Final
Interconnection System Impact Study

Generator Interconnection Request No. TI-13-0701
100 MW Wind Energy Generating Facility
In Kit Carson County, Colorado

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1.0 EXECUTIVE SUMMARY

This System Impact Study (SIS) is for Generator Interconnection Request (GIR) No. TI-13-0701, relating to a proposed 100 MW wind energy Generating Facility (GF) in Kit Carson County, Colorado (Project). The SIS was conducted for the Transmission Provider (TP, Tri-State Generation and Transmission Association, Inc., "Tri-State") in accordance with its Generator Interconnection Procedures (GIP), and includes steady-state power flow (PF), dynamic stability, short-circuit, cost and schedule analyses for interconnection as a Network Resource (NR). In its application the Interconnection Customer (IC) proposed an energization In-Service Date (ISD) of January 1, 2016 and a Commercial Operation Date (COD) of January 1, 2016. Cost and schedule estimates are as provided by the TP, and are "good faith" (typically +/-30% accuracy) level estimates only. Higher accuracy (+/- 20%) would be provided as part of the Generator Interconnection Facilities Study (FacS).

This proposed Project consists of 50 Vestas V110 2.0 wind turbines with one 34.5-230-13.8kV transformer at the main Wind Energy Generating Facility (Project Substation), and requested evaluation of a primary Point of Interconnection (POI) into the Landsman Creek 230 kV substation via a 100 foot transmission line (see Figures 1 and 2 for reference). A new transmission project that Tri-State has planned and budgeted that will affect the results of these studies is the new Burlington - Wray 230kV line project presently scheduled to be completed in 2016 (see Note 1 below).

Steady-state power flow: With use of the 2018HS and 2018LA cases, with the GF at the full 100 MW injection and with the planned new Burlington to Wray 230kV line in service, there were no transmission elements that exceeded their emergency thermal limit. In addition, there were no voltage violations.

Reactive power / voltage regulation: This GF cannot meet the TP's 0.95 p.f. lag to lead criteria at the POI with full 100 MW generation output. The system model provided by the IC shows that this GF can basically meet the TP's 0.95 p.f. lag to lead criteria at the POI with exception of the operating condition with output levels above 91 MW, and also at 0 MW for "VAR neutral" (<2 MVAR). Supplemental reactive power equipment of approximately 2 MVAR of switched shunt capacitors may be required at the full 100 MW GF output to meet the net 0.95 p.f. lag (producing VAR) criteria at the POI. Similarly, approximately 2 MVAR of switched shunt reactors (inductors) may be required on the 34.5 kV bus to offset the extra VARs and meet Tri-State's "VAR neutral" criteria of less than approximately 2 MVAR flow at 0 MW.

The IC is responsible to determine equipment that will be installed to ensure that the GF can achieve the net 0.95 p.f. lag and lead capability across the 0 to 100 MW net generation output rating as measured at the POI. The TP may require a portion of the new MVAR to be supplied by dynamic reactive power support equipment, as to provide 0.95 lag to lead continuously adjustable or dynamic capability as measured at the generator terminals. Prior to entering into a GIA, the IC shall provide data that demonstrates compliance with the TP's reactive criteria.

Dynamic stability analyses were completed for the 2018 HS and LA cases, with short-circuits applied and cleared for multiple transmission line sections near the Landsman Creek 230kV Substation (see Appendix C).

The project requires that the planned Burlington-Wray 230kV line is in-service. The IC project at the 100 MW generation level did not trip during any of the simulated disturbances and the GF

was able to operate at full capacity, local area generators showed stable performance, and remained in synchronism for all contingencies, and acceptable damping and voltage recovery was observed. Refer to Section 5 for further details.

Short-circuit analyses: These results indicate that a 100 MW GF has an approximate 952 amp (3-phase, 5,140 – 4,188) impact and 1,126 amp (SLG, 5,488 – 4,362) impact on the maximum total bus fault current magnitudes at the POI 230kV bus. These impacts do not result in exceeding any breaker interrupt ratings at the new POI or nearby Burlington or Big Sandy Substations.

POI at Landsman Creek 230 kV Switching Station (TPIF and TPNU): The estimated costs for constructing new TP Facilities associated with terminating the IC's new 230 kV interconnection into the existing Landsman Creek Switching Station, consisting of expanding the existing 3-point, 230kV ring bus breaker station into a 4-point, breaker-&-half configuration (see Figure 5 One-Line Diagram in Section 7) are **$3.31 Million**, consisting of $1.14 M for TP Interconnection Facilities (TPIF) plus $2.17 M for TP Network Upgrades (TPNU).

Additional TPNU (beyond POI Switching Station): These cost estimates do not include any TPNU that would be required remote from this POI, either by Tri-State or on Affected Systems, noting that this SIS has not identified any such required work for this GIR.

- TP Interconnection Facilities Costs (TPIF, Non-Reimbursable): $1.14 M
- TP Network Upgrades Costs (TPNU, POI SS Reimbursable): $2.17 M
- **TOTAL Costs for Interconnection: $3.31 M**

The earliest ISD for this GIR will depend upon the scope of the TPNU plus TPIF required for this interconnection as determined by the GIR project MW level. In any event, the ISD would be no earlier than after completion of the TP's new Burlington to Wray 230 kV line project, and a minimum of 12 to 14 months after the execution of the Generator Interconnection Agreement (GIA) or Engineering and Procurement (E&P) contract, and could be significantly longer for additional TPNU that may be required beyond the construction of the TP POI Switching Station.

***NOTES:**

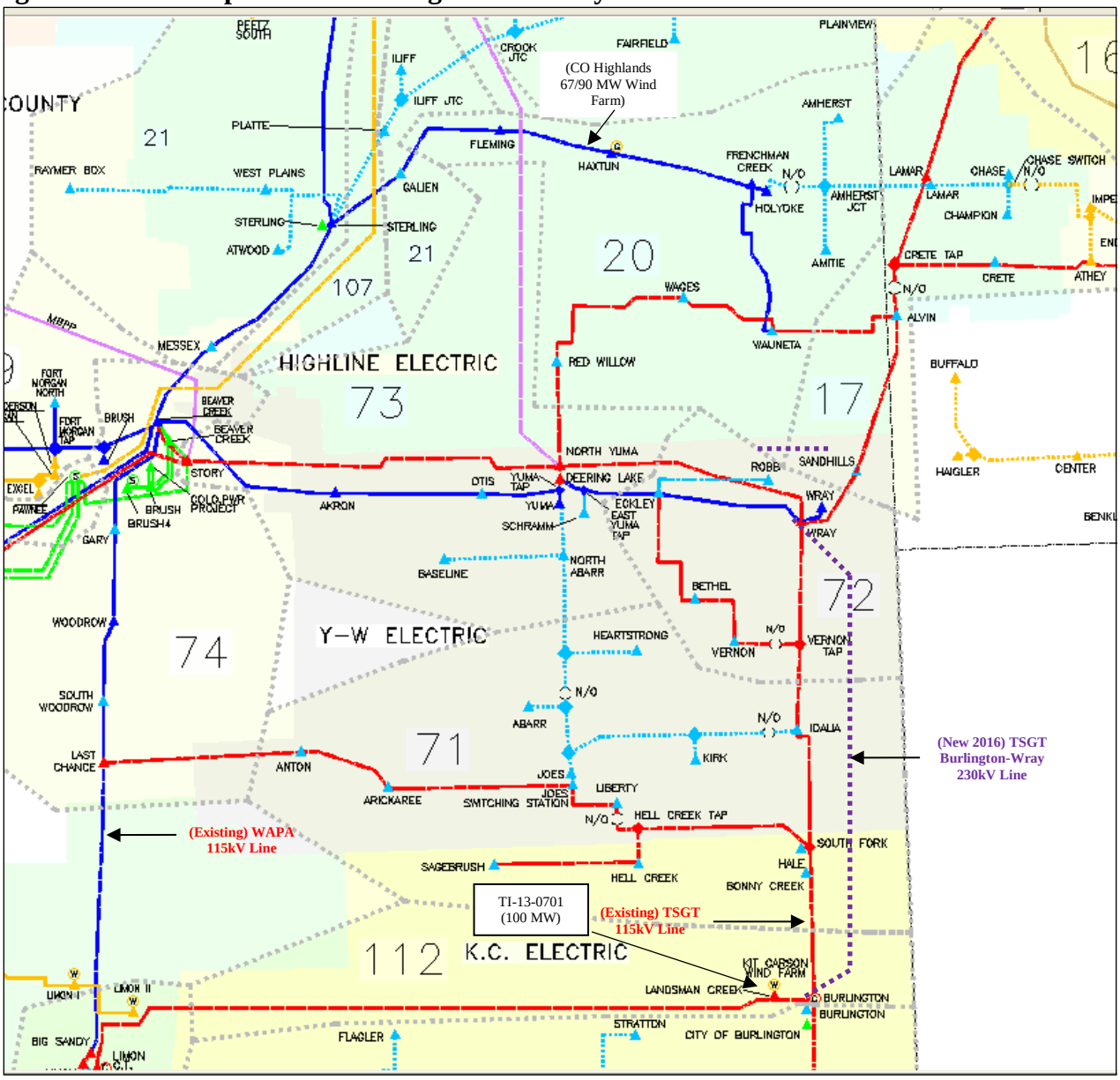
1. Recent Studies completed for other GIRs in this region indicate that until such time that the TP's new Burlington - Wray 230kV transmission line is in service, any additional generation at this requested POI (including this IC's GF) would only be allowed to interconnect using the transmission system on an "as available" basis in accordance with Section 3.2.1(4) of TP's GIP.
2. Per Section 3.2.2.4 of the TP's GIP, "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, and related requirements and contact information.

2.0 BACKGROUND AND SCOPE

On July 1, 2013, the IC submitted a GIR for a 100 MW wind energy GF to be connected to the Landsman Creek 230 kV substation via a 100 foot transmission line. The model data for the GF was revised and updated by the IC through the end of July 2013 and the latest data has been utilized for this study.

This SIS is prepared in accordance with the TP's GIP and relevant FERC, NERC, WECC and TP guidelines. The objectives are to: (1) evaluate the steady state performance of the system to identify the required TPIF and TPNU; (2) check the GF's ability to meet the TP's voltage regulation and reactive power criteria; (3) assess the dynamic performance of the Transmission System under specified stability contingencies; (4) perform a basic short circuit analysis to provide the estimated maximum (N-0) and minimum (N-1) short circuit currents and identify the impacts on the Transmission System with and without the new generation connected; and (5) provide a preliminary estimate of the costs and schedule for all necessary TPIF and TPNU, subject to refinement in an Interconnection Facilities Study (FacS).

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



3.0 GF MODELING DATA

This Project consists of 50 Vestas V110 2.0 wind turbines with one 34.5-230-13.8 kV transformer and an approximate 100 foot 230 kV generator tie transmission line routed from the Project to the Landsman Creek Switching Station. See Figures 1 and 2 for further details. Model data is based upon information provided by the IC. The IC shall provide actual data and confirm actual reactive power operating capabilities prior to the ISD of this Project, and ultimately prior to the IC's GF being deemed by the TP as suitable for Commercial Operation.

Generator Data: The GF request at 100 MW is comprised of 50 Vestas V110-2.0 wind turbines. Table 1 shows the generator data for power flow modeling. Table 2 shows data from the manufacturer's technical documentation. Table 3 shows the Low Voltage Ride Through (LVRT) protection trip levels.

Table 1 - Generator Data for Steady-State Power Flow & Short-Circuit Analyses

Unit	Description	
Pmax	Name plate rating (lumped equivalent gen model)	2.0 MW
Qmin, Qmax	Reactive capability	0.90 lag to 0.90 lead
Et	Terminal voltage	0.69 kV
RSORCE	Synchronous resistance	0.0063 p.u.
XSORCE	Synchronous reactance	0.0758 p.u.

Table 2 - Power Flow Data for Individual Generating Units

Unit	Description	[*Manufacturer*]
MBase	Generator MVA base	2.0 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	2.1 MVA
Xt	Unit Transformer Reactance (on transformer base)	7.3%
Xt/Rt	Unit Transformer X/R ratio	7.4

Table 3 - Voltage Ride-Through Thresholds And Durations

V (%) at HV POI Bus	Delta V (p.u)	Time (sec)
90	-0.10	> 60.0
80	-0.20	2.65 – 11.0
70	-0.30	0.2 - 2.65
0	-1.00	< 0.2
110	0.10	>60.0
115	0.15	2.0 -60.0
120	0.20	0.08 – 2. 0
125	0.25	< 0.005

34.5 kV Collector System: The medium voltage (MV) collector system and generation was modeled as per the collector system layout provided by the IC. The wind farm interconnects to the POI via one 34.5-230-13.8 kV transformer and an equivalent feeder circuit modeled. Collector system impedance is based on typical collector system impedance data.

Main GF Substation Transformer: The substation transformer has ratings of 66/88/110 MVA with the voltage ratio of 34.5 kV (gnd-wye) - 230 kV (gnd-wye) - 13.8 kV (Delta). The transformer impedance is 8.067% on the 66 MVA base FA rating with X/R of 36.

230 kV Generator Tie Line: The GF to POI line impedance is based on 100 feet of 1-795 kcmil ACSR. The continuous thermal rating is 361 MVA with impedance of R = 2.900E-5, X = 2.9400E-5, B = 5.800E-5. All values are in p.u.

4.0 STEADY-STATE POWER FLOW ANALYSIS

4.1 Criteria and Assumptions

Siemens-PTI PSS/E version 32.1.1 software was used for performing the steady-state power flow analysis, with the following study criteria:

1. The TP's GIP 2018, HS and LA (PSS/E-v32) base cases were developed from WECC approved seed cases (12HS4A1P_v32, 18HS2AP, 7/19/12 for GIP 2018), with updates for the TP's latest available Loads & Resources data, topology (line and transformer ratings data, TP planned and budgeted new / future projects, etc.), and updates received from several regional utilities and entities (Affected Systems). These GIP base cases were further updated by the TP for this GIR SIS to reflect generation re-dispatching to further stress the transmission system near the POI of this proposed GF Project. The following base cases were utilized for this SIS:
    a. 2018 HS cases with and without the IC's new GF Project;
    b. 2018 LA cases with and without the IC's new GF Project.
2. The regional generation was adjusted to result in TOT3 path flows of 1650 MW for the 2018 HS and LA cases.
3. The nearby XE-PSCo 400 MW wind generation projects at Missile Site (230 & 345 kV) were included at full output in the case models.
4. The nearby Colorado Highland Wind project generation was included at full output in the case models (existing 67 MW but to be expanded in late 2013 to a total 90 MW net / 91 MW gross, POI WAPA Fleming – Haxtun 115 kV).
5. The output from TI-13-0701 was accommodated by displacing TP generation resources at Craig (applicable if this GIR were as Network Resource application, but the results should be similar as a Non-Network Resource application). To stress the system locally, the generators were dispatched at the following output.

Table 4: Burlington Regional NR Generation Dispatches

Case	Description	Limon Unit 1 (MW)	Limon Unit 2 (MW)	Kit Carson (MW)	Burlington Unit 1 (MW)	Burlington Unit 2 (MW)
1	2018 Heavy Summer	68	68	51	50	50
2	2018 Light Autumn	77	77	51	55	55

6. The GF was modeled according to data provided by the IC. The Project was adequately represented both for assessing power flow and dynamic performance.
7. 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.
8. 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 – Lock All. Not allowing these voltage regulating solution parameters to adjust is to provide worse case results. Note - Additional sets of solution routines to allow LTCs and switched shunts to adjust are performed if necessary to mitigate excessive voltage deviations and/or bus voltages outside of the 0.90 p.u. and 1.10 p.u. voltage limits.
9. 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. N-0 and N-1 conditions were evaluated for any lines and transformers 115kV and greater.
10. All three of the 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 were documented. In addition, thermal overload increases of 2% or more were tabulated.
11. The GF controls the high voltage bus at the POI and should not negatively impact any controlled voltage buses on the Transmission System.
12. Post-contingency power transfer capability is subject to voltage constraints as well as equipment ratings. Each option was tested against NERC/WECC reliability criteria and 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

In addition, transmission lines and transformers were monitored for equipment rating violations using Normal Rating for N-0 and Emergency Rating for N-1 as listed in the power flow data.

4.2. Voltage Regulation and Reactive Power Criteria

1. All interconnections are subject to detailed study and may require additional study using more complex models and software such as PSCAD, EMTP or similar. The required mitigation may be in excess of minimums imposed by published standards, according to the best judgment of the TP's engineers.
2. The GF shall be capable of either producing or absorbing VAR as measured at the high voltage (HV) 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).
3. 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.
4. 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.
5. 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.
6. The GF may utilize switched capacitors or reactors so long as the individual step size is rated to result in a step-change voltage of less than 3% of the POI operating bus voltage. This step change voltage magnitude shall be calculated based upon the minimum system (N-1) short circuit POI bus MVA level as supplied by the TP. The GF is required to supply a portion of the VAR on a continuously adjustable or dynamic basis, as may be supplied from the generators or from a STATCOM or SVC type system. 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 (MV) 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 HV POI bus may be achieved with switched capacitors and reactors.
7. 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 Results

1. N-0 (System Intact, Cat. A) Study Results:
   The proposed project generation can be added with no thermal or voltage violations with all lines in-service.
2. N-1 (Single Contingency Cat. B) Study Results:
   a) Study results for N-1 studies of the 2018 HS and 2018 LA cases are shown in Tables 8 and 9 below.
      i. With use of the 2018 HS case, no thermal or voltage violations were identified. See Table 6 for reference.
      ii. With use of the 2018 LA case, the Wages – Waunita 115 kV transmission line exceeds its 40 MVA rating for three (3) 115 kV line contingencies. In addition, this element is thermally overloaded in the pre-project case, which would be mitigated prior to the project since it is thermally overloaded in the pre-project case. This element is limited by SCADA transducers, with the

next limiting element being the line conductor which is rated at 68 MVA (343A). Tri-State is in the process of working with WAPA to get this limitation resolved (relaying transducers to replace old transducers) to take care of this upgrade as part of its normal course of business. Contingency results are listed in Table 7. Loss of the Lincoln – Midway 230 kV line results in the North Yuma – Story 230 kV loading to 95.7 % of its emergency thermal rating. However, the resultant increased flow on the Affected System is within its thermal rating.

A tabulation of all elements that were triggered by thermal loading is provided in the following tables.

Table 6: 2018 Heavy Summer – Thermal (With Burlington - Wray 230 kV Line)

AFFECTED ELEMENT	CONTINGENCY	Emergency Rating (MVA)	Pre-Project Loading (%)	Post-100 MW Project Loading (%)	Delta (%)	Maximum Project Output w/out Additional NU (MW)	Owner	Notes – Limiting Elements
No elements thermally overloaded.								

Table 7: 2018 Light Autumn–Thermal (With Burlington - Wray 230 kV Line)

AFFECTED ELEMENT	CONTINGENCY	Emergency Rating (MVA)	Pre-Project Percent Loading	Post-100 MW Project Loading (%)	Delta (%)	Maximum Project Output w/out Additional NU (MW)	Owner	Notes – Limiting Elements
Wages-Wauneta 115kV Line†	Fleming-WildhorseCk 115kV Line	40	101.8	111.2	9.4	100	TSGT	Limit: SCADA transducers at Wauneta. Next limiting element line cond at 68.3 MVA. WAPA & TSGT are resolving this limitation.
Wages-Wauneta 115kV Line†	Fleming-Galien 115kV Line	40	100.8	110.2	9.4	100	TSGT	Limit: SCADA transducers at Wauneta. Next limiting element line cond at 68.3 MVA. WAPA & TSGT are resolving this limitation.
Wages-Wauneta 115kV Line†	Sterling-Galien 115kV Line	40	100.2	109.6	9.4	100	TSGT	Limit: SCADA transducers at Wauneta. Next limiting element line cond at 68.3 MVA. WAPA & TSGT are resolving this limitation.
N.Yuma-Story 230kV	Lincoln-Midway 230 kV Line	288	81.1	95.7	14.6	100	TSGT	

†Would be mitigated prior to the project since it is thermally overloaded in the pre-project case.

3. Steady-state voltage violations: With the TP's operating voltage criteria range of 0.90 p.u. to 1.10 p.u., under single contingency outage conditions, there are no voltage violations when the GF is at full output.

4. Steady-state contingency voltage deviation: Each Balancing Authority Area'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 100 MW output, the VAR capability required at the POI ranges from 32.9 MVAR produced (0.95 p.f. lag) to 32.9 MVAR absorbed (0.95 p.f. lead). This would be 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 IC shows reactive capability of +/- 0.90 p.f. Utilizing only the GF capability based on model data supplied by the IC, a steady-state analysis was performed for the POI voltage levels established by the dispatch in the power flow cases HS and LW. 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 voltage at the lumped equivalent model generator terminals and voltage at the POI bus. The system model provided by the IC shows that this GF cannot meet the TP's 0.95 p.f. lag to lead criteria at the POI with full 100 MW generation output. The system model provided by the IC shows that this GF can basically meet the TP's 0.95 p.f. lag to lead criteria at the POI with exception of the operating condition with output levels above 91 MW, and also at 0 MW for "VAR neutral" (<2 MVAR). Supplemental reactive power equipment of approximately 2 MVAR of switched shunt capacitors may be required at the full 100 MW GF output to meet the net 0.95 p.f. lag (producing VAR) criteria at the POI. Similarly, approximately 2 MVAR of switched shunt reactors (inductors) may be required on the 34.5 kV bus to offset the extra VARs and meet Tri-State's "VAR neutral" criteria of less than approximately 2 MVAR flow at 0 MW.

   The IC is responsible to determine equipment that will be installed to ensure that the GF can achieve the net 0.95 p.f. lag and lead capability across the 0 to 100 MW net generation output rating as measured at the POI. The TP may require a portion of the new MVAR to be supplied by dynamic reactive power support equipment, as to provide 0.95 lag to lead continuously adjustable or dynamic capability as measured at the generator terminals. Prior to entering into a GIA, the IC shall provide data that demonstrates compliance with the TP's reactive criteria.

Table 8 Reactive Power Delivered to the WTG Bus, and at POI Bus, Project Size: 100 MW

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	0.955	**0**	4.2	0	0.95	<2	-2.2
	0.9	25	12.1	0.982	24.9	14.7	0.861	0.95	8.2	-6.5
	0.9	50	24.2	1.006	49.5	22.3	0.912	0.95	16.3	-6.0
	0.9	75	36.3	1.026	74	27	0.939	0.95	24.3	-2.7
	0.9	91	44.1	1.038	89.6	29.5	0.950	0.95	29.5	0.0
	0.9	100	48.4	1.044	98.3	**30.1**	0.956	0.95	**32.3**	2.2
LA Base Case – 0.90 p.f. lead (absorbing MVAR)										
	-0.9	0	0	1.056	**0**	**5.1**	0	1.05	<2	**-3.1**
	-0.9	24	-11.6	1.036	23.9	-7.8	0.951	1.05	-7.0	0.0
	-0.9	25	-12.1	1.035	24.9	-8.4	0.948	1.05	-8.2	-0.2
	-0.9	50	-24.2	1.011	49.6	-25.1	0.892	1.05	-16.3	-8.8
	-0.9	75	-36.3	0.982	74	-45.5	0.852	1.05	-24.3	-21.2
	-0.9	100	-48.4	0.948	**98**	-70.5	0.812	1.05	**-32.2**	**-38.3**

5.0 DYNAMIC STABILITY ANALYSIS

5.1 Criteria and Assumptions

5.1.1 NERC/WECC Dynamic Criteria

PSSE version 32.1.1 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.

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

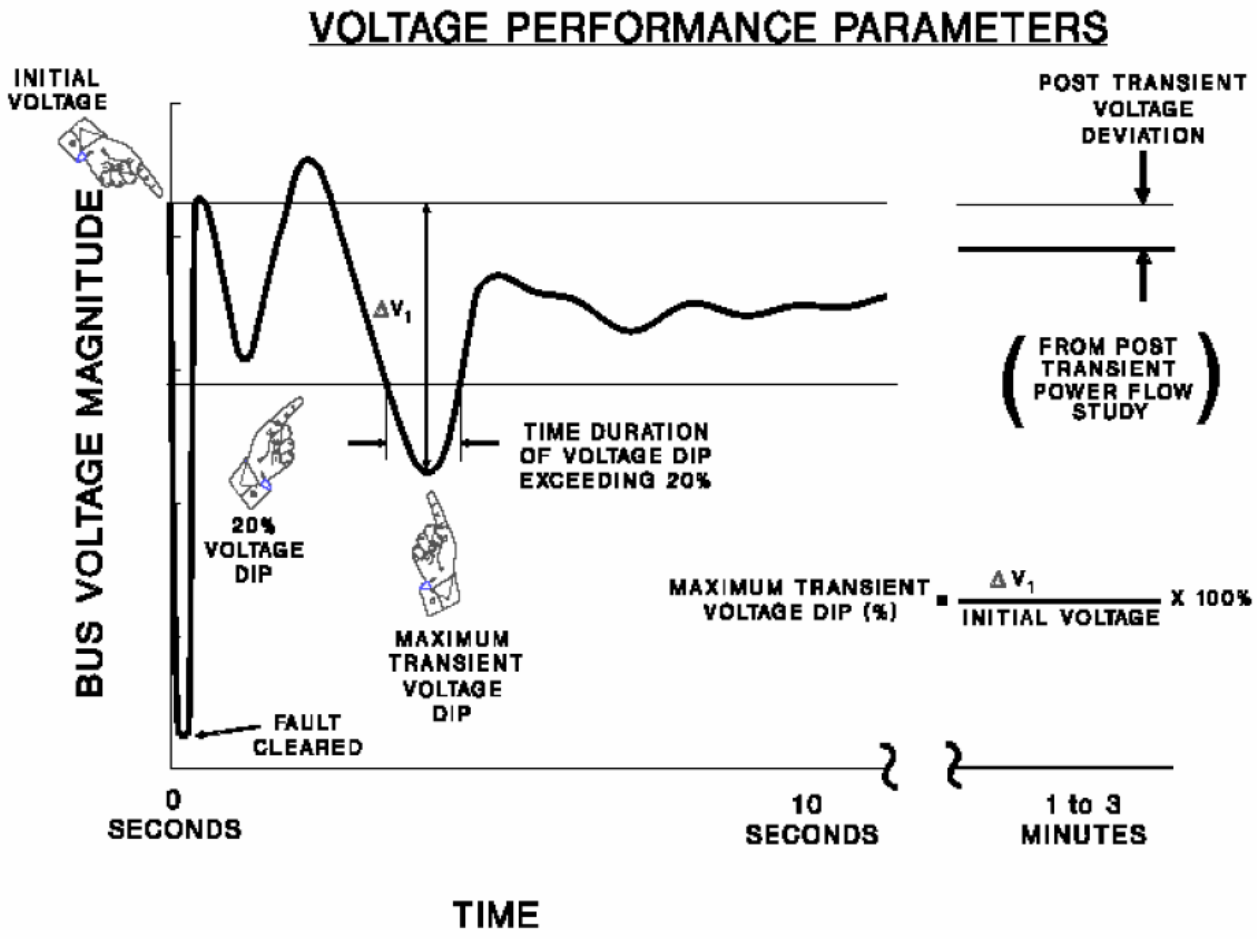


Figure W-1

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."

5.1.2 Voltage Ride-Through Requirements

1. The GF shall be able to meet the dynamic response LVRT requirements consistent with the latest proposed WECC / NERC criteria, in particular, as per the Tri-State 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 effected 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 be tripped after the fault period if this action is intended as part of a Special Protection System (SPS).
5. 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 Vestas V110 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

Dynamic stability was evaluated as follows:

1. The 2018 HS and 2018 LA cases were utilized with the GF in service.

2. System stability is observed by monitoring the Burlington and Lincoln relative rotor angle 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. The corresponding stability contingencies 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		
No.	Description	Bus Numbers
1	5-cycle 3-phase fault at POI 13-0701 230 kV bus, trip Landsman Ck - POI 13-0701 230 kV line	72710-73700
2	5-cycle 3-phase fault at Landsman Ck 230 kV bus, trip Big Sandy - Landsman Ck 230 kV line	73018-72710
3	5-cycle 3-phase fault at Landsman Ck 230 kV bus, trip Burlington - Landsman Ck 230 kV line	73036-72710
4	5-cycle 3-phase fault at Big Sandy 230 kV, trip Big Sandy - Lincoln 230 kV line	73018-73531
5	5-cycle 3-phase fault at Lincoln 230 kV, trip Lincoln - Midway 230 kV line	73531-73413
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 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 autumn show that:

1. The project with 50 Vestas V110 2.0 units (100 MW) wind turbines 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 autumn cases are shown in the following table.

Table 10 - Dynamic Stability Contingency Results

Dynamic Stability Contingencies		Conclusions 2018 Heavy Sumer and 2018 Light Autumn
No.	Description	
1	5-cycle 3-phase fault at POI 13-0701 230 kV bus, trip Landsman Ck - POI 13-0701 230 kV line	Stable
2	5-cycle 3-phase fault at Landsman Ck 230 kV bus, trip Big Sandy - Landsman Ck 230 kV line	Stable
3	5-cycle 3-phase fault at Landsman Ck 230 kV bus, trip Burlington - Landsman Ck 230 kV line	Stable
4	5-cycle 3-phase fault at Big Sandy 230 kV, trip Big Sandy - Lincoln 230 kV line	Stable
5	5-cycle 3-phase fault at Lincoln 230 kV, trip Lincoln - Midway 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 Big Sandy 230 kV, trip Big Sandy 230 - 115 kV transformer	Stable

6.0 SHORT-CIRCUIT ANALYSIS

A short-circuit study was completed for conditions for pre-project and post-project (maximum / worst case 100 MW) conditions. Faults were simulated at the main 230 kV TP POI Switching Station for different scenarios (3-phase and single line-to-ground, for maximum system intact (N-0), and for minimum system (N-1) at the main TP POI Switching Station 230 kV bus.

6.1 Assumptions and Methodology

1. The Tri-State full ASPEN One-Liner software model was used.

2. These studies are based upon a 2016 case year, after the new Tri-State Burlington – Wray 230 kV line is in service.

3. The tie line, transformers, and generators were modeled as supplied by the IC (see Section 3 earlier in this report):

   a. The zero sequence impedance of the 230-34.5 kV transformer was modeled as 85% of the positive sequence impedance.

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

   c. The zero sequence impedance of the tie line was estimated based on the expected construction.

6.2 Results

The results of the short-circuit analyses are show in Table 11, and Figures 2 and 3.

Table 11 - Short Circuit Results (2016 case year)

System Condition*	POI 230kV Bus (Total) 3-Ph Fault Level (Amps)	Duke Energy to Landsman Ck 230kV 3-Ph Fault Flow (Amps)	Big Sandy to Landsman Ck 230kV 3-Ph Fault Flow (Amps)	Landsman Ck to Burlington 230kV 3-Ph Fault Flow (Amps)	Gen 230kV to POI 230kV 3-Ph Fault Flow (Amps)	POI 230kV Bus (Total) SLG Fault Level (Amps)	Duke Energy to Landsman Ck 230kV SLG Fault Flow (Amps)	Big Sandy to Landsman Ck 230kV SLG Fault Flow (Amps)	Landsman Ck to Burlington 230kV SLG Fault Flow (Amps)	Gen 230kV to POI 230kV SLG Fault Flow (Amps)	Thevinin System Equivalent Impedance (R + jX p.u. on 100 MVA, 230 kV base)
POI 230kV Bus Fault (w/o IC 100 MW generation; all lines in service)	**4188**	296	1362	2531		**4362**	613	555	3198		Z1(pos) = 0.00614+j0.05963 Z0(zero) = 0.00871+j0.05198
POI 230kV Bus Fault (w/o IC 100MW generation; Big Sandy to Landsman Ck 230kV Out-of-Service)	2840	296		2545		3172	511		2664		Z1(pos) = 0.00798+j0.08803 Z0(zero) = 0.00943+j0.05963
POI 230kV Bus Fault (w/o IC 100 MW generation); LandsmanCrk to Burlington 230kV Out-of-Service)	1670	296	1376			1517	796	721			Z1(pos) = 0.01716+j0.14930 Z0(zero) = 0.04628+j0.19133
POI 230kV Bus Fault (with IC gen 100MW); all lines in service)	**5140**	296	1362	2531	952	**5488**	578	523	3013	1389	Z1(pos) = 0.00476+j0.04861 Z0(zero) = 0.00516+j0.03912

System Condition*	POI 230kV Bus (Total) 3-Ph Fault Level (Amps)	Duke Energy to Landsman Ck 230kV 3-Ph Fault Flow (Amps)	Big Sandy to Landsman Ck 230kV 3-Ph Fault Flow (Amps)	Landsman Ck to Burlington 230kV 3-Ph Fault Flow (Amps)	Gen 230kV to POI 230kV 3-Ph Fault Flow (Amps)	POI 230kV Bus (Total) SLG Fault Level (Amps)	Duke Energy to Landsman Ck 230kV SLG Fault Flow (Amps)	Big Sandy to Landsman Ck 230kV SLG Fault Flow (Amps)	Landsman Ck to Burlington 230kV SLG Fault Flow (Amps)	Gen 230kV to POI 230kV SLG Fault Flow (Amps)	Thevinin System Equivalent Impedance (R + jX p.u. on 100 MVA, 230 kV base)
POI 230kV Bus Fault (with IC gen 100MW); Big Sandy to Landsman Ck 230kV Out-of-Service)	3792	296		2545	952	4275	497		2593	1195	Z1(pos) = 0.00573+j0.06595 Z0(zero) = 0.00526+j0.04328
POI 230kV Bus Fault (with IC gen 100MW); LandsmanCrk to Burlington 230kV Out-of-Service)	2622	296	1376		952	2701	630	571		1515	Z1(pos) = 0.00959+j0.09524 Z0(zero) = 0.01051+j0.08685

Figure 2: Short-Circuit Model One-Line Diagram (1 of 2)

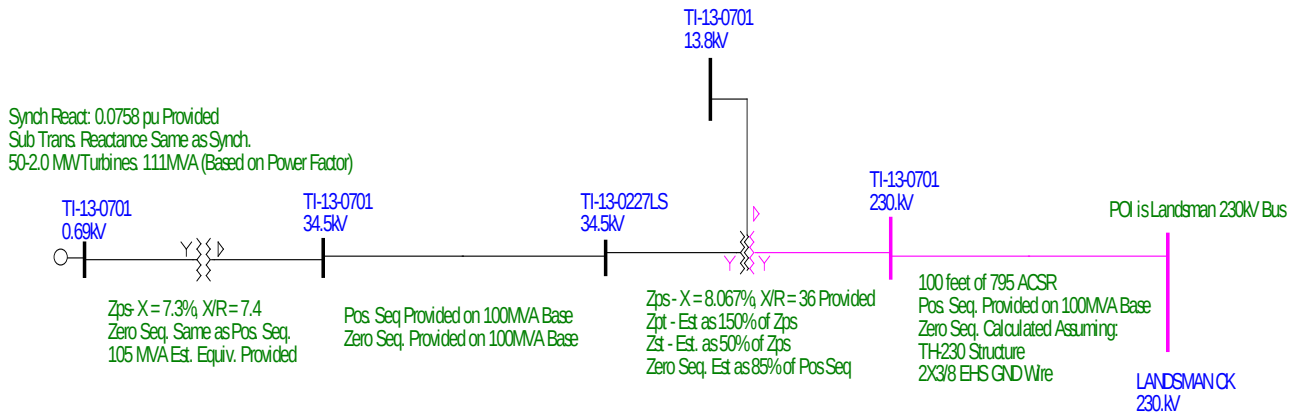
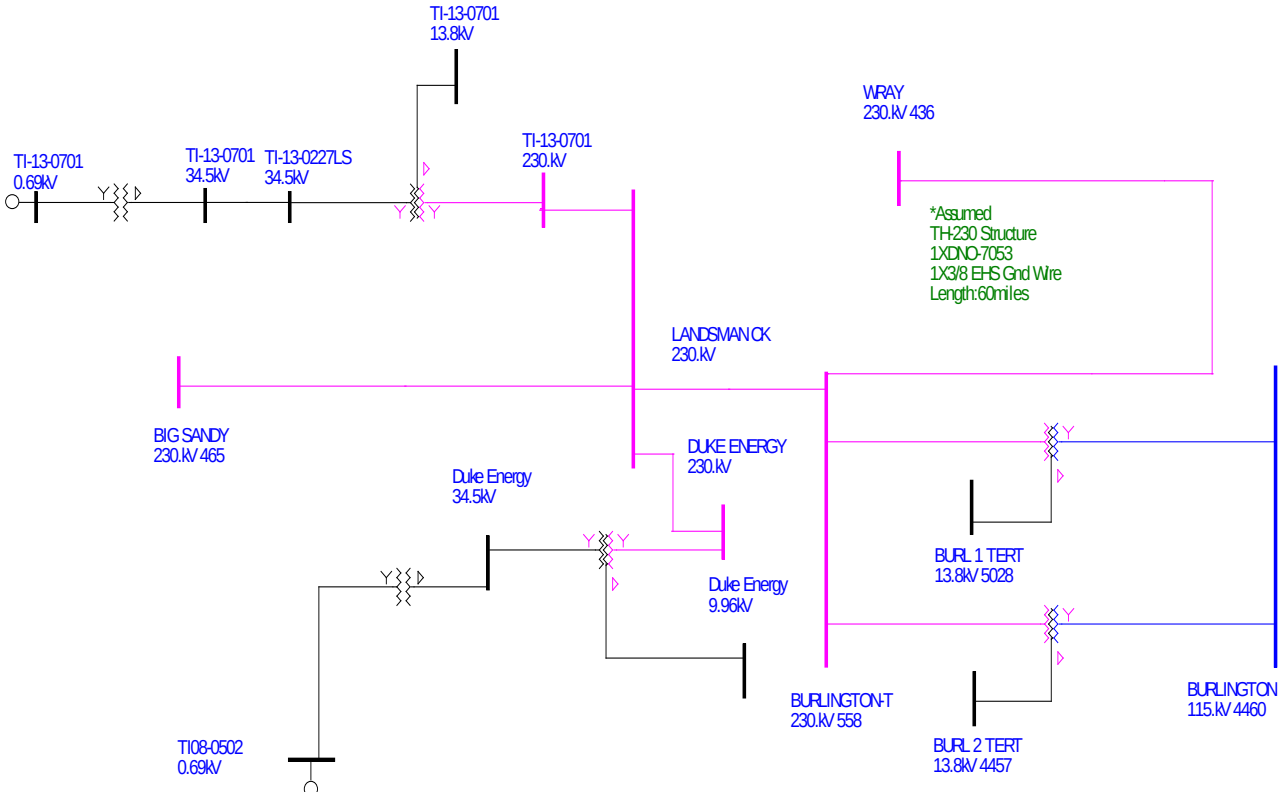


Figure 3: Short-Circuit Model One-Line Diagram (2 of 2)



These results indicate that a 100 MW GF has an approximate 952 amp (3-phase, 5,140 – 4,188) impact and 1,126 amp (SLG, 5,488 – 4,362) impact on the maximum total bus fault current magnitudes at the POI 230kV bus. These impacts do not result in exceeding any breaker interrupt ratings at the new POI or nearby Burlington or Big Sandy Substations.

7.0 SCOPE, COST & SCHEDULE OF TP FACILITIES

All cost estimates are good faith budgetary estimates in 2013 dollars, are approximate "good faith" (typically +/-30% accuracy) level estimates under the assumptions stated below. **Total Cost of TPIF and TPNU**: The estimated total cost is **$ 3.31 Million**. This total is comprised of the TPIF ($1.14 Million), plus the TPNU ($2.17 M) for the new TP facilities required to be constructed at the TP's Landsman Creek 230 kV Switching Station (POI Switching Station), as described in detail in Sections 7.2 and 7.3 below. It is estimated that it will take approximately **12 to 14 months** after completion of the Burlington to Wray 230kV line project and after receiving authorization to proceed for the TP to complete the engineering, design, procurement, construction, and testing activities identified for the scope of work in this SIS. Should a CPCN (or similar) be required by the CPUC for the construction of the additions at TP's POI Landsman Creek Switching Station, then it is estimated that the schedule could be extended by a year or more.

7.1 Scope of Work

The IC's GF 230-34.5-13.8 kV main substation is expected to be located remote from the TP's new POI switching station. It is assumed that the new TP POI Switching Station is to be located in Kit Carson County, (CO) and will interconnect into the existing Landsman Creek 230 kV substation, at a point located approximately 100 feet from the Landsman Creek Substation, and will require expanding the existing 3-point, 230kV ring bus breaker station into a 4-point, breaker-&-half configuration (see Figure 5 One-Line Diagram below).

Note that the IC will be responsible for providing the primary protection (relaying and the interrupting device) for the IC's step-up transformer located in its remote 230-34.5 kV substation yard. Equipment in the TP POI Switching Station will only provide backup protection for the IC's 230-34.5 kV main transformer in the event of equipment failure or malfunction in the IC's facility. To facilitate protective relaying and data acquisition between the TP POI Switching Station and the IC substation, the IC will provide fiber optic cables (OPGW) on its radial 230 kV transmission line to provide communication channels for data communication (SCADA), metering (real time), and protection (relaying).

7.2 Cost Estimates (TPIF & TPNU)

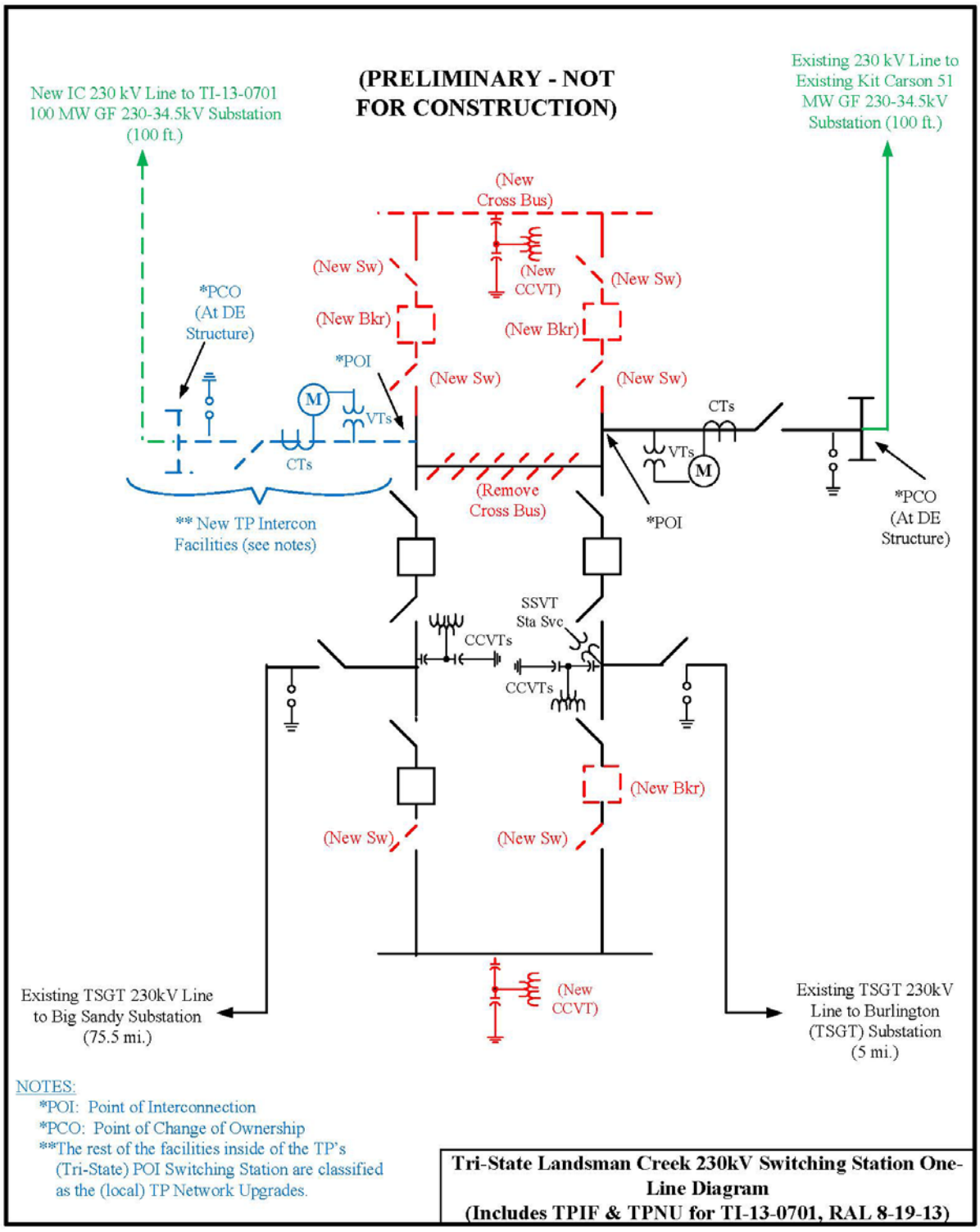
The cost estimates are broken out into two categories: a) TPIF (equipment installed between the POI tap point into the main bus and the Point of Change of Ownership (PCO) line termination dead-end structure inside the switching station fence line; and b) TPNU consisting of the rest of the facilities installed in the TP POI Switching Station, and any additional facilities or modifications to the TP network required in association with the TP POI Switching Station. The estimate includes all site work such as grounding and conduit installation inside the TP's switchyard. Unless otherwise noted, the estimate does not include access roads or any site work outside the TP POI Switching

Station, as these will need to be determined as part of the actual design work once the Project has been approved. The estimates do include the purchase of land, and assumes that all county and environmental permits as required for the TP POI Switching Station will be obtained by the TP, unless otherwise noted.

Total Cost (local POI TPIF and TPNU only): The estimated total cost is

- **$ 3.31 Million**. This total is comprised of the TPIF ($1.14 million), plus the TPNU ($2.17 million), and as shown in Fig. 5, and described in detail in section 7.2 below.

Figure 5 – TP 230 kV (POI) Landsman Creek Switching Station One-Line Diagram



7.2.1 Transmission Provider's Interconnection Facilities:

These are non-reimbursable facilities that are to be constructed, owned and operated by the TP, located between the POI (tap point into the main bus) and the PCO (line dead-end structure inside the substation fence line), and dedicated for the IC's interconnection and power flow. See Figure 5 and Table 11 for reference.

- **Approximate cost of TPIF (at POI – Landsman Creek SS) = $ 1.14 Million**.

Table 12: Summary Cost Estimate Details – TPIF (In TP's POI Switching Station, Non-Reimbursable)

Element	Table 11: Description (TP POI SS – TPIF)	Cost Est. Millions
TPIF **TP Landsman Creek Switching Station (POI)** **(IC 230 kV line termination equipment portion between PCO & POI)**	Engineer, purchase, construct / install and test all TP equipment installed inside of the TP POI Switching Station that is located between the PCO (IC line termination dead-end) and the POI (main bus tap point), consisting primarily of the following equipment: • One (1) 230 kV 3-ph gang line end 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. • One (1) 230 kV lot revenue & PQ metering panel including SEL-735 Rev/PQ meter (typical), Bitronics (typical) line meters, testing / checkout / commissioning. • One (1) lot of relaying for the IC radial 230 kV line protection (SEL-311C primary – pilot, SEL-311C secondary, and SEL-501 breaker-failure). • Three (3) 230 kV surge arresters (140 kV MCOV or as required). • IC line termination SCADA and telemetry communication equipment additions to substation RTU. • Install as required all other associated	**$1.14 M**

Element	Table 11: Description (TP POI SS – TPIF)	Cost Est. Millions
	required substation equipment including but not limited to grounding conductor, conduit and cable, insulators, foundations, support steel and tubular and cable bus.	
	Estimated Time Frame for Engineering, Procurement, Construction, and Commissioning	***12 to 14 Months (*See Schedule Notes)**

7.2.2 Transmission Provider's Network Upgrades:

These are reimbursable facilities, initially funded by the IC and refundable over time per the GIP, to be constructed, owned and operated by the TP, located on the TP's side of the POI. See Figure 5 and Table 12 below for reference.

- **Approximate cost of TPNU (Landsman Creek POI SS) = $ 2.17 Million.**

Table 13: Summary Cost Estimate Details – TPNU (Reimbursable)

Element	Table 12: Description (TP POI SS – TPNU)	Cost Est. Millions
TPNU: **Landsman Creek 230 kV Switching Station** **(not including IC 230 kV line termination equipment)**	Expand the existing 3-point, 230kV ring bus breaker station into a 4-point, breaker-&-half , two bay configuration (see Figure 5 One-Line Diagram below). The new TPNU scope includes typical testing, checkout, and commissioning testing. • Three (3) 230 kV power circuit breakers. • Six (6) 230 kV 3-ph gang disconnect switch and associated structure (for breakers / bus). • Two (2) 230 kV CCVTs (one per main bus). • Two (2) sets of 230 kV bus differential relays (on single panel). • Remove one existing 230 kV main / cross bus section & install new / relocated 230 kV main / cross bus section. • Install as required all other associated required substation equipment including but not limited to grounding conductor, conduit and cable, insulators, foundations, support steel and tubular and cable bus, trenches, site	**(Included in $2.17 M)**

Element	Table 12: Description (TP POI SS – TPNU)	Cost Est. Millions
	prep / yard work, fencing, etc.	
TPNU: **Big Sandy Substation– Relaying Mods**	• Relay settings changes (labor) for new TP POI Switching Station line termination protection configuration.	**(Minimal)**
TPNU: **Landsman Creek Switching Station – Relaying Mods**	• Relay settings changes (labor) for new TP POI Switching Station line termination protection configuration.	**(Minimal)**
	TOTAL TPNU	**$2.17 M**
	Estimated Time Frame for Engineering, Procurement, Construction, and Commissioning	***12 to 14 Months (*See ScheduleNotes)**

General Cost Assumptions

1) The cost estimates provided are based upon typical Power System Planning level estimates and the scope, costs, and schedules will need to be refined as appropriate in the later Facilities Study.

2) Costs are good faith high-level estimates based upon assumptions as stated in this SIS report, in 2013 dollars, and assume that no RUS funding is required for this IC-funded project work.

3) The IC is responsible for funding, construction and ownership of all (radial) transmission facilities from the proposed generator substation to the PCO located at the POI Switching Station.

4) The IC will supply enough transmission conductor from their last structure outside the POI substation for termination into the POI Switching Station line dead-end structure.

5) The IC is responsible for all GF Engineering, Procurement, and Construction for all GF, including any STATCOM type voltage regulation / reactive compensation devices located at their generation site or along their long interconnecting transmission line to just outside the POI sites.

7.3. Schedule (TPIF & TPNU)

It is estimated that it will take approximately 12 to 14 months after receiving authorization to proceed for the TP to complete the engineering, design, procurement, construction, and testing activities identified for the scope of work in this SIS.

The permitting time frames are included, but this study assumes that a CPCN or similar local governmental, environmental, or Federal regulatory authorization requirements are minimal. Actual time frames will vary due to local and Federal requirements, noting that the actual new construction required activities at the existing POI Switching Station (Landsman Creek) site cannot begin until any required permits (if necessary) have been acquired. The schedule for the new TP POI Switching Station assumes that this permitting and acquisition process will take 12 to 14 months to complete. Should a CPCN (or similar) be required by the CPUC for the construction of the additions at TP's POI Landsman Creek Switching Station, then it is estimated that the schedule could be extended by a year or more. Schedule estimates stated are after authorization to proceed has been obtained, such as from a signed GIA, E&P Agreement, or similar.

8.0 CONCLUSIONS

After the new Burlington to Wray 230 kV line is in service in 2016, the project can be interconnected with the following conditions. For the full 100 MW project output, additional NU at the Landsman Creek 230 kV Switching Station (POI) will be required. The estimated total costs are:

- TP Interconnection Facilities Costs (TPIF, Non-Reimbursable): $1.14 M
- TP Network Upgrades Costs (TPNU, POI SS Reimbursable): $2.17 M
- **TOTAL Costs for Interconnection: $3.31 M**

The POI will be at the Landsman Creek 230 kV Switching Station. In its GIR application the IC proposed an energization ISD of January 1, 2016. Based upon this SIS these dates may not be feasible and the IC will need to confirm a new proposed ISD before moving into the Facilities Study phase. This ISD will need to be no earlier than the completion of the new Burlington – Wray 230 kV transmission line project scheduled for completion in 2016, and at least 12 to 14 months after the approval to proceed has been authorized through the execution of either the GIA or an E&P Agreement.

Regarding reactive power / voltage regulation requirements, the system model provided by the IC shows that this GF can meet the TP's 0.95 p.f. lag to lead criteria at the 230 kV POI. In this scenario, the GF cannot produce the required reactive power (VAR) to meet the voltage regulation and associated net 0.95 p.f. lag to 0.95 p.f. lead requirement at the POI. Therefore, supplemental reactive power equipment 28 MVAR of switched shunt capacitors may be required at the full 100 MW GF output to meet the net 0.95 p.f. lag (producing VAR) criteria at the POI. Similarly, approximately 7 to 11 MVAR of switched shunt reactors (inductors) may be required on the 34.5 kV bus to meet the VAR neutral (<2 MVAR) criteria at the POI at 0 MW GF output. The IC has proposed installing supplemental switched capacitors on the main collector 34.5 kV bus at the GF substation, and controlled by the Power Plant Controller (PCC) instead of installing a STATCOM. The TP has informed the IC that they will need to provide detailed studies to show that using switched capacitors with

this controller will have adequate response time to meet Tri-State's requirement for "continuously variable / fast responding" 0.95 p.f. lag / lead capability at the collector bus in association with acting for voltage regulation / control at the POI.

NOTES:

1. Recent Studies completed for other GIRs in this region indicate that until such time that the TP's new Burlington to Wray 230kV transmission line is in service, any additional generation at this requested POI (including this IC's GF) would only be allowed to interconnect using the transmission system on an "as available" basis in accordance with Section 3.2.1(4) of TP's GIP.

2. Per Section 3.2.2.4 of the TP's GIP, "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 OASIS web site for information regarding requests for transmission service, and related requirements and contact information.

9.0 LIST OF APPENDICES

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

Appendix A: Steady State Power Flow Study – List of N-1 Contingencies

Appendix B: Steady State Power Flow Study – Plots

Appendix C: Dynamic Stability Study – Switching Sequences

Appendix D: Dynamic Stability Study – Waveform Plots

Appendix E: Generation Dispatch Summary Listing (BAs 10, 70, 73)

Appendix F: Landsman Creek 230 kV Bus Voltage History 2011-2012