Interconnection System Impact Study
Final Report – January 5, 2016

Generator Interconnection Request No. TI-15-0828
150 MW Wind Energy Generating Facility
In Elbert County, Colorado

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NOTE: Appendices are Tri-State Confidential, are available only to the IC and Affected Systems upon request, and are not for posting on OASIS.

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1.0 EXECUTIVE SUMMARY

This System Impact Study (SIS) is for Generator Interconnection Request No. TI-15-0828, a proposed 150 MW wind energy Generating Facility (GF) located in Elbert County, Colorado. This SIS was prepared in accordance with Tri-State Generation and Transmission Association, Inc. (Tri-State) Generator Interconnection Procedures, and includes steady-state power flow, dynamic stability, short-circuit, cost and schedule analyses for interconnection of the project as a Network Resource.

Studies completed for other interconnection requests in this region indicate that until such time that Tri-State's planned Burlington - Wray 230 kV line is in-service, additional generation can only be accommodated by the transmission system on an as available basis. The Burlington - Wray 230 kV line has a planned in-service date of 2Q/2016.

The proposed Project consists of seventy-five (75) GE 2.0-116 wind turbines and one 34.5-230-13.8 kV transformer at the main wind energy generating facility (GF) with a primary Point of Interconnection (POI) at the Lincoln 230 kV Substation via a three (3) mile 230 kV transmission line (see Figures 1 and 3 for reference).

Three generation dispatch scenarios were studied for this Project: 1) local area generation was modeled as in the WECC base case dispatch, 2) maximum local area generation was dispatched and 3) maximum local area generation was dispatched except the existing Limon generation was replaced by the Project generation - see Table 4.

Steady-state power flow results:

For 2017 Heavy Summer system conditions, no elements exceeded their emergency thermal limits for any of the generation dispatch scenarios.

For 2017 Light Spring system conditions, there were five (5) transmission line sections that exceeded their emergency thermal limits as a result of the Project generation. However, this was only for generation dispatch scenario 2 (maximum local area generation). Generation dispatch scenarios 1 and 3 did not yield any thermally overloaded elements.

For generation dispatch scenario 2, the most significant thermally overloaded element was the Big Sandy – Last Chance 115 kV line which loaded to 116.5% of its conductor thermal rating (109 MVA) for loss of the Lincoln – Midway 230 kV line. As can be seen from Table 7, this line section is moderately loaded to 70% of its capacity in the Pre-Project case for this contingency. The addition of the Project generation produces the overload.

Some additional line sections which are further upstream from the Big Sandy – Last Chance 115 kV line section also exceed their conductor thermal limits. These transmission line sections are owned by the Western Area Power Administration. See Table 7.

To eliminate the thermal overloads on Western's system, the Project generation would need to be reduced to 94 MW or all of the line sections would need to be upgraded to carry additional power. Alternatively, Network Upgrades such as construction of new transmission lines could mitigate the thermally overloaded elements on Western's system. No voltage violations were identified.

Tri-State has a planned Burlington to Lamar 230 kV transmission line in its 2016-2025 Ten-Year Transmission Capital Construction Plan and in Tri-State's Colorado Public Utilities Commission Rule 3627 filing. The estimated in-service date is 4Q/2020. Addition of this project will mitigate all thermally overloaded elements.

Reactive power / voltage regulation:

The GF can meet Tri-State's 0.95 p.f. lag to lead criteria at the POI with exception of output levels greater than 125 MW when producing MVAR and at output levels near 0 MW. Therefore, approximately 4 to 5 MVAR of switched shunt capacitors will be required on the 34.5 kV bus.

The Interconnecting Customer is responsible for installing equipment to ensure that the GF can achieve the net 0.95 p.f. lag and lead capability across the near 0 to 150 MW net generation output as measured at the POI. Prior to entering into a Generator Interconnection Agreement, the Customer must provide data that demonstrates compliance with Tri-State's reactive criteria.

Dynamic stability analysis:

Transient stability analysis was completed with the GE 2.0 MW wind turbine dynamic model. The Project at the 150 MW generation level did not trip during any of the simulated disturbances with acceptable voltage levels for the GE turbines. Local area generators showed stable performance and remained in synchronism for all contingencies. Acceptable damping and voltage recovery was observed (Appendix D).

Short - Circuit analysis:

Results indicate that the GF increases the fault duty by approximately 781 Amperes at the Lincoln 230 kV POI bus. The resultant total fault currents are within Tri-State's substation planned equipment ratings.

Cost and schedule estimates are good faith estimates only (typically +/-30% accuracy). Higher accuracy estimates (+/- 20%) will be provided as part of an Interconnection Facilities Study. The estimated costs for interconnecting the proposed Project are as follows (refer to Figure 3 in Section 7):

• Interconnection Facilities (Non-Reimbursable):	$ 1.1 M
• Network Upgrades (Reimbursable):	$ 2.5 M
TOTAL Cost for Interconnection:	$ 3.6 M

The in-service date for this GF will depend on construction of the Interconnection Facilities and Network Upgrades and will be a minimum of 24 months after the execution of a Generator Interconnection Agreement or Engineering and Procurement contract.

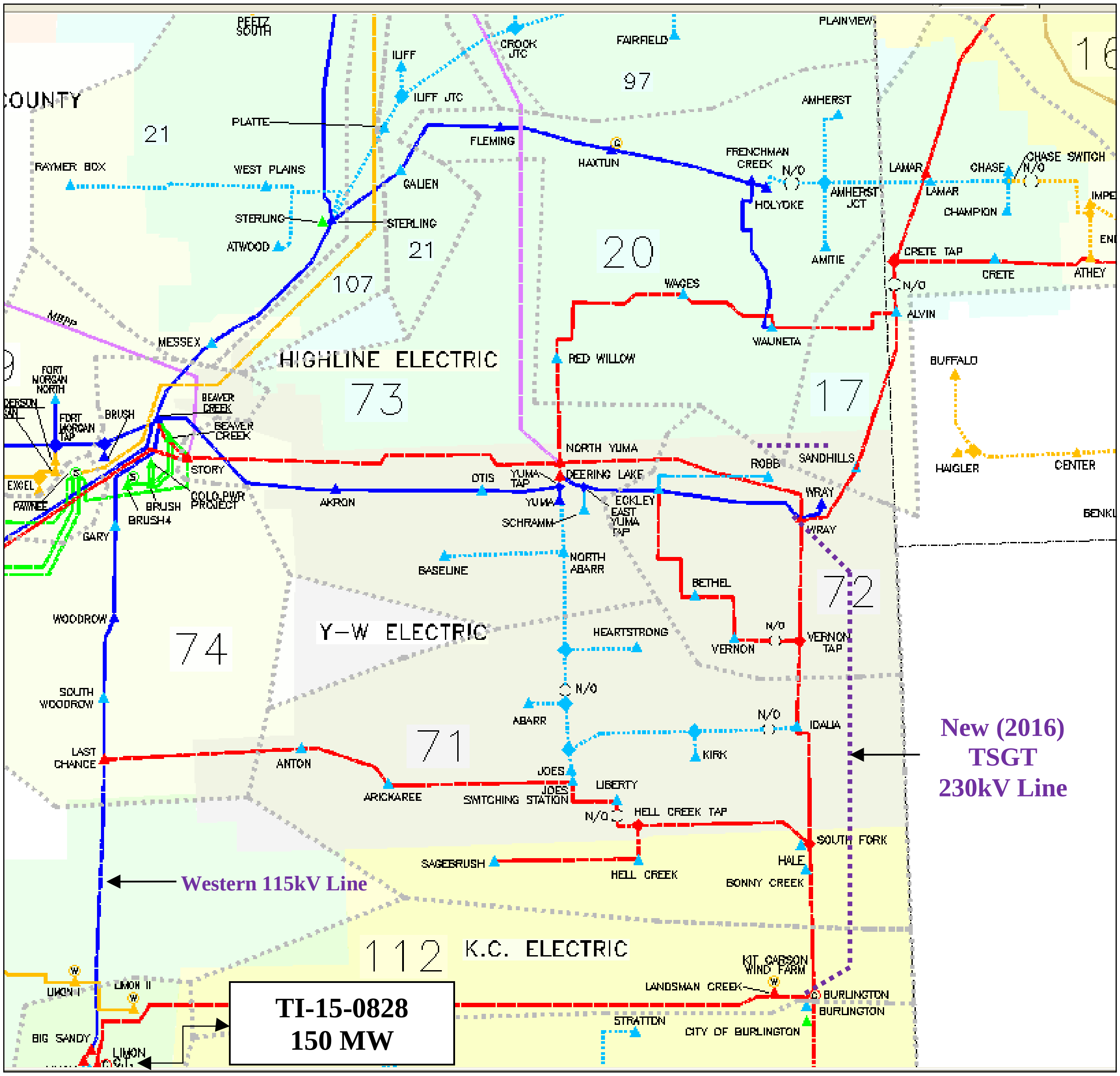
NOTE: Pursuant to Section 3.2.2.4 of the Tri-State's Generation Interconnection Procedures, "Interconnection Service does not convey the right to deliver electricity to any customer or point of delivery. In order for an Interconnection Customer to obtain the right to deliver or inject energy beyond the Generating Facility Point of Interconnection or to improve its ability to do so, transmission service must be obtained pursuant to the provisions of Transmission Provider's Tariff by either Interconnection Customer or the purchaser(s) of the output of the Generating facility." See Tri-State's Open Access Same Time Information System (OASIS) web site for information regarding requests for transmission service, related requirements and contact information.

2.0 BACKGROUND AND SCOPE

On August 28, 2015, the Interconnecting Customer submitted a Generator Interconnection Request for a 150 MW wind energy GF to be located approximately three (3) miles from the Lincoln 230 kV Substation. The application was deemed complete on September 3, 2015 and an Interconnection System Study Agreement was executed on October 23, 2015.

This System Impact Study was prepared in accordance with Tri-State's Generator Interconnection Procedures and relevant FERC, NERC, WECC and Tri-State guidelines. The objectives are: 1) to evaluate the steady state performance of the system with the proposed project, 2) identify Interconnection Facilities and Network Upgrades, 3) check the GF's ability to meet Tri-State's voltage regulation and reactive power criteria, 4) assess the dynamic performance of the transmission system under specified stability contingencies, 5) perform a basic short circuit analysis to provide the estimated maximum (N-0) and minimum (N-1) short circuit currents, and 6) provide a preliminary estimate of the costs and schedule for all necessary Interconnection Facilities and Network Upgrades, subject to refinement in a Facilities Study.

Figure 1 - One-Line Diagram Of Study Area And Location of GF



3.0 GF MODELING DATA

The model consists of a 150 MW equivalent wind turbine generator with one 34.5-230-13.8 kV transformer and a three (3) mile 230 kV generator tie line routed from the project to the Lincoln Substation. See Figure 4 in section 7 of this report for further details. Model data is based on information provided by the Customer. The Customer must provide actual data and confirm actual reactive power operating capabilities prior to interconnecting the project, and ultimately prior to being deemed by Tri-State as suitable for commercial operation.

Generator Data: The study modeled an equivalent generator with a Pmax of 150 MW and reactive capability of 0.90 lag and 0.90 lead, 72.65 and -72.65 MVAR, respectively. The specific generator parameters may be revised for the transient stability analysis potion of this study.

Table 1: Generator Data for Steady-State Power Flow Analyses

Unit	Description	
Pmax	Name plate rating (lumped equivalent gen model)	166.667 MW
Qmin, Qmax	Reactive capability	0.90 lag to 0.90 lead
Et	Terminal voltage	0.69 kV
RSORCE	Synchronous resistance	0.0000 p.u.
XSORCE	Synchronous reactance	0.8 p.u.

Table 2: Power Flow Data for Individual Generating Units

Unit	Description	[*Manufacturer*]
MBase	Generator MVA base	2.2 MVA
Prated	Generator active power rating	2.0 MW
Pmin	Minimum generation	0.2 MW
Vrated	Terminal voltage	0.69 kV
Srated	Unit transformer Rating	2.3 MVA
Xt	Unit Transformer Reactance (on transformer base)	5.75%
Xt/Rt	Unit Transformer X/R ratio	7.5

Table 3: Low Voltage Ride -Through (LVRT) Thresholds and Durations

V (%) at HV POI Bus	Delta V (p.u)	Time (sec)
75	-0.25	1.9
50	-0.50	1.2
30	-0.70	0.7
15	-0.85	0.2
110	0.10	1.0
115	0.15	0.1

34.5 kV Collector System: The wind farm was interconnected to the POI via one 34.5-230-13.8 kV transformer and an equivalent feeder circuit model.

Main GF Substation Transformer: The substation transformer was modeled with ratings of 100/133/166 MVA and a voltage ratio of 34.5 kV (wye-gnd) - 230 kV (wye-gnd) - 13.8 kV (delta). The transformer impedance was assumed to be 9.0% on the 100 MVA base FA rating with X/R of 40.

230 kV Generator Tie Line: The GF to POI line impedance was based on three (3) miles of 1-795 kcmil ACSR. The continuous thermal rating is 430 MVA with an impedance of R = 6.670E-4, X = 4.352E-3, B = 8.46E-3. All values are in p.u.

4.0 STEADY-STATE POWER FLOW ANALYSIS

The Customer requested that the Project be studied as a Network Resource. Network Resource Interconnection integrates a Generating Facility with the Transmission Provider's Transmission System in a manner comparable to the way the Transmission Provider integrates its own generating facilities to serve its native load customers. Therefore, Network Resources in the local area are studied at full output to determine if the aggregate of the existing and proposed generation can be delivered to load consistent with the Transmission Provider's reliability criteria and procedures.

4.1 Criteria and Assumptions

Siemens PTI PSS/E version 33.5.0 software was used for performing the steady-state power flow analysis, with the following study criteria:

1. Tri-State's GIP 2017, heavy summer and light spring (PSS/E-v33) base cases were developed from WECC approved seed cases with updates from the latest available loads and resources data, topology (line and transformer ratings, planned and budgeted projects, etc.), and updates received from regional utilities and Affected Systems. These GIP base cases were further updated by Tri-State to reflect appropriate generation dispatching for this study. The following base cases were utilized for the SIS:
    a. 2017 Heavy Summer cases with and without the new GF project
    b. 2017 Light Spring cases with and without the new GF project
2. To stress the system in the area of the Project, local Tri-State Network Resources were dispatched with the following three scenarios.

Table 4: Local Network Resource Generation Dispatches (MW)

Scenario	Case Description	Limon Unit 1	Limon Unit 2	Kit Carson	Burlington Unit 1	Burlington Unit 2
1	2017 Heavy Summer	57	58	12	26	26
1	2017 Light Spring	0	0	12	0	0
2	2017 Heavy Summer	65	65	51	50	50
2	2017 Light Spring	65	65	51	50	50
3	2017 Heavy Summer	0	0	51	50	50
3	2017 Light Spring	0	0	51	50	50

3. For Scenario 3 (sensitivity cases), the Limon generation was replaced by the Project generation.
4. Power flow (N-0) solution parameters were as follows: Transformer LTC Taps – stepping; Area Interchange Control – tie lines and loads; Phase Shifters and DC Taps – adjusting; and Switched Shunts - enabled.
5. Power flow contingencies (N-1) utilized the following solution settings: Transformer LTC Taps – locked taps; Area Interchange Control – disabled; Phase Shifters and DC Taps – non-adjusting; and Switched Shunts – locked all. (Not allowing these voltage regulating solution parameters to adjust provides worst case results.)
6. All buses, lines and transformers with nominal voltages greater than or equal to 69 kV in the Tri-State and surrounding areas were monitored in all study cases for N-0 and N-1 system conditions.
7. Nearby study areas (PNM, Tri-State, and XE/PSCo) were investigated using the same overload criteria. Any thermal loading greater than 95% of the branch rating with a thermal overload increase of 2% or more was tabulated.
8. This analysis assumes that the GF controls the high voltage bus at the POI and should not negatively impact any controlled voltage buses on the transmission system.
9. Post-contingency power transfer capability is subject to voltage constraints as well as equipment ratings. The Project was tested against NERC/WECC reliability criteria with additions/exceptions as listed in the following Table 5:

Table 5: Voltage Criteria

Tri - State Voltage Criteria for Steady State Power Flow Analysis			
Conditions	**Operating Voltages**	**Delta-V**	**Areas**
Normal N-0	0.95 - 1.05		All
Contingency N-1	0.90 - 1.10	7%	Northeastern New Mexico
Contingency N-1	0.90 - 1.10	7%	Southern New Mexico
Contingency N-1	0.90 - 1.10	6%	Other buses in PNM area
Contingency N-1	0.90 - 1.10	7%	Western Colorado
Contingency N-1	0.90 - 1.10	7%	Southern Colorado
Contingency N-1	0.90 - 1.10	6%	Other Tri-State areas

4.2 Voltage Regulation and Reactive Power Criteria

1. The GF must be capable of either producing or absorbing VAR as measured at the high voltage POI bus at a 0.95 power factor (p.f.), across the range of near 0% to 100% of facility MW rating, as calculated on the basis of nominal POI voltage (1.0 p.u. V).

2. The GF may be required to produce VAR from 0.90 p.u. V to 1.04 p.u. V at the POI. In this range the GF helps to support or raise the POI bus voltage.
3. The GF may be required to absorb VAR from 1.02 p.u. V to 1.10 p.u. V at the POI. In this range the GF helps to reduce the POI bus voltage.
4. The GF may be required to either produce VAR or absorb VAR from 1.02 p.u. V to 1.04 p.u. V at the POI, with typical target regulating voltage being 1.03 p.u. V.
5. The GF may utilize switched capacitors or reactors as long as the individual step size results in a step-change voltage of less than 3% at the POI operating bus voltage. This step change voltage magnitude shall be calculated based on the minimum system (N-1) short circuit POI bus MVA level as supplied by Tri-State.

   The GF is required to supply a portion of the VAR on a continuously adjustable or dynamic basis. The amount of continuously adjustable VAR shall be equivalent to a minimum of 0.95 p.f. produced or absorbed at the generator collector system medium voltage bus, across the full range (0 to 100%) of rated MW output. The remaining VAR required to meet the 0.95 p.f. net criteria at the high voltage POI bus may be achieved with switched reactive devices.
6. When the GF is not producing any real power (near 0 MW), the VAR exchange at the POI shall be near 0 MVAR, i.e., VAR neutral.

4.3 Steady-State Power Flow Results

1. N-0 (System Intact, Category A) Study Results:

   The proposed Project generation (150 MW) can be added with no thermal or voltage violations with all lines in-service and with the new Burlington to Wray 230 kV line in-service.
2. N-1 (Single Contingency, Category B) Study Results:

   Results for N-1 contingencies using the 2017 heavy summer and 2017 light spring cases are shown in Tables 6 and 7 below.

   With the 2017 Heavy Summer case, there were no elements that exceeded their emergency thermal limits for any of the scenarios.

   With the 2017 Light Spring case, there were five (5) transmission line sections that exceeded their emergency thermal limits as a result of the Project generation. However, this was only for generation dispatch scenario 2 (maximum local area generation). Scenarios 1 and 3 did not yield any thermally overloaded elements.

   For generation dispatch scenario 2, the most significant thermally overloaded element was the Big Sandy – Last Chance 115 kV line which loaded to 116.5% of its conductor thermal rating (109 MVA) for loss of the Lincoln – Midway 230 kV line. As can be seen from Table 7, this line section is moderately loaded to 70% of its capacity in the Pre-Project case for this contingency. The addition of the Project generation produces the overload.

Additional line sections further upstream from the Big Sandy – Last Chance 115 kV line also exceed their conductor thermal limits. These transmission line sections are owned by the Western Area Power Administration. See Table 7.

To eliminate the thermal overloads on Western's system, the Project generation would need to be reduced to 94 MW or all of the line sections would need to be upgraded to carry additional power. The line sections total approximately 67 miles in length. The IC is directed to work directly with Western to determine the cost for these upgrades. Alternatively, other Network Upgrades such as construction of new transmission lines could mitigate the thermally overloaded elements on Western's system. No voltage violations were identified.

See item 6 below for possible mitigations for the above overloads.

3. Steady-state voltage violations:

   With an operating voltage range between 0.90 p.u. to 1.10 p.u., under single contingency outage conditions there were no voltage violations with the GF at full output.

4. Steady-state contingency voltage deviation:

   Each Balancing Authority's ΔV requirement was applied as per Table 5. There were no ΔV violations at any of the monitored buses.

5. Reactive power required at the POI:

   At full 150 MW output, the VAR capability required at the POI ranges from 49.30 MVAR produced (0.95 p.f. lag) to 49.3 MVAR absorbed (0.95 p.f. lead). This is the net MVAR to be produced or absorbed by the GF, depending upon the applicable range of voltage conditions at the POI.

   The unit data provided by the Customer shows a reactive capability of +/- 0.9 power factor. Utilizing only the GF capability supplied by the Customer, a steady-state analysis was performed for the POI voltage established by the dispatch in the power flow cases. For reference, Table 8 shows the net VAR flow at several levels of GF output and at fixed generator bus p.f. levels, based on the voltage at the lumped equivalent model generator terminals and the voltage at the POI bus.

   The GF can meet Tri-State's 0.95 p.f. lag to lead criteria at the POI with exception of output levels greater than 125 MW when producing MVAR and at output levels near 0 MW. Therefore, approximately 4 to 5 MVAR of switched shunt capacitors will be required on the 34.5 kV bus.

   The Interconnecting Customer is responsible for installing equipment to ensure that the GF can achieve the net 0.95 p.f. lag and lead capability across the 0 to 150 MW net generation output rating as measured at the POI. Tri-State may require a portion of the new MVAR to be supplied by dynamic reactive power equipment. Prior to entering into a Generator Interconnection Agreement, the Customer must provide data that demonstrates compliance with Tri-State's reactive criteria.

6. As noted in section 2 above, with the GF at full output during light load conditions, several potential line overloads remain even after the Burlington to Wray 230 kV line is placed in-service. Loss of the Lincoln – Midway 230 kV line results in potential overloads to several underlying Western Area Power Administration 115 kV transmission line segments. There are several possible mitigations for these overloads: 1) reduce the Project generation, 2) increase the ratings of the overloaded line sections by rebuilding or re-conductoring as necessary, or 3) construct new transmission into the Project area.

   With respect to the third alternative, Tri-State has proposed a new 230 kV transmission line interconnecting its Burlington Substation to the Lamar Substation in southeast Colorado. This project is presently in Tri-State's 2016-2025 Ten-Year Transmission Capital Construction Plan and in Tri-State's Colorado Public Utilities Commission Rule 3627 filing. The estimated in-service date is 4Q/2020. Power flow results have demonstrated that the Burlington to Lamar 230 kV line will mitigate overloads on the previously identified 115 kV transmission lines owned by Western.

Table 6: 2017 Heavy Summer Scenarios 1, 2 and 3 – Thermal Analysis (With Burlington - Wray 230 kV Line In-Service)

AFFECTED ELEMENT	CONTINGENCY	Emergency Rating (MVA)	Pre-Project Loading (%)	Post-150 MW Project Loading (%)	Delta (%)	Maximum Project Output w/out Additional NU (MW)	Owner	Notes – Limiting Elements
No thermal elements triggered.								

Table 7: 2017 Light Spring Scenario 2 – Thermal Analysis (With Burlington - Wray 230 kV Line In-Service)

AFFECTED ELEMENT	CONTINGENCY	Emergency Rating (MVA)	Pre-Project Loading (%)	Post-150 MW Project Loading (%)	Delta (%)	Maximum Project Output w/out Additional NU (MW)	Owner	Notes – Limiting Elements
BigSandy-Last Chance 115kV Line	Lincoln-Midway 230 kV Line	109	71.9	116.5	44.6	**94**	WAPA	
Last Chance-SouthWoodrow 115kV Line	Lincoln-Midway 230 kV Line	109	70.4	114.6	44.2	100	WAPA	
SouthWoodrow-Woodrow 115kV Line	Lincoln-Midway 230 kV Line	109	69.3	114.2	44.9	100	WAPA	
Gary-Woodrow 115kV Line	Lincoln-Midway 230 kV Line	109	67.9	113.7	45.8	102	WAPA	
BeaverCk-Gary 115kV Line	Lincoln-Midway 230 kV Line	109	66.8	113.2	46.4	104	WAPA	

With 2017 Light Spring system conditions, there were no thermal elements triggered for Scenarios 1 and 3.

Table 8: Reactive Power Delivered to the WTG Bus and at POI Bus
Project Size: 150 MW, GE 2.0-116, 75 Units

Base Case	Fixed P.F. at MV Gen Equiv Collector Bus	P, Q, V At Gen Equiv MV			Net P, Q, V, PF At HV POI Bus					
		Pgen (MW)	Qgen (MVAR)	Voltage (p.u.)	P (MW)	Q (MVAR)	PF at POI	Voltage (p.u.)	MVAR to meet PF Reqd at POI of 0.95	MVAR Short(+) or Excess(-)
HS Base Case – 0.90 p.f. lag (producing MVAR)										
	0.9	0	0.0	0.954	0	4.2	0	0.95	0	-4.2
	0.9	37.5	18.2	0.986	37.1	19.9	0.881	0.95	12.2	-7.7
	0.9	75	36.3	1.014	73.6	31.1	0.921	0.95	24.2	-6.9
	0.9	112.5	54.5	1.039	109.4	38.6	0.943	0.95	36.0	-2.6
	0.9	150	72.6	0.955	144.8	42.5	0.960	0.95	47.6	5.1
LA Base Case – 0.90 p.f. lead (absorbing MVAR)										
	-0.9	0	0	1.054	0	5.1	0	1.05	0	-5.1
	-0.9	37.5	-18.2	1.036	37.2	-15.3	0.925	1.05	-12.2	-3.1
	-0.9	75	-36.3	1.014	73.6	-40.6	0.876	1.05	-24.2	-16.4
	-0.9	112.5	-54.5	0.987	109.2	-71.7	0.836	1.05	-35.9	-35.8
	-0.9	150	-72.6	0.955	143.7	-109.8	0.795	1.05	-47.2	-62.6

5.0 DYNAMIC STABILITY ANALYSIS

5.1 Criteria and Assumptions

5.1.1 NERC/WECC Dynamic Criteria

PSSE version 33.5.0 was used for dynamic stability analysis. Dynamic stability analysis was performed in accordance with the dynamic performance criteria shown in Table W-1 and Figure W-1 from the NERC and WECC TPL-001 through 004 System Performance Criteria. These criteria are shown below.

In addition, the NERC/WECC standard states that "[r]elay action, fault clearing time, and reclosing practice should be represented in simulations according to the planning and operation of the actual or planned systems. When simulating post transient conditions, actions are limited to automatic devices and no manual action is to be assumed."

WECC DISTURBANCE-PERFORMANCE TABLE OF ALLOWABLE EFFECTS ON OTHER SYSTEMS

NERC and WECC Categories	Outage Frequency Associated with the Performance Category (outage/year)	Transient Voltage Dip Standard	Minimum Transient Frequency Standard	Post Transient Voltage Deviation Standard (See Note 2)
A	Not Applicable	Nothing in addition to NERC		
B	≥ 0.33	Not to exceed **25%** at load buses or **30%** at non-load buses. Not to exceed **20% for more than 20 cycles** at load buses.	Not below **59.6** Hz for 6 cycles or more at a load bus.	Not to exceed **5%** at any bus.
C	0.033 – 0.33	Not to exceed **30%** at any bus. Not to exceed **20% for more than 40 cycles** at load buses.	Not below **59.0** Hz for 6 cycles or more at a load bus.	Not to exceed **10%** at any bus.
D	< 0.033	Nothing in addition to NERC		

Table W-1: NERC/WECC Planning Standards, April 2003

VOLTAGE PERFORMANCE PARAMETERS

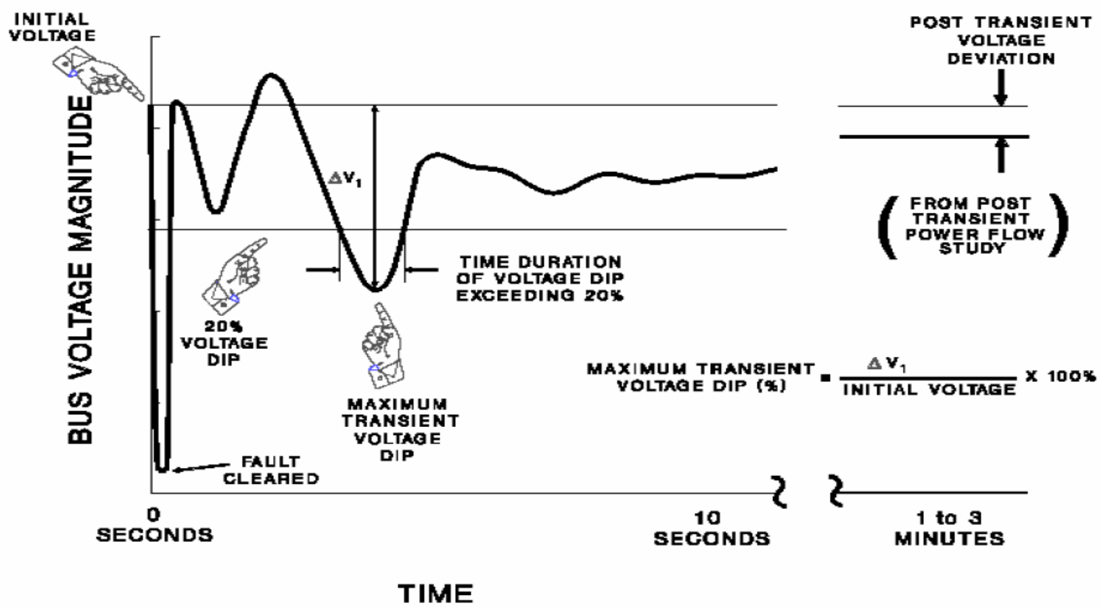


Figure W-1: NERC/WECC Planning Standards, April 2003

5.1.2 Voltage Ride-Through Requirements

1. The GF shall be able to meet the dynamic response LVRT requirements consistent with the latest NERC/WECC criteria and Tri-State's GIP (Appendix G) and FERC Order 661a for LVRT (applicable to Wind Generation Facilities).

2. Generating plants are required to remain in service during faults, three-phase or single line-to-ground (SLG) whichever is worse, with normal clearing times of approximately 4 to 9 cycles, SLG faults with delayed clearing, and subsequent post-fault voltage recovery to pre-fault voltage unless clearing the fault effectively disconnects the generator from the system. The clearing time requirement for a three-phase fault will be specific to the circuit breaker clearing times of the affected system to which the IC facilities are interconnecting. The maximum clearing time the wind generating plant shall be required to withstand for a fault shall be 9 cycles. After which, if the fault remains following the location-specific normal clearing time for faults, the wind generating plant may disconnect from the transmission system. A wind generating plant shall remain interconnected during such a fault on the transmission system for a voltage level as low as zero volts, as measured at the POI. The IC may not disable low voltage ride through equipment while the wind plant is in.
3. This requirement does not apply to faults that may occur between the wind generator terminals and the POI.
4. Wind generating plants may meet the LVRT requirements by the performance of the generators or by installing additional equipment, e.g., Static VAR Compensator, or by a combination of generator performance and additional equipment.

5.2 Base Case Model Assumptions

1. Ride-through characteristics of the GF were based upon data in the default model for GE 2.0 wind turbines.

2. The GF was modeled using data provided by the IC. The collector system was adequately modeled with an equivalent collector system and one 230/34.5 kV substation transformer.

5.3 Methodology

1. The 2017 Heavy Summer and 2017 Light Spring cases were utilized with the GF in service. In addition, the three (3) generation dispatch scenarios were studied.

2. System stability was observed by monitoring the Burlington and Lincoln relative rotor angles and system damping.

3. Three-phase faults were simulated for all contingencies. Two contingencies were simulated for each line: a fault was applied at the near end and then applied at the far end of the transmission line. Contingencies used to evaluate the wind farm's

compliance with NERC/WECC criteria for dynamic stability are listed in the following table.

Table 9: List of Dynamic Stability Contingencies

Dynamic Stability Contingencies		Bus Numbers
No.	Description	
1	5-cycle 3-phase fault at POI 15-0828 230 kV bus, trip Lincoln - POI 15-0828 230 kV line	73531-73800
2	5-cycle 3-phase fault at Lincoln 230 kV, trip Lincoln - Midway 230 kV line	73531-73413
3	5-cycle 3-phase fault at Lincoln 230 kV, trip Lincoln - Big Sandy 230 kV line	73531-73018
4	5-cycle 3-phase fault at Big Sandy 230 kV bus, trip Big Sandy - Landsman Ck 230 kV line	73018-72710
5	5-cycle 3-phase fault at Landsman Ck 230 kV bus, trip Burlington - Landsman Ck 230 kV line	72710-73036
6	5-cycle 3-phase fault at Burlington 230 kV, trip Burlington - Wray 230 kV line	73036-73224
7	5-cycle 3-phase fault at Wray 230 kV, trip Wray - N.Yuma 230 kV line	73224-73143
8	5-cycle 3-phase fault at Big Sandy 230 kV, trip Big Sandy 230 - 115 kV transformer	73018-73017

5.4 Results

Transient stability results identified that the project does not require additional mitigation and is compliant with the NERC/WECC criteria. Simulation results for both summer and spring show that:

1. The Project with 75 GE 2.0 units (150 MW) did not trip during any of the simulated disturbances and the GF was able to operate at full capacity.
2. Local area generators showed stable performance and remained in synchronism for all contingencies.
3. Acceptable damping and voltage recovery was observed.
4. Study conclusions for summer and light spring cases are shown in the following table.

Table 10: Dynamic Stability Contingency Results

Dynamic Stability Contingencies		Conclusions 2017 Heavy Sumer and 2017 Light Spring
No.	Description	
1	5-cycle 3-phase fault at POI 15-0828 230 kV bus, trip Lincoln - POI 15-0828 230 kV line	Stable
2	5-cycle 3-phase fault at Lincoln 230 kV, trip Lincoln - Midway 230 kV line	Stable
3	5-cycle 3-phase fault at Lincoln 230 kV, trip Lincoln - Big Sandy 230 kV line	Stable
4	5-cycle 3-phase fault at Big Sandy 230 kV bus, trip Big Sandy - Landsman Ck 230 kV line	Stable
5	5-cycle 3-phase fault at Landsman Ck 230 kV bus, trip Burlington - Landsman Ck 230 kV line	Stable
6	5-cycle 3-phase fault at Burlington 230 kV, trip Burlington - Wray 230 kV line	Stable
7	5-cycle 3-phase fault at Wray 230 kV, trip Wray - N.Yuma 230 kV line	Stable
8	5-cycle 3-phase fault at Big Sandy 230 kV, trip Big Sandy 230 - 115 kV transformer	Stable

6.0 SHORT-CIRCUIT ANALYSIS

Short-circuit analysis was performed for 3-phase-to-ground and single-line-to-ground faults at the 230 kV Lincoln Switching Station POI bus, using the Aspen OneLiner model. Faults were applied with and without the generation project. Model assumptions are as follows.

6.1 Assumptions and Methodology

1. The model used is shown in Figure 2 below.

2. Analysis was performed assuming the new Tri-State Burlington – Wray 230 kV line is in service.

3. The generation tie line, transformers, and generators were modeled as supplied by the IC (reference Attachment A to Appendix 1 of Interconnection Request):

   a. Zero sequence impedance of the 230-34.5 kV transformer was modeled as specified by the IC.

   b. The transformer delta windings were all modeled to lag the high side phase angles.

   c. The zero sequence impedance of the 230 kV tie line and the 34.5 kV collector system was modeled as three times the positive sequence impedance.

6.2 Results

Table 11 lists results for the 230 kV bus faults and contributions from each of the 230 kV sources into the bus faults. The system impedances for the faulted buses for each configuration is also included (see Figure 2 below). The results indicate that the GF increases the fault duty by approximately 781 Amperes at the 230 kV POI bus. The resultant total fault currents are within Tri-State's planned equipment ratings.

Figure 2: Short-Circuit Model One-Line Diagram

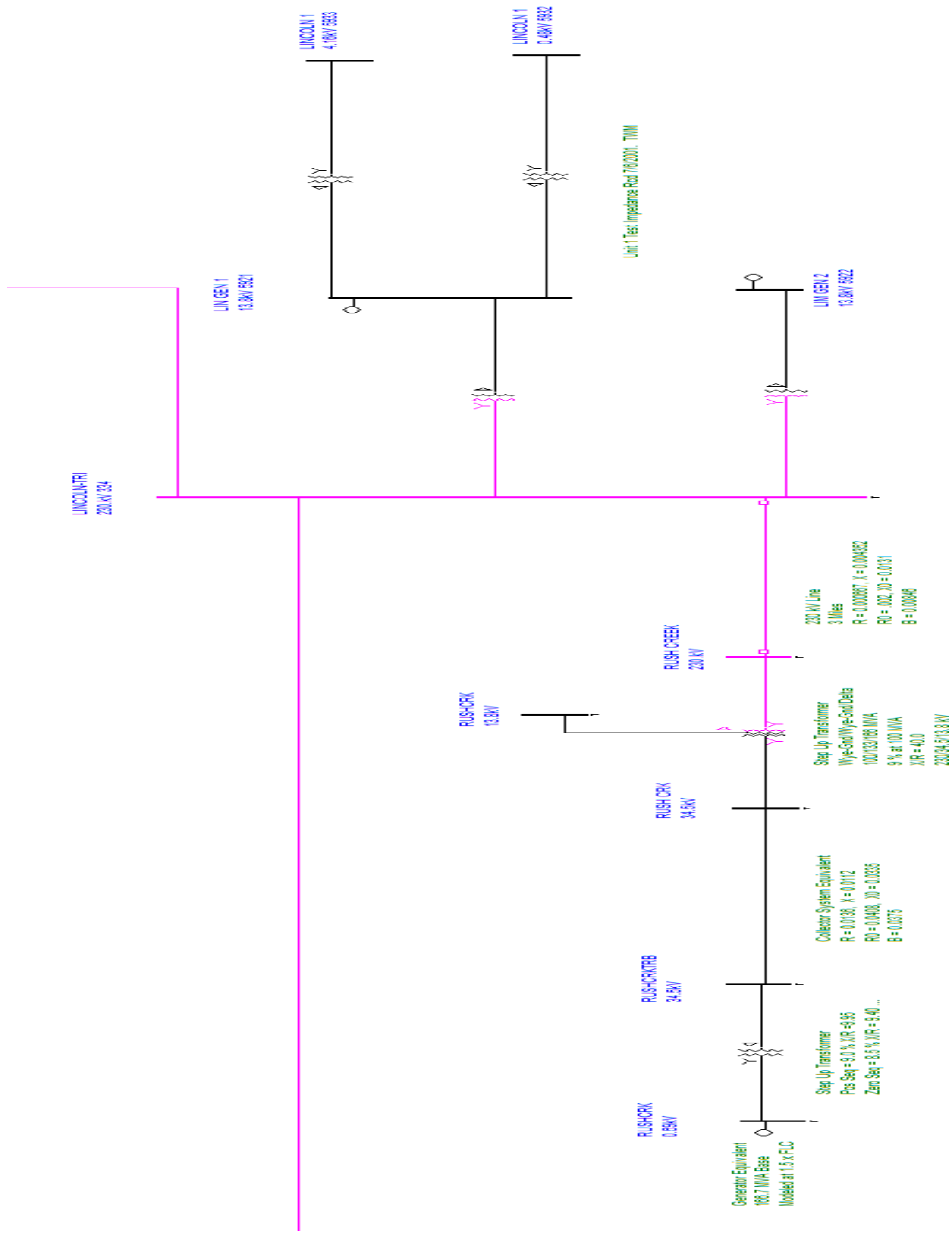


Table 11: Short-Circuit Results (Includes Burlington – Wray 230 kV Line)

System Condition*	POI Bus Total 3-Ph Fault (Amps)	Lincoln T#1 to POI 3-Ph Fault (Amps)	Lincoln T#2 to POI 3-Ph Fault (Amps)	B Sandy to POI 3-Ph Fault (Amps)	Midway to POI 3-Ph Fault (Amps)	Gen HV to POI 3-Ph Fault (Amps)	POI Bus Total SLG Fault (Amps)	Lincoln T#1 to POI SLG Fault (Amps)	Lincoln T#2 to POI SLG Fault (Amps)	B Sandy to POI SLG Fault (Amps)	Midway to POI SLG Fault (Amps)	Gen HV to POI SLG Fault (Amps)	System Equivalent Impedance (R + jX p.u. on 100 MVA, *230* kV base)
230 kV POI Bus Fault (w/o IC generation, N-0)	**5601**	904	904	1587	2216		5911	1895	1895	1286	858		Z1(pos) = 0.0041 + j 0.0446 Z0(zero) = 0.0030 + j 0.0377
230 kV POI Bus Fault (w/o IC generation, N-1 Lincoln T#1 OUT)	4700		904	1587	2216		4633		2184	1482	988		Z1(pos) = 0.00575 + j0.053 Z0(zero) = 0.006 + j0.055
230 kV POI Bus Fault (w/o IC generation, N-1 Lincoln T#2 OUT)	4700	904		1587	2216		4633	2184		1482	988		Z1(pos) = 0.00575 + j0.053 Z0(zero) = 0.006 + j0.055
230 kV POI Bus Fault (w/o IC generation, N-1 Lincoln- B Sandy OUT)	4021	904	904		2218		4354	1783	1783		807		Z1(pos) = 0.0042 + j 0.0623 Z0(zero) = 0.0031 + j 0.0483
230 kV POI Bus Fault (w/o IC generation, N-1 Lincoln-Midway OUT)	3389	904	904	1590			3933	1470	1470	998			Z1(pos) = 0.0057 + j 0.0738 Z0(zero) = 0.0022 + j 0.0441
230 kV POI Bus Fault (w/ IC generation, N-0)	**6055**	904	904	1587	2216	455	6692	1635	1635	1134	740	1593	Z1(pos) = 0.0037 + j 0.0413 Z0(zero) = 0.002 + j 0.0288
230 kV POI Bus Fault (w/ IC generation, N-1 Lincoln T#1 OUT)	5155		904	1587	2216	455	5389		1832	1243	829	1507	Z1(pos) =0.00494 + j 0.0484 Z0(zero) = 0.00329 + j 0.038
230 kV POI Bus Fault (w/ IC generation, N-1 Lincoln T#2 OUT)	5155	904		1587	2216	455	5504	1778		1207	805	1733	Z1(pos) = 0.0049 + j 0.0484 Z0(zero) = 0.00329 + j0.038
230 kV POI Bus Fault (w/ IC generation, N-1 Lincoln- B Sandy OUT)	4476	904	904		2218	455	5084	1488	1488		674	1450	Z1(pos) = 0.00363 + j 0.056 Z0(zero) = 0.002 + j 0.0345
230 kV POI Bus Fault (w/ IC generation, N-1 Lincoln-Midway OUT)	3844	904	904	1590		455	4579	1255	1255	851		1223	Z1(pos) = 0.0048 + j 0.0651 Z0(zero) = 0.0015 + j 0.0323

* LIMON, BURLINGTON, and LANDSMAN GENERATION ENABLED

7.0 SCOPE, COST AND SCHEDULE

The Project will interconnect to the Lincoln 230 kV Substation via a Customer owned 3 mile radial transmission line. (Figure 4, One-Line Diagram).

The cost estimate is broken out into two categories: 1) Interconnection Facilities which include all equipment installed between the POI at the main 230 kV bus and the Point of Change of Ownership (PCO) at the line dead-end structure just inside the Lincoln Substation fence, and 2) Network Upgrades consisting of the rest of the facilities installed in the Lincoln Substation to accommodate the interconnection. The estimate does not include costs to mitigate the transmission line thermal overloads discussed in this report.

Note that the Customer will be responsible for constructing the radial 230 kV transmission line to the GF site and for providing the primary protection (relaying and interrupting device) for the Customer's step-up transformer located in its 230-34.5-13.8 kV substation yard. Equipment at the Lincoln Substation will only provide backup protection for the Customer's 230-34.5-13.8 kV main transformer in the event of equipment failure or malfunction at the Customer's facility.

The Customer is responsible for providing a communication channel, such as fiber optic cable (OPGW) on its radial 230 kV transmission line to provide for SCADA, metering, and protective relaying. The Customer must also provide access to analog, indicating, control and data circuits as required, to integrate the Project into the design and operation of the Tri-State control system.

All costs are good faith estimates based on assumptions as stated in this SIS report. All estimates are in 2015 dollars (refer to Figure 3):

- Interconnection Facilities (Non-Reimbursable): $ 1.1 M
- Network Upgrades (Reimbursable): $ 2.5 M

TOTAL Cost for Interconnection: $ 3.6 M

It is estimated that it will take approximately 24 months after receiving authorization to proceed for Tri-State to complete the engineering, design, procurement, construction, and testing activities identified in the scope of work for this Project.

Figure 3: 230 kV Lincoln Station One-Line Diagram

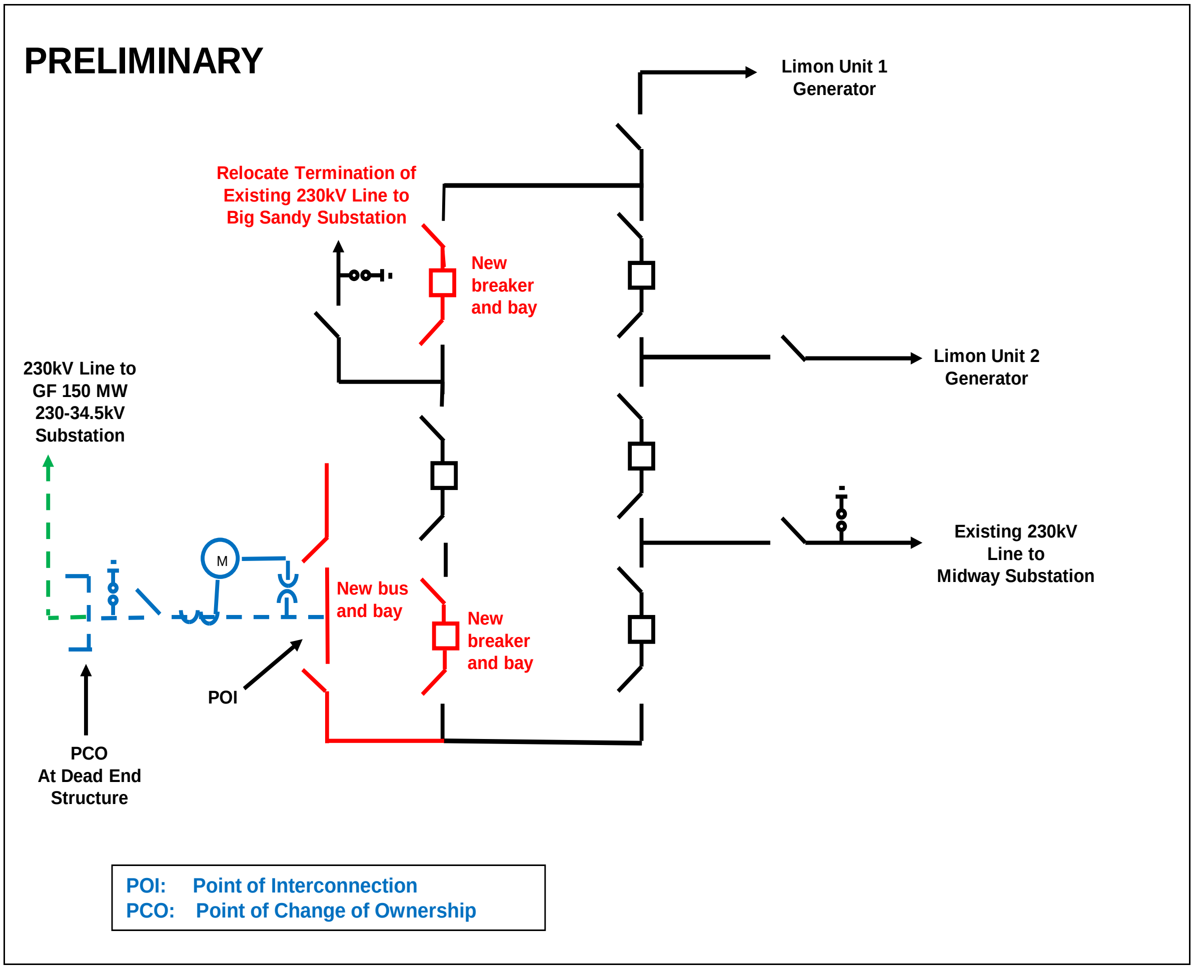


Table 12: Interconnection Facilities (Non-Reimbursable)

Element	Description	Cost Est. Millions
Lincoln Station **230 kV line termination equipment**	Design, purchase, construct and test all equipment installed inside the Lincoln Station that is located between the PCO (line dead-end) and the POI (main bus tap point), consisting primarily of the following equipment: • One (1) 230 kV steel dead-end structure. • One (1) 230 kV slack span from dead-end. • One (1) 230 kV line disconnect switch and associated structure. • *Three (3) 230 kV metering current transformers (CTs), high accuracy class, extended range. • *Three (3) 230 kV metering voltage transformers (VTs, high accuracy class). *Or alternative CT/VT combination metering units. • PQ metering panel including SEL-735 Rev/PQ meter and panel meters. • Relaying for radial 230 kV line protection; SEL 411L primary, SEL 311L secondary, and SEL 501 breaker-failure. Relays will be ordered with dedicated fiberoptic pair connections for enabling line differential protection on both the primary and secondary relays. • Three (3) 230 kV surge arresters. • Line termination SCADA and telecommunication additions to RTU. • Associated station equipment including, but not limited to, site prep, grounding, conduit, cable, foundations, support steel, bus and insulators.	**$1.1 M**

Table 13: Network Upgrades (Reimbursable)

Element	Description	Cost Est. Millions
Lincoln Station	Install necessary equipment in the existing 230 kV bus arrangement to terminate an additional circuit (see Figure 2, One-Line Diagram). Scope includes typical testing, checkout, and commissioning. • Two (2) 230 kV power circuit breakers. • Six (6) 230 kV disconnect switches and associated structures. • 230 kV bus expansion to accommodate additional line position. • Circuit breaker station control panels. • SCADA and telemetry RTU communication equipment modifications. • Associated station equipment including, but not limited to, site prep, grounding, conduit, cable, foundations, support steel, bus and insulators.	**$2.5 M**
Big Sandy Substation – Relaying Mods	• Relay settings changes (labor) for new POI line termination protection.	**(Minimal)**
Midway Switching Station – Relaying Mods	• Relay settings changes (labor) for new POI line termination protection.	**(Minimal)**

Figure 4: Customer Substation One-Line Diagram