# Interconnection System Impact Study
# Final Report – February 19, 2018

## Generator Interconnection Request No. TI-17-0225
## 248.4 MW (Alternate Project Output of 217.35 MW) Wind Energy Generating Facility
## In Goshen County, Wyoming


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# 1.0 EXECUTIVE SUMMARY

This System Impact Study (SIS) is for Generator Interconnection Request No. TI-17-0225, a proposed 248.4 MW wind energy Generating Facility (GF) to be located in Goshen County, Wyoming. In addition, a proposed 217.35 MW wind energy Generating Facility (GF) was studied with the Wayne Child Project improvements modeled. The SIS was prepared in accordance with Tri-State Generation and Transmission Association, Inc. (Tri-State) Generator Interconnection Procedures, and includes steady-state power flow, cost and schedule analyses for interconnection of the project as a Network Resource.

Cost and schedule estimates are good faith estimates only (typically +/-30% accuracy). Higher accuracy estimates (+/- 20%) will be provided as part of a Facilities Study.

The proposed Project consists of seventy-two (72) Vestas V136 3.45 wind turbines and one (1) 34.5-345-13.8 kV transformer at the main wind energy generating facility (GF) with a primary Point of Interconnection (POI) on the Laramie River (LRS) - Story 345 kV line approximately 31.5 miles south of the LRS Substation. The Project will interconnect to the new substation via a five (5) mile transmission line (see Figures 1 and 2 for reference). The alternate Project size consists of sixty-three (63) Vestas V136 3.45 wind turbines.

Twenty-four (24) TOT 3 power flow scenarios per season were studied for this Project for 2020 Heavy Summer and 2020 Light Autumn system conditions.

Steady-state power flow results:

For 2020 Heavy Summer and Light Autumn system conditions, elements that exceed their emergency thermal limits with addition of the Project were identified.

Present system conditions require mitigation to the following elements prior to inclusion of the Project:

1. Laramie River – Ault 345kV line. Mitigation: Terminal upgrades at the Laramie River Substation are required to achieve a rating of 1195 MVA for this line. Or, the Project size will need to be reduced to 0 MW.
2. Laramie River – Stegall 230kV line. Mitigation: Reconductor 59.9-mile transmission line from LRS to Stegall 230kV substations. Or, the Project will need to be reduced at or below 125 MW.
3. Archer – Stegall 230kV line. Mitigation: The 61.2-mile transmission line from Archer to Stegall 230kV substations is a WAPA owned element and therefore will require mitigation from WAPA. Or, the Project will need to be reduced to 0 MW.
4. Low voltage in the Keota area. Mitigation: Install three (3) 10 MVAr shunt capacitors at the Project 34.5kV bus, three (3) 10 MVAr shunt capacitors at the Keota 115kV bus and one (1) 10 MVAr shunt capacitor at the Redbox 115kV bus. These reactive devices will ensure that with addition of the Project, the Keota area voltage will be above 0.9 per unit and less than 8% voltage deviation for an N-1 contingency.

Sensitivity Analysis modeled the Wayne Child 345/230kV transformer, Laramie River-Ault 345kV and Laramie River-Wayne Child-Keota 345kV line improvements.

Inclusion of the sensitivity analysis improvements alleviates thermal overloads to the three (3) identified elements in the present system analysis. None of those elements exceeded their normal or emergency thermal limits. However, the following two (2) elements require mitigation with the sensitivity elements included:

1. Wayne Child – Project POI 345kV line. Mitigation: Construct both POI substation and Wayne Child substation (345 kV Bus) to 3000 amps. Both POI substation and Wayne Child substation assume a 2000 amp bus construction. The 3000 amp construction will add approximately 10% to the cost of both the POI substation and Wayne Child project. Or, the Project will need to be reduced at or below 217.35 MW.
2. Archer – Terry Ranch 230kV line. Loss of the LRS – Ault 345kV line results in the Archer – Terry Ranch 230kV line to exceed its emergency thermal limit of 320 MVA by approximately 9% for the majority of TOT 3 system conditions. Since this WAPA owned element has no available capacity, the Project will need to mitigate this thermal overload. Mitigation: WAPA has indicated that CT's and relays for this line can be upgraded to achieve a 442 MVA line rating.

Details of element overloads are provided in Section 4.3 of the report; however, the above summarizes elements that will need to be mitigated prior to inclusion of the Project.

The Alternate Project size of 217.35 MW output also modeled all Wayne Child Project system improvements.

In addition to the Wayne Child system improvements and the reduced Project output, the Archer – Terry Ranch 230kV terminal equipment is upgraded to achieve a thermal rating of 442 MVA.

Loss of the LRS – Ault 345kV line results in the Wayne Child – Project POI 345kV line loading to 99.9% of its emergency thermal rating of 1195 MVA during the 2020 heavy summer conditions.

Reactive power / voltage regulation:

With the 248.4 MW Project size, results indicate that the GF cannot meet Tri-State's 0.95 p.f. lag to lead criteria at the POI with exception of output levels below 90 MW. At 0 MW, the Projects collector system produces reactive power, which does not meet the VAR neutral requirements (<6 MVAR). Approximately 106 MVAR of switched shunt capacitors and 10 MVAR of switched shunt reactors (inductors) will be required on the 34.5 kV bus to offset the collector system VARs and meet Tri-State's VAR neutral criteria (less than 2 MVAR flow at 0 MW output at the POI).

With the 217.35 MW Project size, results indicate that the GF cannot meet Tri-State's 0.95 p.f. lag to lead criteria at the POI with exception of output levels below 80 MW. At 0 MW, the Projects collector system produces reactive power, which does not meet the VAR neutral requirements (<6 MVAR). Approximately 78 MVAR of switched shunt capacitors and 8 MVAR of switched shunt reactors (inductors) will be required on the 34.5 kV bus to offset the collector system VARs and meet Tri-State's VAR neutral criteria (less than 2 MVAR flow at 0 MW output at the POI).

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 248.4 MW (or 217.35 MW) net generation output rating as measured at the POI. Tri-State requires a portion of the new MVAR to be supplied by dynamic reactive power equipment.

Transient stability results:

Transient stability results identified that the project does not require additional mitigation and is compliant with the NERC/WECC criteria. The Project was studied as a Network Resource.

Simulation results for summer and light autumn system conditions show that:

1. With the Vestas V136 wind turbines (217.35 MW or 248.4 MW), the Project did not trip during any contingencies and had acceptable voltage levels. In addition, the GF was able to operate at full capacity.
2. Acceptable damping and voltage recovery was observed.

The estimated costs for interconnecting the proposed Project are as follows (refer to Figure 2 in Section 5). This assumes a 2000 amp bus construction for both the POI substation and Wayne Child 345 kV bus. A 3000 amp construction will be approximately 10% higher:

| | |
|---|---|
| • Wayne Child Network Upgrades (Reimbursable): | $ 16.50 M |
| • Interconnection Facilities Costs (Non-Reimbursable): | $ 1.09 M |
| • Network Upgrade Costs (Reimbursable): | $ 9.18 M |
| TOTAL Cost (2020 dollars) for Interconnection: | $ 26.77 M |

Estimate does not included required Archer – Terry Ranch 230 kV Network Upgrades. It is the responsibility of the Customer to contact WAPA to determine cost.

**NOTE:** Network upgrade costs are reimbursed only when payments are made to the Transmission Provider under its Tariff for transmission services with respect to the Generating Facility. Network upgrade costs are not reimbursed if transmission services are not secured from the Transmission Provider.

The in-service date for this GF will depend on construction of the Interconnection Facilities, Network Upgrades, and coordination with Laramie River Station planned outages and will be a minimum of 24 months after the execution of a Generator Interconnection Agreement or Engineering and Procurement contract. Interconnection will require outage coordination with MBPP and other regional entities which may impact actual milestone and in-service dates.

**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 February 24, 2017, the Interconnecting Customer submitted a Generator Interconnection Request for a 248.4 MW wind energy GF to be connected approximately five (5) miles from a new 345 kV Substation that will interconnect to the Laramie River – Story 345kV line approximately 31.5 miles south of the Laramie River 345kV substation. The application was deemed complete on March 8, 2017 and an Interconnection System Study Agreement was executed on May 5, 2017. The model data used in this study is that which was provided by the Customer in its Generator Interconnection Request.

On September 18, 2017, the Interconnecting Customer requested that an alternate Project output of 217.35 MW be studied with only the Wayne Child Project improvements included. This is based on results from the initial power flow analysis.

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.

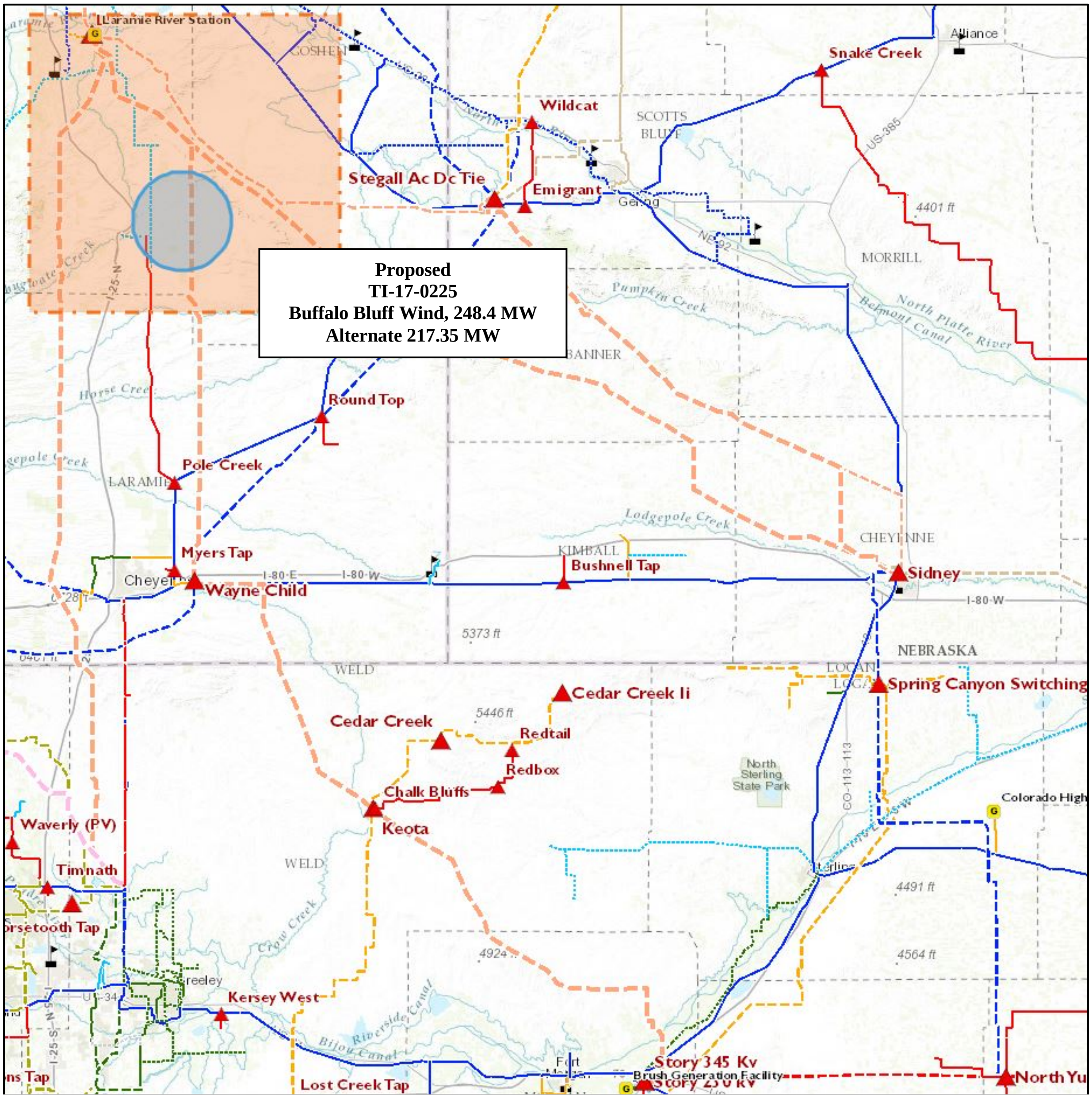


**Figure 1:** *Area Map - One-Line Diagram Of Study Area And Location of GF*

## 3.0 GF MODELING DATA

The project consists of one (1) 248.4 MW (217.35 MW for alternate output) equivalent wind turbine generator with one (1) 34.5-345-13.8 kV transformers and a five (5) mile 345 kV generator tie line that will interconnect to the Laramie River – Story 345kV line approximately 31.5 miles south of the Laramie River 345kV substation. See Figures 1 and 2 for further details. Model data is based upon 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 one (1) equivalent generator with a Pmax of 248.4 MW (217.35 MW for alternate output) and reactive capability of 0.902 lag and 0.918 lead, 118.9 and -107.3 MVAr (104.03 and -93.89 MVAr for alternate output), respectively. The specific generator parameters may be revised for the transient stability analysis.

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

| Unit | Description | Project Output | Alternate Project Output |
|---|---|---|---|
| Pmax | Name plate rating (lumped equivalent gen model) | 248.4 MW | 217.35 MW |
| Qmin, Qmax | Reactive capability | 0.902 lag to 0.918 lead | 0.902 lag to 0.918 lead |
| Et | Terminal voltage | 0.65 kV | 0.65 kV |
| RSORCE | Synchronous resistance | 0.0052 p.u. | 0.0052 p.u. |
| XSORCE | Synchronous reactance | 0.8590 p.u. | 0.8590 p.u. |

**Table 2:** *Power Flow Data for Individual Generating Units*

| Unit | Description | [*Manufacturer*] |
|---|---|---|
| MBase | Generator MVA base | 3.45 MVA |
| Prated | Generator active power rating | 3.45 MW |
| Pmin | Minimum generation | 0.2 MW |
| Vrated | Terminal voltage | 0.65 kV |
| Srated | Unit transformer Rating | 4 MVA |
| Xt | Unit Transformer Reactance (on transformer base) | 9.00% |
| Xt/Rt | Unit Transformer X/R ratio | 12.9 |

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

| V (%) at HV POI Bus | Delta V (p.u) | Time (sec) |
|---|---|---|
| 90 | -0.10 | 60.0 |
| 85 | -0.15 | 11 |
| 70 | -0.30 | 2.6 |
| 0 | -1.00 | 0.55 |
| 110 | 0.10 | 3600 |
| 121 | 0.21 | 2 |
| 136 | 0.36 | 0.15 |

**34.5 kV Collector System:** The medium voltage collector system was modeled with typical collector system equivalent impedances based upon the WECC Guide. The wind farm was interconnected via one (1) equivalent 34.5-0.65 kV, 288 MVA (252 MVA for alternate Project) transformer with 9% impedance, X/R of 12.9 and an equivalent feeder circuit model.

**Main GF Substation Transformer:** The substation transformer was modeled with ratings of 172/229/286 MVA and a voltage ratio of 34.5 kV (wye-gnd) - 345 kV (wye-gnd) - 13.80 kV (delta). The transformer impedance was assumed to be 11.9% on the 172 MVA base FA rating with X/R of 50.

**345 kV Generator Tie Line:** The GF to POI line impedance was based on five (5) miles of 2-795 kcmil ACSR. The continuous thermal rating is 1084 MVA with an impedance of R = 275.0E-6, X = 2.415E-3, B = 31.035E-3. All values are in p.u.

# 4.0 STEADY-STATE POWER FLOW ANALYSIS

## 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 2020, HS and LA (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 for this SIS to reflect appropriate generation dispatching for this study. The following base cases were utilized for the SIS:
    a. 2020 Heavy Summer cases with and without the new GF project,
    b. 2020 Light Autumn cases with and without the new GF project.
2. The request was studied as a stand-alone project and did not include other generation requests that may exist in Tri-State's GIP queue.
3. The proposed Project output was accommodated by displacing generation resources at Dryfork (applicable as if this GF were a Network Resource, but with results similar to a Non-Network Resource).
4. The following ratings were used for this study:
    - Sidney 230/115kV transformer: 240 MVA (260 MVA with tertiary reactors off)
    - Stegall 230/115kV No.1 transformer: 167 MVA normal/emergency thermal rating.
    - LRS – Stegall 230kV line: 478/550 MVA normal/emergency thermal rating.
    - Archer – Stegall 230kV line: 459/478 MVA normal/emergency thermal rating.
    - Archer – Wayne Child 230 kV line: 637/661 MVA normal/emergency thermal rating.
    - Archer – Terry Ranch 230 kV line: 320/320 MVA normal/emergency thermal rating.
5. 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.
6. 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 voltage solution parameters to adjust provides worst case results.)
7. All buses, lines and transformers with nominal voltage levels 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.

8. All three of the nearby study areas (WAPA, Tri-State, and XE/PSCo) were investigated using the same overload criteria. Any thermal loading greater than 98% of the branch rating with a thermal overload increase of 2% or more was tabulated.
9. 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.
10. To stress TOT 3 (WECC Path 36), a 24-point generation matrix utilized in similar studies was used (Table 5). Generation was dispatched in accordance with the matrix cells and flows across TOT3 were stressed by increasing remote generation in the Pacific Northwest, Idaho, and Montana and decreasing generation in Colorado. TOT3 is considered stressed when overload or voltage violations begin to appear in the vicinity of TOT3 under these increased flows. The impact on TOT3 flows due to Project injection levels was then determined using the following methodology:
    a) TOT3 was stressed pre-Project.
    b) Project injection levels were increased and equivalent generation was displaced at Comanche to minimize the impact on TOT3.
    c) The metering point for the LRS – Wayne Child 345kV line is currently at the LRS end of the line. The metering point would need to be moved to the Project POI end of the Project POI – Wayne Child 345kV line.

**Table 4:** *TOT 3 24-point matrix of TOT 3 limits*

| CPP = 66 MW | 300 MW E to W | 0 MW | 300 MW W to E |
|---|---|---|---|
| LRS = 1140 MW<br>Pawnee = 777 MW | 20HS: 1700<br>20LA: 1591 | 20HS: 1590<br>20LA: 1505 | 20HS: 1259<br>20LA: 1399 |
| LRS = 570 MW<br>Pawnee = 777 MW | 20HS: 1408<br>20LA: 1430 | 20HS: 1155<br>20LA: 1204 | 20HS: 870<br>20LA: 975 |
| LRS = 1140 MW<br>Pawnee = 280 MW | 20HS: 1720<br>20LA: 1616 | 20HS: 1600<br>20LA: 1536 | 20HS: 1231<br>20LA: 1414 |
| LRS = 570 MW<br>Pawnee = 280 MW | 20HS: 1425<br>20LA: 1448 | 20HS: 1150<br>20LA: 1220 | 20HS: 870<br>20LA: 992 |
| **CPP = 243 MW** | **300 MW E to W** | **0 MW** | **300 MW W to E** |
| LRS = 1140 MW<br>Pawnee = 777 MW | 20HS: 1685<br>20LA: 1520 | 20HS: 1580<br>20LA: 1484 | 20HS: 1298<br>20LA: 1387 |
| LRS = 570 MW<br>Pawnee = 777 MW | 20HS: 1405<br>20LA: 1410 | 20HS: 1146<br>20LA: 1192 | 20HS: 870<br>20LA: 965 |
| LRS = 1140 MW<br>Pawnee = 280 MW | 20HS: 1720<br>20LA: 1595 | 20HS: 1592<br>20LA: 1518 | 20HS: 1275<br>20LA: 1405 |
| LRS = 570 MW<br>Pawnee = 280 MW | 20HS: 1406<br>20LA: 1437 | 20HS: 1153<br>20LA: 1210 | 20HS: 875<br>20LA: 981 |

11. A sensitivity was simulated with the following system improvements:

a) Wayne Child 345/230kV transformer was included.

b) LRS – Ault 345kV line, LRS – Wayne Child 345kV line and Wayne Child – Keota 345kV line normal/emergency ratings increase to 1195 MVA.

c) The metering point with the Wayne Child Project is at the Wayne Child end of the Wayne Child - Keota 345kV line.

With these system improvements, the 24-point generation matrix was revised for the TOT 3 pre-project flows. The summary of pre-project TOT 3 flows is provided in Table 6.

**Table 5:** *TOT 3 24-point matrix of TOT 3 limits, Sensitivity Cases*

| CPP = 66 MW | 300 MW E to W | 0 MW | 300 MW W to E |
|---|---|---|---|
| LRS = 1140 MW<br>Pawnee = 777 MW | 20HS: 1640<br>20LA: 1290† | 20HS: 1485<br>20LA: 1200† | 20HS: 1060<br>20LA: 1120† |
| LRS = 570 MW<br>Pawnee = 777 MW | 20HS: 1290<br>20LA: 1170 | 20HS: 1080<br>20LA: 1117 | 20HS: 852<br>20LA: 882 |
| LRS = 1140 MW<br>Pawnee = 280 MW | 20HS: 1722<br>20LA: 1378† | 20HS: 1502<br>20LA: 1280† | 20HS: 1052<br>20LA: 1000† |
| LRS = 570 MW<br>Pawnee = 280 MW | 20HS: 1310<br>20LA: 1352 | 20HS: 1090<br>20LA: 1140 | 20HS: 830<br>20LA: 895 |
| **CPP = 243 MW** | **300 MW E to W** | **0 MW** | **300 MW W to E** |
| LRS = 1140 MW<br>Pawnee = 777 MW | 20HS: 1540<br>20LA: 1190† | 20HS: 1471<br>20LA: 1150† | 20HS: 1100<br>20LA: 1130† |
| LRS = 570 MW<br>Pawnee = 777 MW | 20HS: 1282<br>20LA: 1245† | 20HS: 1060<br>20LA: 1105 | 20HS: 846<br>20LA: 875 |
| LRS = 1140 MW<br>Pawnee = 280 MW | 20HS: 1680<br>20LA: 1240† | 20HS: 1490<br>20LA: 1195† | 20HS: 1080<br>20LA: 1000† |
| LRS = 570 MW<br>Pawnee = 280 MW | 20HS: 1298<br>20LA: 1334 | 20HS: 1080<br>20LA: 1128 | 20HS: 860<br>20LA: 886 |

†Laramie River (LRS) generation was reduced to mitigate thermal overloads to the Archer – Terry Ranch 230kV line.

For the light load cases with high Laramie River generation (a1, a2 and c1 for CPP = 66 and CPP = 243), when the TOT 3 flow is reduced, flow on the Archer – Terry Ranch 230kV line increases. As a result, reducing flow to the Archer – Terry Ranch 230kV line by reducing TOT 3 flow was not effective. Therefore, the LRS generation was reduced until the line was loaded at 100%. This is not a result of the Project, but an operational constraint.

12. Generation from Montana, Northern Wyoming and Colorado were used to adjust TOT 3 transfer levels after Project generation was inserted,

13. 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**.**

**Table 6:** *Voltage Criteria*

| Tri-State Voltage Criteria for Steady State Power Flow Analysis | | |
|---|---|---|
| **Conditions** | **Operating Voltages** | **Delta-V** |
| Normal (P0 Event) | 0.95 - 1.05 | N/A |
| Contingency (P1 Event) | 0.90 - 1.10 | 8% |
| Contingency (P1 Event) | 0.92 – 1.10 (PRPA Only) | 8% |
| Contingency (P2-P7 Event) | 0.90 - 1.10 | None |

### 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, 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 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 P0) Study Results:

   The proposed project generation (both 248.4 MW and 217.35 MW) can be added with no thermal or voltage violations with all lines in-service for both the 2020 Heavy Summer and Light Autumn system conditions.

2. N-1 (Single Contingency, Category P1) Study Results:

   Results for N-1 contingencies using the 2020 Heavy Summer and 2020 Light Autumn cases with CPP=66 and CPP=243 are shown in Tables 9 and 10 below. In addition, Tables 11 and 12 show results for the Wayne Child 345/230kV transformer sensitivity.

   Table 8 identifies TOT 3 system conditions for the twelve (12) cases that are referenced (first column) in the results tables.

   i. With the 2020 Heavy Summer case, elements that exceed their emergency thermal limits with addition of the Project were identified.

      Loss of the Project POI – Wayne Child 345kV line results in the LRS – Ault 345kV line to exceed its emergency thermal limit of 956 MVA by approximately 8%. Mitigation: Terminal upgrades at the Laramie River Substation are required to achieve a rating of 1195 MVA for this line. Or, the Project size will need to be reduced to 0 MW.

      Loss of the LRS – Ault 345kV line results in the LRS – Stegall 230kV line to exceed its emergency thermal limit of 550 MVA by approximately 10%. Mitigation: Reconductor 59.9-mile transmission line from LRS to Stegall 230kV substations. Or, the Project size will need to be reduced at or below 70 MW.

   ii. With the 2020 Light Autumn case, elements that exceed their emergency thermal limits with addition of the Project were identified.

      Loss of the Project POI – Wayne Child 345kV line results in the LRS – Ault 345kV line to exceed its emergency thermal limit of 956 MVA by approximately 8%. Mitigation: Terminal upgrades at the Laramie River Substation are required to achieve a rating of 1195 MVA for this line. Or, the Project size will need to be reduced to 0 MW.

      Loss of the LRS – Ault 345kV line also results in the Archer – Stegall 230kV line to exceed its emergency thermal limit of 478 MVA by approximately 8%. Mitigation: The 61.2-mile transmission line from Archer to Stegall 230kV substations is a WAPA owned element and therefore will require mitigation from WAPA. Or, the Project size will need to be reduced to 0 MW.

      Loss of the LRS – Ault 345kV line results in the LRS – Stegall 230kV line to exceed its emergency thermal limit of 550 MVA by approximately 5%. Mitigation: Reconductor 59.9-mile transmission line from LRS to Stegall 230kV substations. Or, the Project size will need to be reduced at or below 125 MW.

   iii. Sensitivity Analysis: Wayne Child 345/230kV transformer, LRS-Ault 345kV line and LRS-Wayne Child-Keota 345kV line upgrades.

      Inclusion of the Wayne Child 345/230kV transformer, LRS-Ault 345kV and LRS-Wayne Child-Keota 345kV line upgrades alleviates thermal overloads to elements identified in the present system analysis, which include the following lines: LRS – Ault 345kV line, LRS – Stegall 230kV line and the Archer – Stegall 230kV line. None of these elements exceeded their normal or emergency thermal limits in the sensitivity analysis. However, two (2) elements exceed emergency thermal limits.

With the 2020 Heavy Summer case, elements that exceed their emergency thermal limits with addition of the Project were identified.

Loss of the LRS – Ault 345kV line results in the Wayne Child – Project POI 345kV line to exceed its emergency thermal limit of 1195 MVA by approximately 1.4%. Mitigation: Construct both POI substation and Wayne Child substation (345 kV Bus) to 3000 amps. Both POI substation and Wayne Child substation assume a 2000 amp bus construction. Or, the Project will need to be reduced at or below 217.35 MW.

With the 2020 Light Autumn case, elements that exceed their emergency thermal limits with addition of the Project were identified.

Loss of the LRS – Ault 345kV line results in the Archer – Terry Ranch 230kV line to exceed its emergency thermal limit of 320 MVA by approximately 9% for the majority of TOT 3 system conditions. Since this WAPA owned element has no available capacity, the Project will need to mitigate this thermal overload. Mitigation: WAPA has indicated that CT's and relays for this line can be upgraded to achieve a 442 MVA line rating.

iv. Alternate Project size of 217.35 MW with Wayne Child 345/230kV transformer, LRS-Ault 345kV line and LRS-Wayne Child-Keota 345kV line upgrades.

In addition, the Archer – Terry Ranch 230kV terminal equipment is upgraded to achieve a thermal rating of 442 MVA.

With the 2020 Heavy Summer case, no elements exceed their emergency thermal limits with addition of the Project.

Loss of the LRS – Ault 345kV line results in the Wayne Child – Project POI 345kV line loading to 99.9% of its emergency thermal rating of 1195 MVA.

With the 2020 Light Autumn case, no elements exceed their emergency thermal limits with addition of the Project.

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 voltage violations with the GF at full output.

   For 2020 Heavy Summer conditions and high LRS generation, loss of the Laramie River – Ault 345kV line results in voltage levels below 0.9 per unit and voltage deviations greater than 8% in the Keota area. These issues were also observed in the pre-project cases. As a result, three (3) 10 MVAr shunt capacitors were modeled at the Redbox 115kV bus to provide voltage support. With these reactive devices modeled in the pre-project base case, all buses in the Keota area were above 0.9 per unit and voltage deviations were less than 8% for loss of the Laramie River – Ault 345kV line.

With the reactive devices identified in the pre-project base case modeled, the Laramie River – Ault 345kV line outage was simulated for the c1 matrix base cases. The following table shows that all pre-project voltage levels are greater than 0.9 per unit and the voltage deviation is less than 8% for all buses in the Keota area.

**Table 7:** *Keota Area Steady-State Voltage Performance*

| | Pre-Contingency | | Post-Contingency | | | | |
|---|---|---|---|---|---|---|---|
| Bus | Pre-Project (per unit V) | Post-Project (per unit V) | Pre-Project (per unit V) | Post-Project (per unit V) | Pre-Project (% Vdev) | Post-Project (% Vdev) | Delta |
| 72140 Keota 345 | 1.0089 | 1.00300 | 0.9446 | 0.9075 | -6.4 | -9.5 | -3.2 |
| 72141 Keota 115 | 1.0082 | 1.00220 | 0.9421 | 0.9038 | -6.6 | -9.8 | -3.3 |
| 72142 Redbox 115 | 1.0068 | 1.00050 | 0.9382 | 0.8983 | -6.8 | -10.2 | -3.4 |
| 72143 RedBox 69 | 0.9816 | 0.97510 | 0.9108 | 0.8694 | -7.2 | -10.8 | -3.6 |
| 72144 Redtail 115 | 1.0033 | 0.99700 | 0.9344 | 0.8943 | -6.9 | -10.3 | -3.4 |
| 72145 Redtail 34.5 | 1.0339 | 1.03950 | 0.9609 | 0.9293 | -7.1 | -10.6 | -3.5 |
| 72146 ChlkBlff 115 | 1.0079 | 1.00180 | 0.9418 | 0.9034 | -6.6 | -9.8 | -3.3 |
| 72147 ChlkBlff 12.5 | 1.022 | 1.02730 | 0.9482 | 0.9157 | -7.2 | -10.9 | -3.6 |
| 72811 WL_Child 345 | 1.0135 | 1.00800 | 0.9579 | 0.9179 | -5.5 | -8.9 | -3.5 |

The post-project base cases have voltage levels less than 0.9 per unit and voltage deviations greater than 10%. As a result, voltage mitigation is required. Mitigation: Install three (3) 10 MVAr shunt capacitors at the Project 34.5kV bus, three (3) 10 MVAr shunt capacitors at the Keota 115kV bus and one (1) 10 MVAr shunt capacitor at the Redbox 115kV bus. These reactive devices will ensure that with addition of the Project, the Keota area voltage will be above 0.9 per unit and less than 8% voltage deviation for an N-1 contingency.

Sensitivity: For the 2020 Heavy Summer conditions, loss of the Sidney 230-115kV transformer results in voltage levels below 0.9 per unit and voltage deviations greater than 8% in the underlying 115kV system for the a1 and c1 matrix cases. The pre-project base case exhibited these issues. With addition of the Project, the voltage levels and voltage deviations slightly improve. As a result, the Project is not responsible for voltage mitigation.

4. Steady-state contingency voltage deviation: Each Balancing Authority's ΔV requirement was applied as per Table 7. There were ΔV violations at several monitored buses prior to addition of shunt capacitors in the pre-project case.

5. Reactive power required at the POI:

   At full 248.4 MW output, the VAR capability required at the POI ranges from 81.65 MVAR produced (0.95 p.f. lag) to 81.65 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 0.902 lag (producing) and 0.918 lead (absorbing) 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 13 and 14 tabulate 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.

   With the 248.4 MW Project size, results indicate that the GF cannot meet Tri-State's 0.95 p.f. lag to lead criteria at the POI with exception of output levels below 90 MW. At 0 MW, the Projects collector system produces reactive power, which does not meet the VAR neutral requirements (<6 MVAR). Approximately 106 MVAR of switched shunt capacitors and 10 MVAR of switched shunt reactors (inductors) will be required on the 34.5 kV bus to offset the collector system VARs and meet Tri-State's VAR neutral criteria (less than 2 MVAR flow at 0 MW output at the POI).

   With the 217.35 MW Project size, results indicate that the GF cannot meet Tri-State's 0.95 p.f. lag to lead criteria at the POI with exception of output levels below 80 MW. At 0 MW, the Projects collector system produces reactive power, which does not meet the VAR neutral requirements (<6 MVAR). Approximately 78 MVAR of switched shunt capacitors and 8 MVAR of switched shunt reactors (inductors) will be required on the 34.5 kV bus to offset the collector system VARs and meet Tri-State's VAR neutral criteria (less than 2 MVAR flow at 0 MW output at the POI).

   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 248.4 MW net generation output rating as measured at the POI. Tri-State requires a portion of the new MVAR to be supplied by dynamic reactive power equipment.

6. The existing LRS generation is currently restricted to 680 MW during an outage of either the LRS-Story or LRS-Ault 345 kV lines. This is required to maintain system reliability in the event of an outage on the remaining LRS 345 kV line. The proposed Project will be curtailed prior to curtailing the existing LRS units based on current ownership rights in the MBPP system.

   However, with the proposed Project (and no Wayne Child system upgrades), this report identifies a potential overload of the LRS – Ault 345kV line for a loss of the Project POI to Wayne Child 345 kV line section of the LRS – Story 345 kV line beyond the emergency thermal rating. As a result, this element will need to be upgraded as a part of the Projects mitigation to interconnect, unless the Wayne Child Project is in-service.

   Similarly, for full Project output (and no Wayne Child system upgrades), loss of the LRS – Ault 345kV line results in a potential overload to the LRS – Stegall 230 kV line and Archer – Stegall 230kV line. Based on the 680 MW restriction, the LRS – Stegall 230 kV potential line overload would exist above the 30-minute 550 MVA emergency line rating and the Archer – Stegall 230kV line potential line overload would exist above the 478 MVA emergency line rating. As a result, these elements will need to be upgraded as a part of the Projects mitigation to interconnect, unless the Wayne Child Project is in-service.

7. Energy Resource Interconnection Service permits delivery of the Project output using the existing non-firm capacity of the transmission system on an as available basis. Energy Resource Interconnection Service does not, in and of itself, convey any right to deliver the GF output to any specific customer or point of delivery. There currently is no firm transmission capacity available north to south across the TOT3 path.

**Table 8:** *TOT 3 Case Matrix Key*

| | DC Ties | | |
|---|---|---|---|
| **Key Generation** | **300 MW East to West** | **0 MW** | **300 MW West to East** |
| LRS 1140 MW (Net), Pawnee 777 MW (Net) | a1 | a2 | a3 |
| LRS 570 MW (Net), Pawnee 777 MW (Net) | b1 | b2 | b3 |
| LRS 1140 MW (Net), Pawnee 280 MW (Net) | c1 | c2 | c3 |
| LRS 570 MW (Net), Pawnee 280 MW (Net) | d1 | d2 | d3 |

**Table 9:** *2020 Heavy Summer – Thermal Analysis*

| Matrix Location | AFFECTED ELEMENT | CONTINGENCY | Emergency Rating (MVA) | Pre-Project Percent Loading | Post-248.4 MW -Project Percent Loading | Delta | Maximum Output w/out Upgrade (MW) | Owner |
|---|---|---|---|---|---|---|---|---|
| **CPP=66MW** | | | | | | | | |
| a1 | LRS (73108) - Ault (73012) 345kV | Project-POI (73650) - WL_Child (72811) 345kV | 956.1 | 99.9 | 107.7 | 7.8 | 0 | TSGT |
| a2 | LRS (73108) - Ault (73012) 345kV | Project-POI (73650) - WL_Child (72811) 345kV | 956.1 | 99.8 | 107.4 | 7.6 | 0 | TSGT |
| a3 | LRS (73108) - Stegall (73190) 230kV | LRS (73108) - Ault (73012) 345kV | 550 | 93.6 | 108.5 | 14.9 | 70 | BASIN |
| **CPP=243MW** | | | | | | | | |
| a1 | LRS (73108) - Ault (73012) 345kV | Project-POI (73650) - WL_Child (72811) 345kV | 956.1 | 99.8 | 107.4 | 7.6 | 0 | TSGT |
| a2 | LRS (73108) - Ault (73012) 345kV | Project-POI (73650) - WL_Child (72811) 345kV | 956.1 | 99.9 | 107.4 | 7.5 | 0 | TSGT |
| a3 | LRS (73108) - Stegall (73190) 230kV | LRS (73108) - Ault (73012) 345kV | 550 | 94.4 | 109.4 | 15.0 | 90 | BASIN |

**Table 10:** *2020 Light Autumn – Thermal Analysis*

| Matrix Location | AFFECTED ELEMENT | CONTINGENCY | Emergency Rating (MVA) | Pre-Project Percent Loading | Post-248.4 MW -Project Percent Loading | Delta | Maximum Output w/out Upgrade (MW) | Owner |
|---|---|---|---|---|---|---|---|---|
| **CPP=66MW** | | | | | | | | |
| a1 | LRS (73108) - Ault (73012) 345kV | Project-POI (73650) - WL_Child (72811) 345kV | 956.1 | 100.0 | 108.0 | 8.0 | **0** | TSGT |
| a1 | Archer (73009)-Stegall (73190) 230kV | LRS (73108) - Ault (73012) 345kV | 478 | 100.0 | 103.1 | 3.1 | **0** | WALM |
| a3 | LRS (73107)-Stegall (73190) 230kV | LRS (73108) - Ault (73012) 345kV | 550 | 90.8 | 104.6 | 13.8 | **125** | WALM |
| **CPP=243MW** | | | | | | | | |
| a1 | LRS (73108) - Ault (73012) 345kV | LRS (73108) - Project-POI (73650) 345kV | 956.1 | 98.3 | 106.5 | 8.2 | **0** | TSGT |
| a1 | Archer (73009)-Stegall (73190) 230kV | LRS (73108) - Ault (73012) 345kV | 478 | 99.8 | 103.2 | 3.4 | **0** | WALM |
| a3 | LRS (73108) - Stegall (73190) 230kV | LRS (73108) - Ault (73012) 345kV | 560 | 91.5 | 105.0 | 13.5 | **150** | BASIN |

**Table 11:** *2020 Heavy Summer – Thermal Analysis, Sensitivity: Wayne Child Transformer*

| Matrix Location | AFFECTED ELEMENT | CONTINGENCY | Emergency Rating (MVA) | Pre-Project Percent Loading | Post-248.4 MW -Project Percent Loading | Delta | Maximum Output w/out Upgrade (MW) | Owner |
|---|---|---|---|---|---|---|---|---|
| **CPP=66MW** | | | | | | | | |
| a1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 99.9 | 108.9 | 9.0 | **0** | WALM |
| c1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 98.9 | 107.8 | 8.9 | **28** | WALM |
| c1 | WL_Child (72811) - TI-17-0225 (73650) 345kV | Ault (73012) - LRS (73108) 345kV | 1195 | 93.4 | 101.4 | 8.0 | **217.35** | WALM |
| **CPP=243MW** | | | | | | | | |
| a1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100 | 109.3 | 9.3 | **0** | WALM |
| c1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 99.8 | 108.8 | 9.0 | **0** | WALM |
| c1 | WL_Child (72811) - TI-17-0225 (73650) 345kV | Ault (73012) - LRS (73108) 345kV | 1195 | 91.4 | 99.3 | 7.9 | 248.4 | WALM |

**Table 12:** *2020 Light Autumn – Thermal Analysis, Sensitivity: Wayne Child Transformer*

| Matrix Location | AFFECTED ELEMENT | CONTINGENCY | Emergency Rating (MVA) | Pre-Project Percent Loading | Post-248.4 MW -Project Percent Loading | Delta | Maximum Output w/out Upgrade (MW) | Owner |
|---|---|---|---|---|---|---|---|---|
| **CPP=66MW** | | | | | | | | |
| a1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 109.0 | 9.0 | 0 | WALM |
| a2 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 108.5 | 8.5 | 0 | WALM |
| a3 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 109.2 | 9.2 | 0 | WALM |
| b1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 109.1 | 9.1 | 0 | WALM |
| b2 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 104.1 | 4.1 | 0 | WALM |
| c1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 108.3 | 8.3 | 0 | WALM |
| c2 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 108.5 | 8.5 | 0 | WALM |
| c3 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 108.7 | 8.7 | 0 | WALM |
| **CPP=243MW** | | | | | | | | |
| a1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 109.2 | 9.2 | 0 | WALM |
| a2 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 99.3 | 108.6 | 9.3 | 0 | WALM |
| a3 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 99.9 | 109.2 | 9.3 | 0 | WALM |
| b1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.0 | 109.3 | 9.3 | 0 | WALM |
| b2 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 93.9 | 103.0 | 9.2 | 0 | WALM |
| c1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 99.8 | 108.9 | 9.1 | 0 | WALM |
| c2 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 99.8 | 109.1 | 9.3 | 0 | WALM |
| c3 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 99.9 | 109.2 | 9.3 | 0 | WALM |
| d1 | Archer (73009) - Terry_Ranch (73488) 230kV | Ault (73012) - LRS (73108) 345kV | 320 | 100.2 | 109.5 | 9.3 | 0 | WALM |

**Table 13:** *Reactive Power Delivered to the WTG Bus, and at POI Bus, Project Size: 248.4 MW, Vestas V136 3.45 MW, 72 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 – 0.902 p.f. lag (producing MVAR) | | | | | | | | | | |
| | 0.902 | 0 | 0.0 | 0.914 | 0 | 10.18 | 0 | 0.95 | 0 | -10.2 |
| | 0.902 | 62.1 | 29.7 | 0.981 | 61.38 | 28.89 | 0.905 | 0.95 | 20.2 | -8.7 |
| | 0.902 | 124.2 | 59.4 | 1.023 | 121.59 | 28.88 | 0.973 | 0.95 | 40.0 | 11.1 |
| | 0.902 | 186.3 | 89.2 | 1.045 | 180.7 | 11.53 | 0.998 | 0.95 | 59.4 | 47.9 |
| | 0.902 | 248.4 | 118.9 | 1.043 | 238.43 | -28.03 | 0.993 | 0.95 | 78.4 | 106.4 |
| LA Base Case – 0.918 p.f. lead (absorbing MVAR) | | | | | | | | | | |
| | -0.918 | 0 | 0 | 1.059 | 0 | 13.65 | 0 | 1.05 | 0 | -13.7 |
| | -0.918 | 62.1 | -26.8 | 0.997 | 61.47 | -23.47 | 0.934 | 1.05 | -20.2 | -3.3 |
| | -0.918 | 124.2 | -53.7 | 0.9 | 121.08 | -88.18 | 0.808 | 1.05 | -39.8 | -48.4 |
| | -0.918 | 186.3 | -80.5 | 0.9 | 180.1 | -116.46 | 0.840 | 1.05 | -59.2 | -57.3 |
| | -0.918 | 248.4 | -107.3 | 0.9 | 237.62 | -156.47 | 0.835 | 1.05 | -78.1 | -78.4 |

**Table 14:** *Reactive Power Delivered to the WTG Bus, and at POI Bus, Project Size: 217.35 MW, Vestas V136 3.45 MW, 63 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 – 0.902 p.f. lag (producing MVAR) | | | | | | | | | | |
| | 0.902 | 0 | 0.0 | 0.911 | 0 | 7.56 | 0 | 0.95 | 0 | -7.6 |
| | 0.902 | 54.34 | 26.0 | 0.973 | 53.71 | 24.78 | 0.908 | 0.95 | 17.7 | -7.1 |
| | 0.902 | 108.7 | 52.0 | 1.015 | 106.4 | 27.2 | 0.969 | 0.95 | 35.0 | 7.8 |
| | 0.902 | 163 | 78.0 | 1.04 | 158.09 | 16.22 | 0.995 | 0.95 | 52.0 | 35.7 |
| | 0.902 | 217.4 | 104.0 | 1.048 | 208.78 | -9.87 | 0.999 | 0.95 | 68.6 | 78.5 |
| LA Base Case – 0.918 p.f. lead (absorbing MVAR) | | | | | | | | | | |
| | -0.918 | 0 | 0 | 1.055 | 0 | 10.13 | 0 | 1.05 | 0 | -10.1 |
| | -0.918 | 54.34 | -23.5 | 1.002 | 53.79 | -21.36 | 0.929 | 1.05 | -17.7 | -3.7 |
| | -0.918 | 108.7 | -46.9 | 0.919 | 106.06 | -74.87 | 0.817 | 1.05 | -34.9 | -40.0 |
| | -0.918 | 163 | -70.4 | 0.9 | 157.48 | -106.56 | 0.828 | 1.05 | -51.8 | -54.8 |
| | -0.918 | 217.4 | -93.9 | 0.9 | 207.95 | -137.83 | 0.834 | 1.05 | -68.3 | -69.5 |

# 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 Figures W-1 and W-2 from the NERC/WECC TPL-001-WECC-CRT-3 Transmission System Planning Performance Criteria.

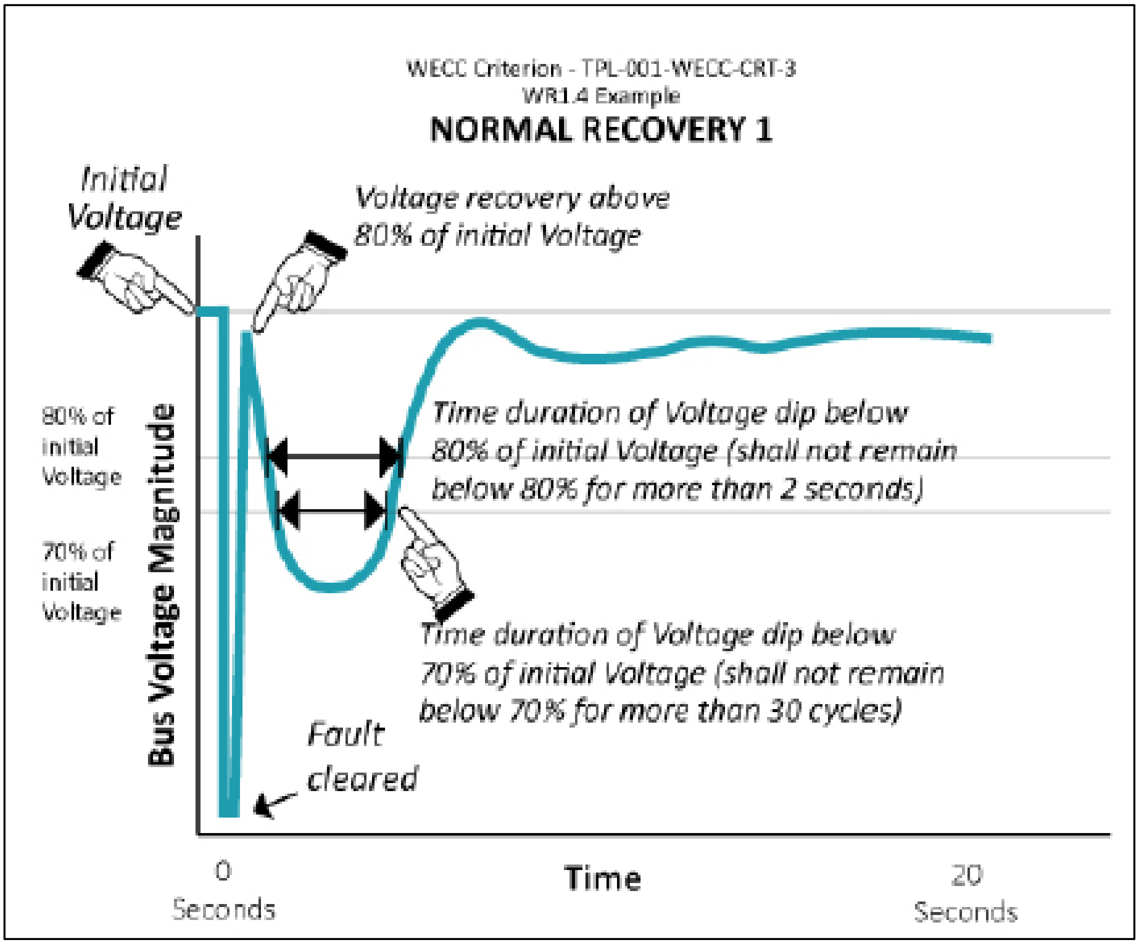


**Figure 2:** *Bus Voltage Normal Recovery 1*

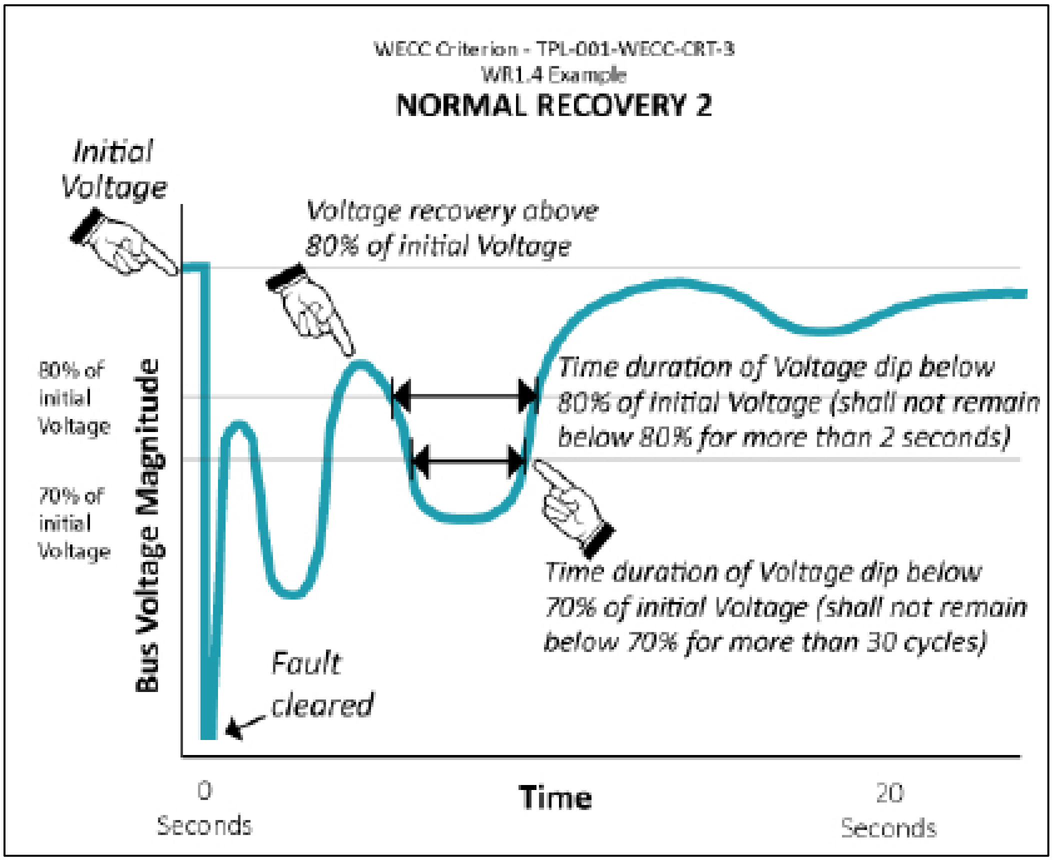


**Figure 3:** *Bus Voltage Normal Recovery 2*

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 Low Voltage Ride Through (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.
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 plant is in-service.

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. A Vestas user written model was used for the simulations. Transient stability analysis was completed with the Vestas V136 wind model (VestasGS_8_1_1_PSSE33.dll).
2. The Project base case modeled Laramie River generation at its full output in the heavy summer base case. The light autumn base case modeled only the Laramie River Unit 1 generator on-line.
3. The collector system was modeled with an equivalent collector system and one 345/34.5 kV substation transformer.

### 5.3 Methodology

Dynamic stability was evaluated as follows:

1. The 2020 HS and 2020 LA base cases were utilized with the GF in service.
2. System stability is observed by monitoring the voltage and relative rotor angles of local machines 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 15:** *List of Dynamic Stability Contingencies*

| Dynamic Stability Contingencies | | Bus Numbers |
|---|---|---|
| No. | Description | |
| 1 | 4-cycle 3-phase fault at POI 17-0225 345 kV, trip Project POI – HS_17-0225 345 kV line | 73650 - 73652 |
| 2 | 4-cycle 3-phase fault at POI 17-0225 345 kV, trip Project POI – Laramie River 345 kV line | 73650 - 73108 |
| 3 | 4-cycle 3-phase fault at POI 17-0225 345 kV, trip Project POI – Wayne Child 345 kV line | 73650 - 72811 |
| 4 | 4-cycle 3-phase fault at Wayne Child 345 kV, trip Wayne Child – Keota 345 kV line | 72811 - 72140 |
| 5 | 4-cycle 3-phase fault at Keota 345 kV, trip Keota – Story 345 kV line | 72140 - 73193 |
| 6 | 4-cycle 3-phase fault at Laramie River 345 kV, trip Laramie River – Ault 345 kV line | 73108 - 73012 |
| 7 | 4-cycle 3-phase fault at Ault 345 kV, trip Ault – Craig 345 kV line | 73012 - 79014 |
| 8 | 5-cycle 3-phase fault at Laramie River 230 kV, trip Laramie River – Sawmill Creek 230 kV line | 73107 - 72906 |
| 9 | 5-cycle 3-phase fault at Laramie River 230 kV, trip Laramie River – Stegall 230 kV line | 73107 - 73190 |
| 10 | 5-cycle 3-phase fault at Stegall 230 kV, trip Stegall – Sidney 230 kV line | 73190 - 73180 |
| 11 | 5-cycle 3-phase fault at Sidney 230 kV, trip Sidney – Spring Canyon 230 kV line | 73180 - 73579 |
| 12 | 5-cycle 3-phase fault at Archer 230 kV, trip Archer – Stegall 230 kV line | 73009 - 73190 |
| 13 | 5-cycle 3-phase fault at Wayne Child 230 kV, trip Archer – Wayne Child 230 kV line | 73009 - 72818 |
| 14 | 5-cycle 3-phase fault at Laramie River 345 kV, trip Laramie River 345/230 kV No.1 Transformer | 73107 - 73108 |
| 15 | 5-cycle 3-phase fault at Laramie River-2 24 kV, trip Laramie River Generator Unit 2 | 73130 |

### 5.4 Results

Transient stability results identified that the project does not require additional mitigation and is compliant with the NERC/WECC criteria. The Project was studied as a Network Resource.

Simulation results for summer and light autumn system conditions show that:

1. With the Vestas V136 wind turbines (217.35 MW or 248.4 MW), the Project did not trip during any contingencies and had acceptable voltage levels. In addition, the GF was able to operate at full capacity.
2. Acceptable damping and voltage recovery was observed.
3. It is assumed that there was a modeling glitch for contingencies that simulated a line fault at the Laramie River 345kV substation. For either contingency 2 or 6, a three (3) cycle fault was applied at the Project POI or Ault, then the fault was removed and a line fault was applied at the Laramie River 345kV end of the line for one (1) cycle, then the fault was removed. These actions resulted in the simulation to freeze at 0.59 seconds (5 cycles after fault). The following actions were done to try to get a solution: 1) change simulation time step, 2) change the acceleration factor and 3) change voltage at generator terminals.

   As a result, the simulation was done with only a four (4) cycle three phase fault that tripped the line – no single line fault.

   Since the fault is well damped with the four (4) cycle fault, it is believed that the non-solution is a glitch with the provided proprietary model.

# 6.0 SHORT-CIRCUIT ANALYSIS

Short-circuit analysis was performed for 3-phase-to-ground and single-line-to-ground faults at the 345 kV POI bus, using the Aspen OneLiner model. Faults were applied with and without the Project generation. Model assumptions are as follows.

## 6.1 Assumptions and Methodology

1. The model used is shown in Figure 3 below.
2. The Point of Interconnection is on the Laramie River Station – Keota 345 kV transmission line, 31.5 miles south of Laramie River Station. The line impedance of the sections between LRS, the Project POI and Story 345 kV were provided by Tri-State Power System Planning.
3. A collector system for an output of 248.4 MW and 217.35 MW was modeled with a single 345/34.5/13.8 kV, 172/229/286 MVA transformer with voltage ratios of 34.5 kV (wye-gnd) - 345 kV (wye-gnd) - 13.8 kV (delta). The transformer impedance was specified in Attachment A of the interconnect request.
   a. Zero Sequence impedance of the 345/34.5 kV transformers was modeled using data provided by the Customer.
   b. The transformer delta windings were all modeled to lag the high side phase angles.
   c. The zero sequence impedance of the 345 kV tie line and the 34.5 kV collector system was modeled from the one-line drawing provided by the Customer (Attachment A).
   d. The system was modeled with a 345/230 KV autotransformer at Wayne Child. This transformer is currently planned to be installed in 2021 but would have to be expedited if this Generation was added.

## 6.2 Results

There are two tables shown in this section. Table 16 shows the results with 248 MW of wind generation is added. Table 17 shows the results with 217.35 MW of wind generation added. Both tables list results for the 345 kV bus faults at the POI with contributions from each of the 345 kV sources into the bus faults. The system impedances for the faulted buses for each configuration are also included. The results indicate that the GF increases the fault duty by approximately 1213 Amperes at the 345 kV POI bus for both models and 341 Amperes for a 3 phase fault. The resultant total fault currents are within planned equipment ratings.

**Table 16:** *Short Circuit Results (248.4 MW Gen)*

| System Condition | POI 345kV Bus Total 3-Ph Fault (Amps) | LRS to POI 345kV 3-Ph Fault (Amps) | POI to Wayne Child 345kV 3-Ph Fault (Amps) | Gen HV to POI 3-Ph Fault (Amps) | POI 345kV Bus Total SLG Fault (Amps) | LRS to POI 345kV SLG Fault (Amps) | POI to Wayne Child 345kV SLG Fault (Amps) | Gen HV to POI SLG Fault (Amps) | Thevinin System Equivalent Impedance R + jX p.u. 100 MVA, 345 kV base |
|---|---|---|---|---|---|---|---|---|---|
| **POI 345kV Bus Fault w/o 248.4 MW generation N-0** | **9152** | 5702 | 3451 | | **7136** | 4457 | 2679 | | Z1(pos) = 0.001 + j 0.0182<br>Z0(zero) = 0.00796 + j 0.033 |
| 345kV POI Bus Fault w/o 300 MW generation LRS - POI 345kV Out | 3683 | | 3683 | | 2774 | | 2774 | | Z1(pos) = 0.00387 + j0.04547<br>Z0(zero) = 0.0211 + j0.0879 |
| 345kV POI Bus Fault w/o 300 MW generation POI-Wayne Child 345kV Out | 5928 | 5928 | | | 4549 | 4549 | | | Z1(pos) = 0.00139 + j0.02823<br>Z0(zero) = 0.0128 + j0.0529 |
| **POI 345kV Bus Fault with 248.4 MW generation N-0** | **9493** | 5702 | 3451 | 341 | **8349** | 3811 | 2291 | 2275 | Z1(pos) =0.001 + j 0.0176<br>Z0(zero) = 0.0046 + j 0.0244 |
| 345kV POI Bus Fault with 300 MW generation LRS – POI 345kV Out | 4023 | | 3683 | 341 | 3881 | | 1957 | 1944 | Z1(pos) =0.00328+ j 0.0414<br>Z0(zero) = 0.0065 + j 0.0451 |
| 345kV POI Bus Fault with 300 MW generation POI-Wayne Child 345kV Out | 6269 | 5928 | | 341 | 5727 | 3602 | | 2148 | Z1(pos) = 0.00126 + j 0.0266<br>Z0(zero) = 0.00573+ j0.0337 |

**Table 17:** *Short Circuit Results (217.35 MW Gen)*

| System Condition | POI 345kV Bus Total 3-Ph Fault (Amps) | LRS to POI 345kV 3-Ph Fault (Amps) | POI to Wayne Child 345kV 3-Ph Fault (Amps) | Gen HV to POI 3-Ph Fault (Amps) | POI 345kV Bus Total SLG Fault (Amps) | LRS to POI 345kV SLG Fault (Amps) | POI to Wayne Child 345kV SLG Fault (Amps) | Gen HV to POI SLG Fault (Amps) | Thevinin System Equivalent Impedance R + jX p.u. 100 MVA, 345 kV base |
|---|---|---|---|---|---|---|---|---|---|
| **POI 345kV Bus Fault w/o 217.35 MW generation N-0** | **9152** | 5702 | 3451 | | **7136** | 4457 | 2679 | | Z1(pos) = 0.001 + j 0.0182<br>Z0(zero) = 0.00796 + j 0.0331 |
| 345kV POI Bus Fault w/o 217.35MW generation LRS - POI 345kV Out | 3683 | | 3683 | | 2774 | | 2774 | | Z1(pos) = 0.00387 + j0.04527<br>Z0(zero) = 0.0211 + j0.0879 |
| 345kV POI Bus Fault w/o 300 MW generation POI-Wayne Child 345kV Out | 5928 | 5928 | | | 4549 | 4549 | | | Z1(pos) = 0.00139 + j0.02823<br>Z0(zero) = 0.0128 + j0.0529 |
| **POI 345kV Bus Fault with 217.35 MW generation N-0** | **9455** | 5702 | 3451 | 304 | **8276** | 3839 | 2307 | 2157 | Z1(pos) =0.0010 + j 0.0177<br>Z0(zero) = 0.0046 + j 0.0245 |
| 345kV POI Bus Fault with 217.35 MW generation LRS – POI 345kV Out | 3985 | | 3683 | 303 | 3818 | | 1983 | 1851 | Z1(pos) =0.0033+ j 0.0418<br>Z0(zero) = 0.00657 + j 0.0452 |
| 345kV POI Bus Fault with 217.35 MW generation POI-Wayne Child 345kV Out | 6231 | 5928 | | 303 | 5658 | 3638 | | 2043 | Z1(pos) = 0.00127 + j 0.0268<br>Z0(zero) = 0.00574+ j0.0338 |

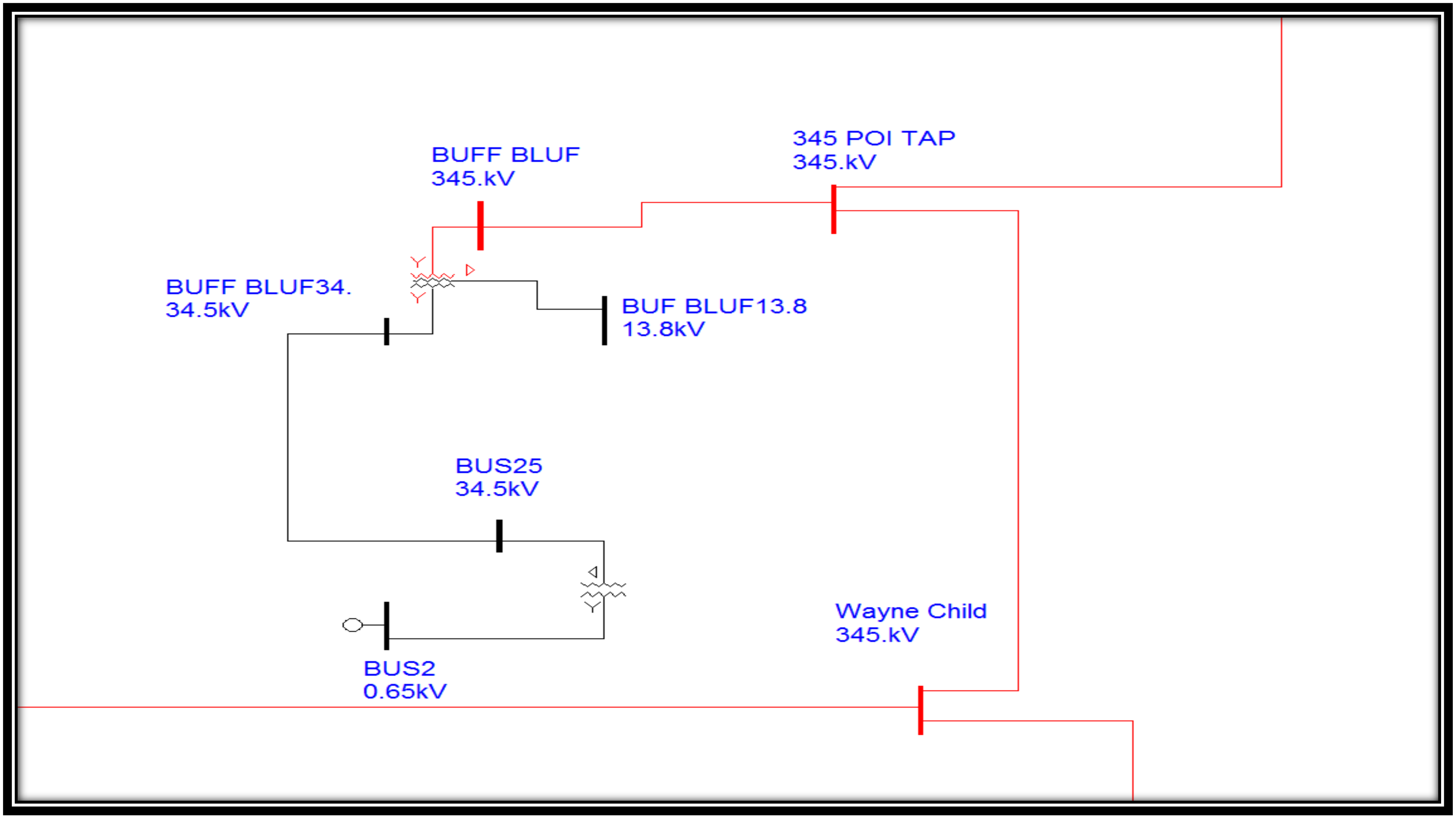


**Figure 4:** *Short Circuit Model*

## 7.0 SCOPE, COST AND SCHEDULE

The estimated total cost to interconnect the Project assumes a Breaker-and-Half configuration substation operated as a 3-Breaker Ring bus. The estimate further assumes that the Customer will construct the 345 kV radial line from the Customer's main project substation to the new Station that intercepts the Laramie River – Story 345kV line.

The cost estimate is broken out into two categories: 1) Interconnection Facilities which include all equipment installed between the POI at the main 345 kV bus and the Point of Change of Ownership (PCO) at the line dead-end structure just inside the new Station fence, and 2) Network Upgrades consisting of the rest of the facilities installed in the new Station to accommodate the interconnection. See Figure 2. The estimate includes all site work such as grounding and conduit installation inside the substation.

Note that the Customer will be responsible for constructing the radial 345 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 345-34.5-13.8 kV substation yard. Equipment at the new Station will only provide backup protection for the Customer's 345-34.5-13.8 kV main transformer in the event of equipment failure or malfunction at the Customer's facility. To facilitate protective relaying and data acquisition, the Customer will need to include fiber optic cables (OPGW) on its radial 345 kV transmission line to provide communication channels for SCADA, metering (real time), and protective relaying.

The Customer is responsible for all engineering, procurement and construction of all GF facilities, including any STATCOM type voltage regulation / reactive compensation devices.

All costs are good faith estimates based on assumptions as stated in this SIS report. All estimates are in 2020 dollars (refer to Figure 5). This assumes a 2000 amp bus construction for both the POI substation and Wayne Child 345 kV bus. A 3000 amp construction will be approximately 10% higher:

| | |
|---|---|
| • Wayne Child Network Upgrades (Reimbursable): | $ 16.50 M |
| • Interconnection Facilities Costs (Non-Reimbursable): | $ 1.09 M |
| • Network Upgrade Costs (Reimbursable): | $ 9.18 M |
| TOTAL Cost (2020 dollars) for Interconnection: | $ 26.77 M |

Estimate does not include required Archer – Terry Ranch 230 kV Network Upgrades. It is the responsibility of the Customer to contact WAPA to determine cost.

**NOTE:** Network upgrade costs are reimbursed only when payments are made to the Transmission Provider under its Tariff for transmission services with respect to the Generating Facility. Network upgrade costs are not reimbursed if transmission services are not secured from the Transmission Provider.

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. The schedule may be significantly affected should a Certificate of Public Convenience and Necessity be required by the Colorado Public Utilities Commission. The in-service date for this GF will depend on construction of the Interconnection Facilities, Network Upgrades, and coordination with Laramie River Station planned outages. Interconnection will require outage coordination with MBPP and other regional entities which may impact actual milestone and in-service dates.

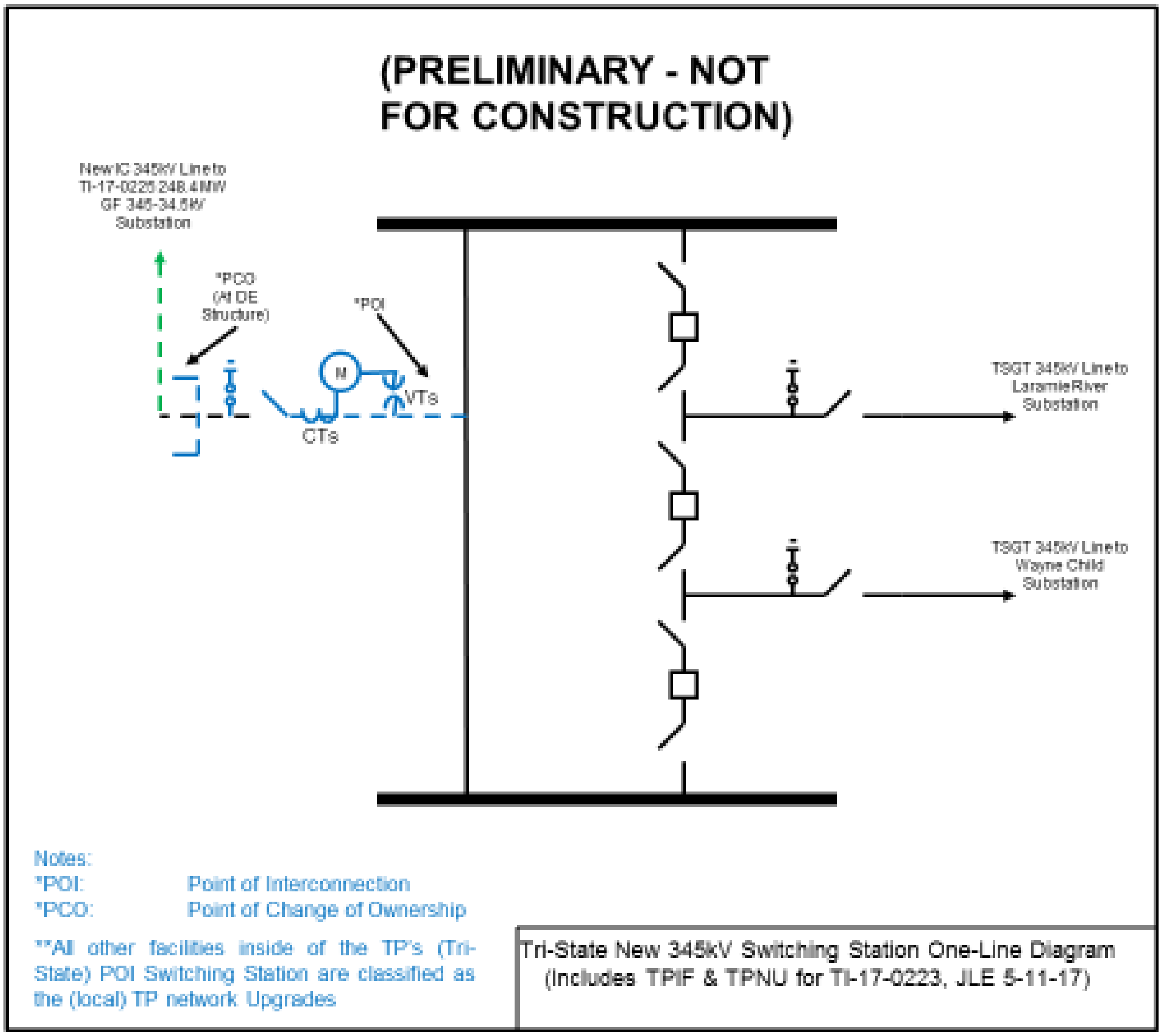


**Figure 5:** *345 kV New Station One-Line Diagram*

**Table 18:** *Summary Cost Estimate Details – Interconnection Facilities (Non-Reimbursable)*

| Element | Description | Cost Est. Millions |
|---|---|---|
| **New Station**<br><br>**345 kV line termination equipment** | Design, purchase, construct / install and test all equipment installed inside the New Station that is located between the PCO (line dead-end) and the POI (main bus tap point), consisting primarily of the following equipment:<br><br>• One (1) 345 kV monopole dead-end structure<br>• One (1) 345 kV slack span from monopole to existing structure at New Station.<br>• One (1) 345 kV 3-ph gang line end disconnect switch and associated structure.<br>• *Three (3) 345 kV metering current transformers (CTs), high accuracy class, extended range.<br>• *Three (3) 345 kV metering voltage transformers (VTs, high accuracy class). *Or alternative CT/VT combination metering units.<br>• PQ metering panel including SEL-735 Rev/PQ meter (typical) and line meters.<br>• Relaying for radial 345 kV line protection; primary, secondary, and breaker-failure.<br>• Three (3) 345 kV surge arresters (140 kV MCOV or as required).<br>• Line termination SCADA and telecommunication additions to RTU.<br>• Other associated substation equipment including, but not limited to, grounding, conduit, cable, foundations, support steel, bus and insulators. | **$1.09 M** |

**Table 19:** *Summary Cost Estimate Details – Network Upgrades (Reimbursable)*

| Element | Description | Cost Est. Millions |
|---|---|---|
| **New Station** | Install necessary equipment in the breaker-and-half 345 kV bus to terminate an additional circuit (see Figure 2, One-Line Diagram). Scope includes typical testing, checkout, and commissioning.<br><br>• Three (3) 345 kV power circuit breaker.<br>• Six (6) 345 kV 3-ph gang disconnect switches and associated structures.<br>• Circuit breaker station control panel<br>• SCADA and telemetry RTU communication equipment modifications.<br>• Other associated substation equipment including, but not limited to, grounding, conduit, cable, foundations, support steel, bus and insulators. | **$9.18 M** |
| **Laramie River Substation – Relaying Mods** | • Relay settings changes (labor) for new POI line termination protection. | **(Minimal)** |
| **Wayne Child Substation – Relaying Mods** | • Relay settings changes (labor) for new POI line termination protection. | **(Minimal)** |

## 8.0 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: List of Contingencies**