000,000. It is estimated to take 24-36 months to complete this work after execution of ISA and ICSA.

Non-Direct Connection Cost Estimate

TP network upgrade n4258 to uprate the Carson to Rawlings 500 kV line to approximately 4300 MVA. The estimated cost is $22,000,000. It is estimated to take 20 months to complete. The time line to complete is based on being able to obtain outages to uprate line.

Interconnection Customer Requirements

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

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 TP Manuals M-01 and M-14D, and TP Tariff Sections 24.1 and 24.2.

Network Impacts

The Queue Project Z1-086 was studied as a 1630.0 MW (Capacity 1630.0 MW) injection tapping the Carson – Brunswick 500 kV line in the ITO area. Project Z1-086 was evaluated for compliance with applicable reliability planning criteria (TP, NERC, NERC Regional Reliability Councils, and Transmission Owners) for summer peak conditions in 2017. The stability analysis used a 2019 model and 1681MW injection. Queue project Z1-086 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
1127_B2_A	CONTINGENCY '1127_B2_A' OPEN BRANCH FROM BUS 314902 TO BUS 916370 CKT 1 / 314902 8CARSON 500 916370 Z1-086 500 1 END
8MORRSVL _8NO ANNA _033	CONTINGENCY '8MORRSVL _8NO ANNA _033' DISCONNECT BRANCH FROM BUS 314916 TO BUS 314918 CKT 1 /* 500/500KV, AREA 345/345. END

Generator Deliverability

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

Overload Number	Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Flowgate Appendix
1	N-1	1127_B2_A	CPLE - DVP	6PERSON230 T-6HALIFAX 230 kV line	304070	314697	1	DC	97.42	131.8	ER	712	244.79	1
2	N-1	1127_B2_A	DVP - DVP	6HALIFAX-6CLOVER 230 kV line	314697	314686	1	AC	82.18	112.47	ER	749	226.93	2

TP network upgrades n3289, n3290, and n3292 to build a 14 mile Heritage to Rawlings 500kV Line to approximately 3402 MVA. Work includes the Rawlings switching substation and re-arrangement at Carson substation. Included in this is a portion of the network upgrade n3287 to connect the new line into Heritage. These network upgrades were previously identified in TP Queue X2-076 due to the violations identified in Duke Progress. The cost allocation for $85,000,000 between the X2-076 project and the Z1-086 project will be determined during the facility study while performing a joint study with Duke Progress.

a. Install three breaker ring bus substation (Rawlings) on line 556 (n3289). The estimated cost is $6,000,000.
b. Construct new 500 kV 591 line between line 570 and 556 (n3290). The estimated cost is $78,000,000.
c. Rearrange the Carson 500 kV substation configuration to separate line 556 and 570 from the same breaker bay (n3292). The estimated cost is $1,000,000.
d. Construct one bay of the seven breaker switching substation (Heritage) for the new 591 line (portion of n3287).

With the network upgrades above added to the study an additional thermal violation was identified.

Overload Number	Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution
3	N-1	1127_B2_A	DVP - DVP	556BKRSTA-8CARSON 500 kV line	314995	314902	1	AC	75.69	102.55	ER	3402	923.75

TP network upgrade n4258 to uprate the Carson to Rawlings 500 kV Line to approximately 4300 MVA. The estimated cost is $22,000,000. It is estimated to take 20 months to complete. The time line to complete is based on being able to obtain outages to uprate line.

Queue	MW contribution	Percentage of Cost	Cost($M)
Z1-086	86.75	100.00%	22.0000

Multiple Facility Contingency

(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)

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 TP Queue)

Overload Number	Type	Contingency Name	Affected Area	Facility Description	Bus From	Bus To	Circuit	Power Flow	Loading % Initial	Loading % Final	Rating Type	Rating MVA	MW Contribution	Flowgate Appendix
4	N-1	8MORRSVL _8NO ANNA _033	DVP - DVP	8NO ANNA-8LDYSMTH 500 kV line	314918	314911	1	DC	103.7	112.61	ER	3219	291.53	4

TP network upgrade n0718.1 to build a 15-mile long North Anna – Lady Smith 2nd 500 kV line and install 500 kV breakers at North Anna and Ladysmith Stations. The estimated cost is $44,000,000. It is estimated to take 30 months to complete. Previously identified in PJM Queue Q65.

Queue	MW contribution	Percentage of Cost	Cost($44M)
Q65	400.00	43.57%	19.1697
X2-076	226.59	24.68%	10.8590
Z1-086	291.53	31.75%	13.9713

Steady-State Voltage Requirements

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

None

Stability and Reactive Power Requirement for Low Voltage Ride Through

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

Requirements

The following actions are required for Z1-086:

1. **Operating Restrictions**: There are N-1-1 operating conditions (such as maintenance outage) that result in transient instability with the addition of the Greensville units (Z1-086). Specifically, the following N-1 system conditions (pre-contingency) result in transient instability and/or poorly damped oscillations for the next contingency:
    - Brunswick-Rawlings 500kV line O/S
    - Z1-086-Carson 500kV line O/S
    - Rawlings-Carson 500kV line O/S

    To mitigate this instability, immediate operating restrictions must be enforced following an N-1 (planned or forced). For any of the system conditions defined above, without further study, generation at this location (Brunswick/Greensville) must be limited to:

Operating Restriction Recommendation Table

Online Generation	Brunswick Max Output [MW]	Z1-086 Max Output [MW]
If Brunswick is Offline…	N/A	<1200
If Z1-086 is Offline…	1376 (max)	N/A
If both Plants are Online…*	1376 (max)*	0*
*This assumes Brunswick is dispatched to full capacity. Z1-086 must be restricted to below its Pmin output of 862 MW. This assumes that the unit is normally operated with all combustion turbines running and the steam running at Pmin quantity.		

It is noted that Z1-086 is less stable than the Brunswick plant based on the parameters provided. Therefore, it must be restricted to a lower MW limit than Brunswick. These operating restrictions likely will require additional studies and possible further restriction on the units' output. This also is studied under 2019 light load and summer peak

conditions, and does not cover all possible system conditions. Therefore, system conditions could arise in the operational timeframe that could further limit the units' output.

2. **Installation of out-of-step protection**: This study was made using a certain set of operating conditions. There may be other operating conditions, although less probable, that can create stability problems either during high transfer or high voltage conditions. It is the Customer's responsibility to protect their own equipment from damage due to disturbances on the transmission system by installing out-of-step protection on their generators.

Recommendations

The following actions are recommended for Z1-086:

1. **Additional PSS Tuning Studies**: It is strongly recommended that additional PSS tuning studies be performed to ensure that the power system stabilizer is sufficiently damping out the oscillations of interest. The model provided uses the PSS2B model in PSS/e, whereas similar plants such as Warren County Power Station use the PSS2A model. Parameters are slightly modified between the two and should be investigated further. This could help lessen the restrictions identified above.

2. **Construction of Z1-086-Carson #2 500kV line**: For N-1-1 operating conditions (such as maintenance outage), the combination of Z1-086 and the existing Brunswick generating facility results in transient instability for a number of contingencies. These operating conditions can occur during times of maintenance and forced outage. Specifically, generation remaining connected to the grid solely through Brunswick-Wake 500kV line results in insufficient synchronizing torque to maintain stability. To mitigate this potentially unstable condition, and also to maintain voltage stability in the Clover area, the addition of Z1-086-Carson #2 500kV line provides a sufficiently strong connection to the grid at a low cost relative to other transmission infrastructure solutions.

3. **Coordinated Study with Duke / Progress Energy:** It is recommended that TP coordinate with Progress to ensure there are no negative impacts by the proposed Z1-086 project on their network. A study comprising both ITO and Duke / Progress Energy systems to develop comprehensive Operating Restrictions may be warranted.

   For more details see Attachment 2.

Light Load Analysis

(Study to determine that the Transmission System is capable of delivering the system generating capacity at light load)

Not required

Potential Congestion due to Local Energy Deliverability

TP 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.

Not applicable

ITO Analysis

ITO assessed the impact of the proposed Queue Project #Z1-086 interconnection as 1681MW of energy (Capacity 1630.0 MW) for compliance with reliability criteria on ITO's Transmission System. The system was assessed using the summer 2017 RTEP case provided to ITO by TP. 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's 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 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. The results of these studies are discussed in more detail below.

A. Category B Analysis (Single Contingency):

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

B. 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

C. 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 First Contingency Incremental Transfer Capacity between utilities. The results of these studies can be found in Tables A and B for both with and without Z1-086.

Table A: Import Study Results

Import Study Results			
Area	**Summer 2017**	**Summer 2017 with Z1-086**	**Limiting Element**
AEP	2000+	2000+	None
APS	2000+	2000+	None
CPL	2000+	-411	None
TP	2000+	2000+	None

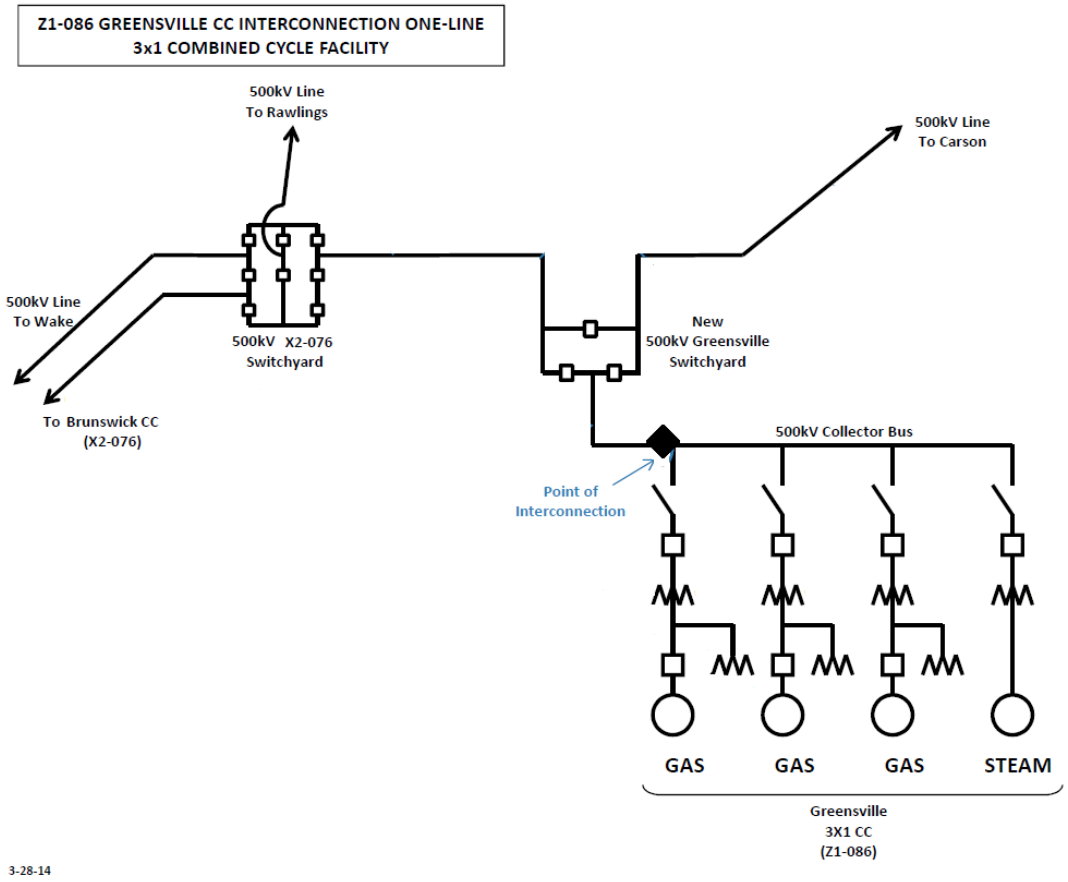
Table B: Export Study Results

Export Study Results			
Area	**Summer 2017**	**Summer 2017 with Z1-036**	**Limiting Element**
AEP	2000+	2000+	None
APS	2000+	2000+	None
CPL	2000+	2000+	None
TP	2000+	2000+	None

ITO's Planning Criteria indicates a need to have approximately 2000 MW of import and export capability. The results of these import and export studies indicate that the proposed generation facility will impact ITO's import or export capability. Upgrades required to reliably interconnect the proposed generating facility with ITO's Transmission Facilities will resolve the identified deficiencies.

Attachment 1. Z1-086

Single Line



Attachment 2.

Z1-086 Stability Study Report

Introduction

This study evaluates the stability and dynamics for TP queue project Z1-086 on the ITO transmission system facilities only. The Z1-086 project is a combined cycle comprising of one steam turbine generator (ST) and three combustion turbine generators (C1, C2, C3) connecting to a new facility located approximately 0.5 miles from the new Brunswick 500kV switching station along the new Brunswick-Carson 500kV line. This new Brunswick 500kV substation is a new switching station added to the existing Carson-Wake 500kV line approximately 30 miles from Carson and 90 miles from Wake. Z1-086 queue project requests 1630 MW capacity / 1681 MW energy at the point of interconnection.

For this stability study, the Z1-086 project was studied with total net generating output of 1681 MW delivered to the grid (combustion and steam units modeled with 12.5 MW and 5.0 MW stations service, respectively).

Note: This study by ITO does not evaluate the stability and dynamic impacts for the above mentioned queue project for faults on the Duke / Progress Energy system.

Analysis

The stability study for Z1-086 was performed using the 2019 heavy summer base case and 2019 light load base case conditions. The most severe contingencies were studied for this particular generating resource to ensure transient stability during and immediately after faults on the transmission system. Three phase faults with normal clearing and single-line-to-ground faults with delayed clearing were studied. For the purposes of this study, fault clearing time is:

- 500kV normal clearing: 3 cycle and 4 cycle for near and far side, respectively.
- 500kV delayed clearing: 12 cycle near side (delayed clearing with backup) and 4 cycle far side.

Queue project Z1-086 was modeled as one 23 kV steam generator and three 20 kV combustion generators (see Appendix 4). The generators were dispatched into leading power factor region as required by ITO Planning criteria. In general, the units were dispatched at approximately 50% under-excitation (about 50% of Qmin) for each N-0 base case condition studied. The generators have the following MW and MVAR output characteristics.

Table 1. Generator Output Characteristics

	ST	C1	C2	C3
Pmax [MW]	629	365	365	365
Station Load	5	12.5	12.5	12.5

[MW]				
Qmax [MVAR]	368	169	169	169
Qmin [MVAR]	-262	-160	-160	-160
50% Qmin [MVAR]	-131	-80	-80	-80

Note: N-1-1 transient stability analysis did not consider redispatch of the units' MW output prior to applying the next N-1 contingency in dynamics (time step integration); however, the units were set with 50% under-excitation in all cases (unless terminal voltage below 0.95 pu). The terminal voltage in each of the cases is shown in the table below:

Table 2. Base Case Conditions

Root Case	Operating Cond	Condition	500kV	C1/C2/C3	ST
2019SLL		N-0 Base	1.0349	0.9539	0.9626
		BRUNS-RAWL O/S	1.0341	0.9531	0.9618
		Z1-086-CARS O/S	1.0360	0.9550	0.9637
		RAWL-CARS O/S	1.0348	0.9538	0.9625
		Z1-086-CARS O/S	1.0349	0.9539	0.9626
	CARS #2 Add	N-0 Base	1.0349	0.9539	0.9626
	CARS #2 Add	BRUNS-RAWL O/S	1.036	0.9550	0.9637
2019SUM		N-0 Base	1.0341	0.9531	0.9618
	BRUNS ONLY – No Z1-086	N-0 Base			
	BRUNS ONLY – No Z1-086	BRUNS-RAWL O/S			
	BRUNS ONLY – No Z1-086	RAWL-CARS O/S			

	Z1-086 ONLY – No BRUNS	N-0 Base	1.0254	0.9509	0.9566
				-60MVAR	-110 MVAR
		BRUNS-RAWL O/S	1.0327	0.9517	0.9604
		BRUNS-WAKE O/S	1.0339	0.9529	0.9617
		RAWL-CLOV O/S	1.0908	0.9498	0.9586
		Z1-086-CARS O/S	1.0339	0.9529	0.9617
	CARS #2 Add	RAWL-CARS O/S	1.0351	0.9541	0.9628
	CARS #2 Add	BRUNS-RAWL O/S	1.0401	0.9591	0.9678
	CARS #2 Add	RAWL-CARS O/S	1.0385	0.9575	0.9575
	CARS #2 Add	Z1-086-CARS O/S	1.0341	0.9531	0.9618

Results

Results – 2019 Heavy Summer and Light Load

Stability results in tabular form regarding transient swing angle are provided in Appendix 5. Absolute angle is shown, and very large absolute angle is indication of out-of-step conditions. Further analysis is performed for oscillation damping analysis of concern. Observations regarding transient stability performance for Z1-086 and the Brunswick generating facility are as follows:

1. Z1-086 (and Brunswick plant) maintains transient stability with acceptable swing angle for all N-1 three-phase (3P) fault conditions and breaker failure single-line-to-ground (SLG) fault conditions. Oscillation damping for these contingencies is acceptable according to ITO Planning criteria.
2. N-1 maintenance outages pose a stability restriction on safe and reliable operation of the Z1-086 project as well as Brunswick generating facility. Complete simulation results are included in the Appendix 5 and 6.

- Loss of Carson-Z1-086 500kV line with Rawlings-Brunswick 500kV line out-of-service (O/S) results in instability.
- Loss of Rawlings-Brunswick 500kV line with Carson-Z1-086 line O/S is unstable.
- Loss of Z1-086-Carson 500kV line with Rawlings-Carson 500kV O/S results in severe transient instability at Brunswick, Z1-086, and Clover generating plants.

3. Transient stability results demonstrate that if Brunswick generating facility is generating at full capacity, Z1-086 will be forced to shut down due to operating restriction and minimum output (Pmin) requirements (as modeled in the case).
4. Stability results demonstrate a lower frequency oscillation in the 0.02-0.05 Hz range that is an indication that further PSS tuning studies should be performed to improve stability for these conditions.

Results – Operating Restrictions

To understand how generation in this area must be dispatched for an N-1 pre-contingency outage (forced or planned), three distinct conditions are considered:

1. Brunswick Generation Online Only – Z1-086 is offline.
2. Z1-086 Generation Online Only – Brunswick is offline.
3. Combined output of Brunswick & Z1-086 – Brunswick is assumed to have full capacity rights and priority is given to dispatching Brunswick for this analysis.

Results from this analysis in terms of maximum absolute angle are shown in Appendix 6.

Oscillation damping results for restricted output conditions are also considered by analyzing transient ringdown. Results for oscillation ringdown analysis are shown in the table below.

Table 3. Restricted Output Modal Analysis

BRUNSWICK ONLY

Window 1	Freq [Hz]	1.053	0.282	0.718
	Real	-0.180646	-1.3404	-0.432645
	Imaginary	6.61367	1.77036	4.51225
	Energy	16.156	5.5723	3.0951
	Damping %	2.730385	60.363397	9.5444593
Window 2	Freq [Hz]	1.05	0.862	0.688
	Real	-0.220996	-0.327488	-1.05016
	Imaginary	6.59975	5.41622	4.32335
	Energy	9.7463	3.3758	3.093
	Damping %	3.3466753	6.0354084	23.604054

1376 MW Reduction

Window 1	Freq [Hz]	0.977	0.859	0.634
	Real	-0.1129	-0.121443	-0.3231

	Imaginary	6.13923	5.39799	3.98401
	Energy	9.699	3.9317	2.0939
	Damping %	1.838682	2.2492127	8.0833805
Window 2	Freq [Hz]	0.565	0.829	0.982
	Real	-1.9465	-1.59522	-0.11907
	Imaginary	3.55038	5.20645	6.16739
	Energy	8.8779	8.385	7.2901
	Damping %	48.074098	29.295081	1.9302787

1207 MW Reduction

Window 1	Freq [Hz]	0.999	0.865	0.642
	Real	-0.270063	-0.17618	-0.242455
	Imaginary	6.27381	5.43487	4.03451
	Energy	12.882	4.658	1.7077
	Damping %	4.3006265	3.239958	5.9987056

The following observations are made:

1. Brunswick Generation Only – Brunswick experiences relatively low damping ratio for the system conditions used. This is a separate issue that will need to be addressed. However, this is used as a baseline for this analysis in terms of oscillatory and transient stability.
2. Z1-086 Generation Only – At full output, Z1-086 is transient unstable for N-1-1 contingencies.
    a. Therefore, MW output is restricted first to 1376 MW (to match Brunswick output) in the 2019SUM heavy summer case (which is more stable). Although the unit maintains synchronism, oscillation damping is insufficient.
    b. Generating output is set to 1207, which is approximately 70% of maximum generating capability. The unit maintains synchronism with measured oscillation damping for the predominant mode of 0.999 Hz of 4.3% with a secondary mode of 0.865 Hz with 3.24% damping ration. This is considered sufficient for the purposes of this study, and the primary oscillation frequency is above the 4% criteria in the ITO Planning Manual.
3. Combined Brunswick & Z1-086 – For this analysis, Brunswick is dispatched at full output and Z1-086 is studied as variable scheduled generation. Results show that even with Z1-086 set to minimum output power, Pmin, oscillation damping remains negative. Therefore, it is determined that Z1-086 must remain offline when Brunswick is scheduled near full output for certain N-1 system conditions identified.

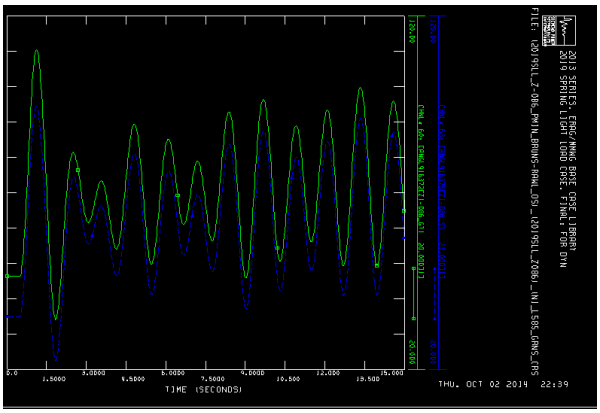


Figure 1. Undamped oscillation frequency for Brunswick + Z1-086 at Pmin.

Results – 2019 Heavy Summer with Modified PSS Settings

The tables below show oscillation ringdown analysis results for various perturbations of the PSS settings. These studies were performed on the base case with Brunswick-Rawlings 500 out of service pre-contingency and then the Z1-086-Carson contingency is applied, with the Brunswick unit offline and Z1-086 at 1376 MW output (to match maximum Brunswick output). Legend of case names is as follows:

- PSS0 – Data as Provided
- PSS1 – Change Washout Filters to 10 sec
- PSS2 – Change Gain to 10
- PSS3 – Change Gain to 2
- PSS4 – Change to PSS2A Model (Match Warren County Power Station)

The modal information contained below is generated from PSS/e modal analysis using Least Squares / Eigenvector Fit by Initial Points, and ensuring that small error ratio and high signal to noise ratio is achieved. Energy is ranked left to right in the table below.

Table 4. PSS Tuning Modal Analysis Results

BRUNSWICK ONLY

Window 1	Freq [Hz]	1.053	0.282	0.718
	Real	-0.180646	-1.3404	-0.432645
	Imaginary	6.61367	1.77036	4.51225
	Energy	16.156	5.5723	3.0951
	Damping %	2.730385	60.363397	9.5444593
Window 2	Freq [Hz]	1.05	0.862	0.688
	Real	-0.220996	-0.327488	-1.05016
	Imaginary	6.59975	5.41622	4.32335
	Energy	9.7463	3.3758	3.093
	Damping %	3.3466753	6.0354084	23.604054

PSS0

Window 1	Freq [Hz]	0.953	0.925	0.563
	Real	-0.161419	-0.188842	0.0058838
	Imaginary	5.98723	5.80938	3.53445
	Energy	28.083	22.819	0.54607
	Damping %	2.6950755	3.2489234	-0.166471
Window 2	Freq [Hz]	0.981	0.873	0.68
	Real	-0.114955	-0.155767	-1.32441
	Imaginary	6.1636	5.48389	4.27027
	Energy	6.4491	3.5218	2.1548
	Damping %	1.8647383	2.839302	29.622657

PSS1

Window 1	Freq [Hz]	0.96	0.916	1.41
	Real	-0.102707	-0.281596	-0.36387
	Imaginary	6.03318	5.758	8.8533
	Energy	15.41	14.566	0.2621
	Damping %	1.7021226	4.8846796	4.106526
Window 2	Freq [Hz]	0.982	0.874	0.679
	Real	-0.0993	-0.143068	-1.18524
	Imaginary	6.16873	5.48918	4.26742
	Energy	6.7119	3.2217	1.9723
	Damping %	1.6095231	2.605479	26.761149

PSS2

Window 1	Freq [Hz]	0.898	0.947	1.325
	Real	-0.392178	-0.160423	-1.10344
	Imaginary	5.6453	5.94978	8.32253
	Energy	15.196	11.004	0.25627
	Damping %	6.9302796	2.695305	13.143449
Window 2	Freq [Hz]	0.976	0.866	0.646
	Real	-0.221911	-0.152419	-0.98247
	Imaginary	6.13361	5.44092	4.05989
	Energy	3.8846	3.2778	1.0529
	Damping %	3.6155854	2.8002476	23.520527

PSS3

Window 1	Freq [Hz]	0.971	0.905	1.431
	Real	-0.046875	-0.286146	-1.12292
	Imaginary	6.1014	5.68323	8.98932
	Energy	13.018	9.9402	0.40152

	Damping %	0.7682436	5.0285488	12.395376
Window 2	Freq [Hz]	0.982	0.874	0.701
	Real	-0.044479	-0.123643	-1.02159
	Imaginary	6.17307	5.49178	4.40707
	Energy	8.8839	3.0369	1.8017
	Damping %	0.7205142	2.250849	22.581931

PSS4

Window 1	Freq [Hz]	0.763	0.828	0.954
	Real	-1.06275	-0.046525	-0.103629
	Imaginary	4.79232	5.20437	5.99106
	Energy	5.0499	3.7681	1.8523
	Damping %	21.650141	0.8939188	1.7294686
Window 2	Freq [Hz]	0.847	0.937	0.88
	Real	-0.179459	-0.393072	-1.24357
	Imaginary	5.31872	5.88474	5.52795
	Energy	7.0207	4.7917	2.4065
	Damping %	3.3721823	6.6646625	21.947545

The results show no major improvement by increasing the washout filter time constants. Oscillation damping is moderately improved for an increase in PSS Gain from 5 to 10, and conversely negatively impacted by a reduction in PSS Gain from 5 to 2. Mirroring the Warren County Power Station units' PSS settings on the Z1-086 model does not produce sufficient damping, leading to the conclusion that it may not necessarily be an issue with the PSS. But further study is required.

Results – 2019 Heavy Summer and Light Load w/ Added Z1-086-Carson #2 500kV Line

Stability results in tabular form regarding transient swing angle are provided in Appendix 5. Observations regarding transient stability performance for Z1-086 and the Brunswick generating facility are as follows:

1. Z1-086 (and Brunswick plant) maintains transient stability with acceptable swing angle for all identified transient unstable conditions in the 2019SUM and 2019SLL discussed above. Oscillation damping is also improved for this addition.
2. In the N-1-1 conditions, all credible contingencies result in transient stability with the additional Z1-086-Carson #2 line.

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

CONTINGENCY '1127_B2_A'
OPEN BRANCH FROM BUS 314902 TO BUS 916370 CKT 1 / 314902 8CARSON 500 916370 Z1-086 500 1
END

Bus Number	Bus Name	Full Contribution
242750	05PHILPO	0.03
315131	1EDGECMA	0.14
315132	1EDGECMB	0.14
LTF	W4-049	7.98
LTF	X2-042	34.53
909841	X2-076 C	6.51
LTF	X4-041	8.48
LTF	Y1-002	33.95
LTF	Y1-004	43.79
LTF	Y1-007	30.42
LTF	Y2-004	17.09
LTF	Y2-005	6.84
LTF	Y2-006	17.55
LTF	Y2-033	6.19
LTF	Y2-034	20.04
LTF	Y2-035	22.9
LTF	Y2-114	5.61
LTF	Y2-115	6.16
LTF	Y3-028	10.83
LTF	Y3-069	17.06
LTF	Y3-072	17.06
LTF	Y3-094	27.46
LTF	Z1-025	12.45
LTF	Z1-027	7.22
LTF	Z1-046	13.64
LTF	Z1-067	5.36
LTF	Z1-071	4.31
916371	Z1-086 C	244.79

Appendix 2

CONTINGENCY '1127_B2_A'
OPEN BRANCH FROM BUS 314902 TO BUS 916370 CKT 1 / 314902 8CARSON 500 916370 Z1-086 500 1
END

Bus Number	Bus Name	Full Contribution
242701	05LEESVI	0.17
242750	05PHILPO	0.04
246843	05SMG1	0.2
246844	05SMG2	0.54
246845	05SMG3	0.31
246846	05SMG4	0.55
246847	05SMG5	0.21
315150	1BUGGS 1	0.51
315151	1BUGGS 2	0.51
315131	1EDGECMA	0.15
315132	1EDGECMB	0.15
315165	1HURT 1	0.18
315166	1HURT 2	0.18
315158	1KERR 1	0.08
315159	1KERR 2	0.23
315160	1KERR 3	0.23
315161	1KERR 4	0.23
315162	1KERR 5	0.23
315163	1KERR 6	0.23
315164	1KERR 7	0.23
244221	INDDRVL	0.08
315167	O06_DP01	0.02
315419	Q-070	0.03
242889	REUSENS	0.01
297087	V2-040	0.05
902621	W2-049	0.51
LTF	W4-049	7.4
907491	X1-084	0.54
LTF	X2-042	34.7
909841	X2-076 C	6.03
LTF	X4-041	8.49
LTF	Y1-002	33.98
LTF	Y1-004	43.91
LTF	Y1-007	30.5
LTF	Y2-004	17.12
LTF	Y2-005	6.84

LTF	Y2-006	17.55
LTF	Y2-033	6.17
LTF	Y2-034	19.96
LTF	Y2-035	21.66
LTF	Y2-114	5.61
LTF	Y2-115	6.16
LTF	Y3-028	10.92
LTF	Y3-069	17.13
LTF	Y3-072	17.13
LTF	Y3-094	27.66
915731	Y3-119 C	0.44
LTF	Z1-025	12.45
LTF	Z1-027	7.25
LTF	Z1-046	13.77
LTF	Z1-067	5.11
LTF	Z1-071	4.4
916371	Z1-086 C	226.93

Appendix 3

CONTINGENCY '8MORRSVL _8NO ANNA _033'
DISCONNECT BRANCH FROM BUS 314916 TO BUS 314918 CKT 1 /* 500/500KV, AREA 345/345.
END

Bus Number	Bus Name	Full Contribution
315170	1BREMO 3	0.31
315171	1BREMO 4	0.68
315150	1BUGGS 1	0.3
315151	1BUGGS 2	0.3
315094	1CHESPK1	16.3
315095	1CHESPK2	16.3
315096	1CHESPK3	22.17
315097	1CHESPK4	31.71
315098	1CHESPKA	0.07
315099	1CHESPKB	0.18
315153	1CLOVER1	2.42
315154	1CLOVER2	2.45
315131	1EDGECMA	0.24
315132	1EDGECMB	0.24
315108	1ELIZAR1	0.57
315109	1ELIZAR2	0.5
315110	1ELIZAR3	0.53
315139	1GASTONA	0.5
315141	1GASTONB	0.5
315260	1GOSPRTA	0.01
315261	1GOSPRTB	0.02
315262	1GOSPRTC	0.01
315158	1KERR 1	0.06
315159	1KERR 2	0.18
315160	1KERR 3	0.18
315161	1KERR 4	0.18
315162	1KERR 5	0.18
315163	1KERR 6	0.18
315164	1KERR 7	0.18
315111	1LKKINGA	0.26
315112	1LKKINGB	0.26
315172	1LOISA A	0.89
315173	1LOISA B	0.89
315174	1LOISA C	0.89
315175	1LOISA D	0.89
315176	1LOISA E	1.82
315225	1N ANNA1	21.88

315226	1N ANNA2	21.54
315126	1ROARAP2	0.23
315128	1ROARAP4	0.21
315134	1ROAVALA	0.75
315135	1ROAVALB	0.2
315136	1ROSEMG1	0.35
315138	1ROSEMG2	0.17
315137	1ROSEMS1	0.22
315177	1SANNAG1	0.84
315179	1SANNAG2	0.84
315178	1SANNAS1	0.43
315180	1SANNAS2	0.43
315115	1SHAMPT1	0.29
315083	1SPRUNCA	0.24
315084	1SPRUNCB	0.24
315085	1SPRUNCC	0.18
315086	1SPRUNCD	0.18
315073	1STONECA	4.35
315090	1YORKTN1	18.66
315091	1YORKTN2	19.36
314643	3O INLET	0.08
314539	3UNCAMP	2.03
314621	3WEYERH	0.13
315446	Q-065	1096.9
315419	Q-070	0.05
297087	V2-040	0.02
900671	V4-068 C	0.01
901081	W1-029 C	5.7
902241	W2-022 C OP1	1.3
902621	W2-049	0.21
903530	W3-066 C1OP1	2.87
903531	W3-066 C2OP1	2.87
LTF	W4-049	6.16
909841	X2-076 C	7.5
913391	Y1-086 C	0.03
914001	Y2-001 C	< 0.01
914181	Y2-066	0.04
914221	Y2-076	0.08
916051	Z1-036 C	5.64
916241	Z1-068 C	0.22
916371	Z1-086 C	291.53

Appendix 4

Generator Model Parameters

Combustion Turbine Generator Models:

Generator Model: GENROU
Excitation Model: EXST1
Governor Model: GAST
Power System Stabilizer Model: PSS2B

Steam Turbine Generator Models:

Generator Model: GENROU
Excitation Model: EXST1
Governor Model: N/A
Power System Stabilizer Model: PSS2B

```
/ ******  Z1-086  ******
916372  'GENROU'  1         7.8         0.045        0.87        0.074
          4.34       0.0         2.02         1.97        0.289
          0.468       0.226       0.158       0.16        0.7    /
916372  'GAST'    1          0.04        0.1          1           5.0
          1.0         3           1.0         0.05        0.1    /
916372  'EXST1'   1          0.008       999         -999        0.5
          1.90        171.5       0.029       4.52        -1.82
          0.11        0.0         1                       /
916372  'PSS2B'   1          2          0        3          0          4          1
          2          2          0.0      2          1000        2
          0.22        1.0         0.4      0.1         5
          0.28        0.02        0.28     0.02        0.25
          1.5         999         -999     999         -999
          0.05        -0.05 /
916373  'GENROU'  1         7.8         0.045        0.87        0.074
          4.34       0.0         2.02         1.97        0.289
          0.468       0.226       0.158       0.16        0.7    /
916373  'GAST'    1          0.04        0.1          1           5.0
          1.0         3           1.0         0.05        0.1    /
916373  'EXST1'   1          0.008       999         -999        0.5
          1.90        171.5       0.029       4.52        -1.82
          0.11        0.0         1                       /
916373  'PSS2B'   1          2          0        3          0          4          1
          2          2          0.0      2          1000        2
          0.22        1.0         0.4      0.1         5
          0.28        0.02        0.28     0.02        0.25
          1.5         999         -999     999         -999
          0.05        -0.05 /
```

```
916374  'GENROU'  1         7.8         0.045        0.87        0.074
          4.34       0.0         2.02         1.97        0.289
          0.468       0.226       0.158       0.16        0.7    /
916374  'GAST'    1          0.04        0.1          1           5.0
          1.0         3           1.0         0.05        0.1    /
916374  'EXST1'   1          0.008       999         -999        0.5
          1.90        171.5       0.029       4.52        -1.82
          0.11        0.0         1                       /
916374  'PSS2B'   1          2          0        3          0          4          1
          2          2          0.0      2          1000        2
          0.22        1.0         0.4      0.1         5
          0.28        0.02        0.28     0.02        0.25
```

```
            1.5         999         -999        999         -999
            0.05        -0.05 /
916375  'GENROU'  1         6.7         0.017       0.74        0.029
            4.05        0.0         1.60        1.57        0.258
            0.422       0.226       0.161       0.16        0.68    /
916375  'EXST1'   1         0.008       999         -999        0.48
            1.72        137.8       0.029       5.21        -1.93
            0.19        0.0         1                       /
916375  'PSS2B'   1         2         0       3         0         4         1
            2         2         0.0       2         1000        2
            0.247       1.0         0.4       0.1         5
            0.30        0.03        0.30      0.03        0.3
            1.5         999         -999        999         -999
            0.05        -0.05 /
```

Appendix 5

Case Name	Stable?	Max Angle	Element
(2019SLL_1207_NoBruns_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	87.08	
(2019SLL_1207_NoBruns_RAWL-CARS_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	80.9	
(2019SLL_1207_NoBruns_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	61.04	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(FB_BRUN1).txt	No	1.47E+05	ANGL315105[1BRUNSWICKS119.000]S1 0.1467E+06
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(FB_BRUN2).txt	No	8.74E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(FB_RAWL1).txt	Yes	82.13	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	89.55	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	77.45	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	92.46	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	97.02	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	94.06	
(2019SLL_2013Series_Z-086)_(2019SLL_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	97.77	
(2019SLL_2013Series_Z-086_BRUNS-RAWL_OS)_(2019SLL_PSS2A)_(N1_L585_GRNS_CRSN).txt	No	5.18E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_2013Series_Z-086_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	No	6.66E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_2013Series_Z-086_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	No	6.66E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_N11_CARS2_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	92.11	
(2019SLL_N11_CARS2_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	91.31	
(2019SLL_NoBruns_Z-086_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	No	1.48E+05	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_NoBruns_Z-086_RAWL-CARS_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	132.5	
(2019SLL_NoBruns_Z-086_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	No	7.90E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SLL_Z-086_PMIN_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	110.4	
(2019SUM_1207_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	58.52	
(2019SUM_1376_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_1376_NoBruns_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	79.05	
(2019SUM_1376_NoBruns_Z086-CARS_OS)_(19SUM_Z086_Ed1)_(N1_L591_BRUN_RAWL).txt	Yes	79.05	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS0)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS1)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS2)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS2A)_(N1_L585_GRNS_CRSN).txt	Yes	80.23	
(2019SUM_1376_PSS_BRUNS-RAWL_OS)_(2019SUM_PSS3)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	

(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(FB_BRUN1).txt	No	1.47E+05	ANGL315105[1BRUNSWICKS119.000]S1 0.1467E+06
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(FB_BRUN2).txt	No	8.74E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(FB_RAWL1).txt	Yes	43.22	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L511_RAWL_CRSN).txt	Yes	51.63	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L556_CLOV_RAWL).txt	Yes	46.57	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L570_BRUN_WAKE).txt	Yes	50.48	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L585_GRNS_CRSN).txt	Yes	59.55	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L591_BRUN_RAWL).txt	Yes	55.17	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(N1_L595_BRUN_GRNS).txt	Yes	57.57	
(2019SUM_2013Series_Z-086)_(2019SUM_2013Series_Z-086)_(P2_BRUN_GNSVL_Sim).txt	No	1.51E+05	ANGL315105[1BRUNSWICKS119.000]S1 0.1506E+06
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	48.53	
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	47.23	
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	55.58	
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	No	6.63E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_2013Series_Z-086_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	53.31	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	58.34	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	45.89	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	68.15	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	63.09	
(2019SUM_2013Series_Z-086_BRUNS-WAKE_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	59.36	
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	45.02	
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	54.01	
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	No	6.30E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	49.49	
(2019SUM_2013Series_Z-086_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	51.76	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	48.8	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	46.4	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	56.65	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	51.82	
(2019SUM_2013Series_Z-086_RAWL-CLOV_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	54.49	
(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L511_RAWL_CRSN).txt	Yes	130.5	
(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L556_CLOV_RAWL).txt	Yes	46.02	
(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L570_BRUN_WAKE).txt	Yes	60.4	

(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	No	6.61E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_2013Series_Z-086_Z086-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	No	8.89E+04	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_BrunsOn_BRUNS-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	57.01	
(2019SUM_BrunsOn_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L595_BRUN_CARS).txt	Yes	55.98	
(2019SUM_BrunsOn_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_CARS).txt	Yes	53.21	
(2019SUM_N11_CARS2_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	55.47	
(2019SUM_N11_CARS2_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	47.04	
(2019SUM_N11_CARS2_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	54.98	
(2019SUM_N11_CARS2_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	55.34	
(2019SUM_N11_CARS2_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	55.17	
(2019SUM_PSS1_1376_BR_OS)_(2019SUM_PSS)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
(2019SUM_Z-086_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	No	1.47E+05	ANGL916375[Z1-086_ST 23.000]1
(2019SUM_Z-086_NoBruns_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	91.61	
(2019SUM_Z-086_NoBruns_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	43.83	
(2019SUM_Z-086_NoBruns_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	No	1.47E+05	ANGL916375[Z1-086_ST 23.000]1

Appendix 6

Description	Case Name	Stable?	Max Angle	Element
SLL Case - Z1-086 & Brunswick @ Pmax	(2019SLL_2013Series_Z-086_BRUNS-RAWL_OS)_(2019SLL_PSS2A)_(N1_L585_GRNS_CRSN).txt	No	5.18E+04	ANGL916375[Z1-086_ST 23.000]1
	(2019SLL_2013Series_Z-086_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	No	6.66E+04	ANGL916375[Z1-086_ST 23.000]1
	(2019SLL_2013Series_Z-086_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	No	6.66E+04	ANGL916375[Z1-086_ST 23.000]1
SLL Case - Z1-086 Dispatched to 1207 MW	(2019SLL_1207_NoBruns_BRUNS-RAWL_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	87.08	
	(2019SLL_1207_NoBruns_RAWL-CARS_OS)_(2019SLL_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	80.9	
	(2019SLL_1207_NoBruns_Z086-CARS_OS)_(2019SLL_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	61.04	
SUM Case - Z1-086 Dispatched to 1207 MW	(2019SUM_1207_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	58.52	
SUM Case - Z1-086 Dispatched to 1376 MW	(2019SUM_1376_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	80.04	
	(2019SUM_1376_NoBruns_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	Yes	79.05	
	(2019SUM_1376_NoBruns_Z086-CARS_OS)_(19SUM_Z086_Ed1)_(N1_L591_BRUN_RAWL).txt	Yes	79.05	
SUM Case - Z1-086 Dispatched to Pmax	(2019SUM_Z-086_NoBruns_BRUNS-RAWL_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	No	1.47E+05	ANGL916375[Z1-086_ST 23.000]1
	(2019SUM_Z-086_NoBruns_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L585_GRNS_CRSN).txt	Yes	91.61	
	(2019SUM_Z-086_NoBruns_RAWL-CARS_OS)_(19SUM_Z086)_(N1_L595_BRUN_GRNS).txt	Yes	43.83	
	(2019SUM_Z-086_NoBruns_Z086-CARS_OS)_(19SUM_Z086)_(N1_L591_BRUN_RAWL).txt	No	1.47E+05	ANGL916375[Z1-086_ST 23.000]1