Provisional Interconnection Study Report for PI-2023-6 (Amended)

07/26/2024

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1.0 Executive Summary

The PI-2023-6 project is a Provisional Interconnection request for a 500 MW Wind Generating Facility with a Point of Interconnection (POI) at the Goose Creek 345 kV substation. PI-2023-6 is the Provisional Interconnection request later submitted as Generation Interconnection Request 5RSC-2024-28 in the 5RSC cluster.

The total cost of the transmission system improvements required for PI-2023-6 to qualify for Provisional Interconnection Service is estimated to be $15.148 million (Table 11 and

Table 12).

The initial maximum permissible output of PI-2023-6 Generating Facility is 500 MW. The maximum permissible output of the Generating Facility in the PLGIA[1] would be reviewed quarterly and updated, if there are changes to the system conditions assumed in this analysis, to determine the maximum permissible output.

Security: Based on 5RSC-2024-28 in the 5RSC selection of Energy Resource Interconnection Service (ERIS), the security associated with the Network Upgrades that might be identified at the conclusion of the 5RSC-2024-28 Large Generation Interconnection Procedure (LGIP) in the 5RSC cluster is estimated to be approximately $5 million.

The Interconnection Customer assumes all risk and liabilities with respect to changes between the PLGIA and the LGIA[2], including changes in output limits and Interconnection Facilities, Network Upgrades, Distribution Upgrades, and/or System Protection Facilities cost responsibility.

Note Provisional Interconnection Service in and of itself does not convey transmission service.

[1] **Provisional Large Generator Interconnection Agreement (PLGIA)** shall mean the interconnection agreement for Provisional Interconnection Service established between Transmission Provider and/or the Transmission Owner and the Interconnection Customer. The pro forma agreement is provided in Appendix 8 and takes the form of the Large Generator Interconnection Agreement, modified for provisional purposes.

[2] **Large Generator Interconnection Agreement (LGIA)** shall mean the form of interconnection agreement applicable to an Interconnection Request pertaining to a Large Generating Facility that is included in the Transmission Provider's Tariff.

2.0 Introduction

PI-2023-6 is the Provisional Interconnection Service [3] request for a 500 MW Wind Generating Facility located in Cheyenne County, Colorado.

- The POI of this project the Goose Creek 345 kV substation, a new switching station as part of the Colorado Power Pathway project (CPP).
- The Commercial Operation Date (COD) to be studied for PI-2023-6 as noted on the Provisional Interconnection request for is December 1, 2025.

The geographical location of the transmission system near the POI is shown in Figure 1. Note an approximation was used to overlay the new Colorado Power Pathway onto the current one-line diagram.

[3] **Provisional Interconnection Service** shall mean an Interconnection Service provided by Transmission Provider associated with interconnecting the Interconnection Customer's Generating Facility to Transmission Provider's Transmission System and enabling that Transmission System to receive electric energy and capacity from the Generating Facility at the Point of Interconnection, pursuant to the terms of the Provisional Large Generator Interconnection Agreement and, if applicable, the Tariff.

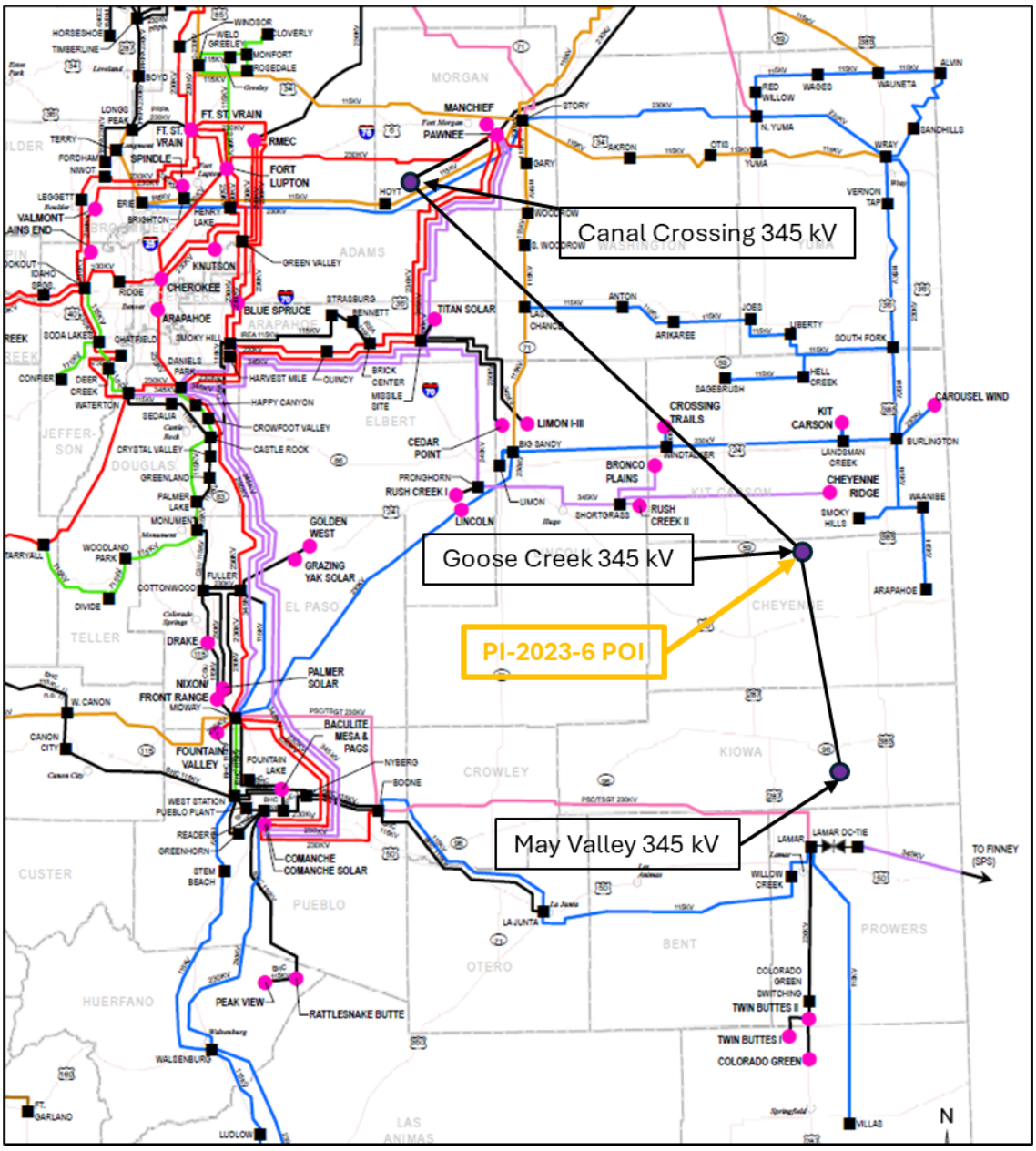


Figure 1: Point of Interconnection of PI-2023-6

3.0 Study Scope

The purpose of this study is to determine the impacts to the PSCo system and the Affected Systems from interconnecting PI-2023-6 for Provisional Interconnection Service. Consistent with the assumption in the study agreement, PI-2023-6 selected Energy Resource Interconnection Service (ERIS) [4].

The scope of this report includes voltage and reactive capability evaluation, steady state (thermal and voltage) analysis, transient stability analysis, short-circuit analysis, and cost estimates for Interconnection Facilities and Station Network Upgrades. The study also identifies the estimated Security [5] and Contingent Facilities associated with the Provisional Service.

3.1 Steady State Criteria

The following Criteria are used for the reliability analysis of the PSCo system and Affected Systems:

P0—System Intact conditions:

Thermal Loading: <=100% of the normal facility rating

Voltage range: 0.95 to 1.05 per unit

P1 & P2-1—Single Contingencies:

Thermal Loading: <=100% Normal facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: <=8% of pre-contingency voltage

P2 (except P2-1), P4, P5 & P7—Multiple Contingencies:

Thermal Loading: <=100% Emergency facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: <=8% of pre-contingency voltage

[4] **Energy Resource Interconnection Service** shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission system to be eligible to deliver the Generating Facility's electric output using the existing firm and non-firm capabilities of the Transmission Provider's Transmission System on an as available basis.

[5] **Security** estimates the risk associated with the Network Upgrades and Interconnection Facilities that could be identified in the corresponding LGIA.

3.2 Transient Stability Criteria

The transient voltage stability criteria are as follows:

a. Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds of the initiating event for all P1 through P7 events for each applicable Bulk Electric System (BES) bus serving load.
b. Following fault clearing and voltage recovery above 80%, voltage at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds, for all P1 through P7 events.
c. For Contingencies without a fault (P2.1 category event), voltage dips at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.

The transient angular stability criteria are as follows:

a. P1—No generating unit shall pull out of synchronism. A generator being disconnected from the system by fault clearing action or by a special Protection System is not considered an angular instability.
b. P2–P7—One or more generators may pull out of synchronism, provided the resulting apparent impedance swings shall not result in the tripping of any other generation facilities.
c. P1–P7—The relative rotor angle (power) oscillations are characterized by positive damping (i.e., amplitude reduction of successive peaks) > 5% within 30 seconds.

3.3 Breaker Duty Analysis Criteria

Fault Current after PI addition should not exceed 100% of the Breaker Duty rating. PSCo can only perform breaker duty analysis on the PSCo system. Before the PI goes in-service the Affected Systems may choose to perform a breaker duty analysis to identify breaker duty violations on their system.

3.4 Study Methodology

For PSCo and non-PSCo facilities, thermal violations attributed to the request include all new facility overloads with a thermal loading >100% and increased by 1% or more from the benchmark case overload post the Generator Interconnection Request (GIR) addition.

The voltage violations assigned to the request include new voltage violations which resulted in a further variation of 0.01 per unit.

Since the request is for Provisional Service, if thermal or voltage violations are seen, the maximum permissible Provisional Interconnection before violations is identified. For voltage violations caused by reactive power deficiency at the POI, voltage upgrades are identified.

The Provisional Interconnection request should meet the transient stability criteria stated in Section 3.1. If the addition of the GIR causes any violations, the maximum permissible Provisional Interconnection Service before violations is identified.

3.5 Contingency Analysis

The transmission system on which steady state contingency analysis is run includes the WECC designated areas 70 and 73.

The transient stability analysis is performed for the following worst-case contingencies shown in **Error! Reference source not found.**.

Table 1 – Transient Stability Contingencies

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)
1	Canal Crossing 345 kV	P1	Canal Crossing – Missile Site 345 kV ckt 1	4
2	Canal Crossing 345 kV	P1	Canal Crossing – Pawnee 345 kV ckt 1	4
3	Goose Creek 345 kV	P1	Goose Creek – Canal Crossing 345 kV ckt 1	4
4	Goose Creek 345 kV	P1	Goose Creek - Cheyenne Ridge 345 kV ckt 1 Cheyenne Ridge Wind Generation	4
5	Goose Creek 345 kV	P1	Goose Creek – Shortgrass 345 kV ckt 1	4
6	Shortgrass 345 kV	P1	Shortgrass – Pronghorn 345 kV ckt 1	4
7	Goose Creek 345 kV	P1	PI-2023-6 Generation	4
8	Daniels Park 345 kV	P4	Daniels Park - Missile Site 345 kV ckt 1 Daniels Pak 345 kV Cap Bank	12

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)
9	Pronghorn 345 kV	P4	Pronghorn - Rush Creek 345 kV ckt Rush Creek Wind Generation Daniels Park 345 kV Cap Bank	12
10	Canal Crossing 345 kV	P4	Goose Creek - Canal Crossing 345 kV ckt 1 Goose Creek - Canal Crossing 345 kV ckt 2 Canal Crossing 345 kV Cap Bank	12

3.6 Study Area

The Eastern Colorado study area includes WECC designated zones 706. As described in Section 3.11 of the BPM, the study pocket East is comprised of the eastern Colorado transmission system with major generation injecting into Pawnee, Beaver Creek and Missile Site substations. The study did not identify any impacts to Affected Systems.

4.0 Base Case Modeling Assumptions

The study was performed using the 2024HS3 WECC base case that has been modified to represent 2026 heavy summer loading conditions. The following planned transmission projects are modeled in the Base Case:

- Canal Crossing 345 kV substation
- Fort Saint Vrain 345 kV substation
- Goose Creek 345 kV substation
- May Valley 345 kV substation
- Sand 230 kV substation
- Kestrel 230 kV substation
- Coyote 230 kV substation
- Poder 115 kV substation
- Metro Water 115 kV substation
- Pintail 115 kV substation
- DCPL Tap 115 kV substation
- Carl Tap 69 kV substation

The following additional changes were made to the CORE Electrical Cooperative model in the Base Case:

- Citadel 115 kV substation
- Spring Valley 115 kV substation
- Deer Trail 115 kV substation

The Base Case model includes higher-queued and existing PSCo and Affected System generation resources.

4.1 Benchmark Case Modeling

The Benchmark Case was created from the Base Case described in Section 4.0 by changing the study pocket generation dispatch to reflect heavy generation in the Eastern Colorado study pocket. This was accomplished by adopting the stressed generation dispatch given in Table 2.

Table 2 – Generation Dispatch Used to Create the Eastern Colorado Benchmark Case (MW is Gross Capacity)

Bus No.	Bus Name	Base kV	ID	Status	Pgen (MW)	Pmax (MW)
70310	PAWNEE	22	C1	1	526.00	526.00
70314	MANCHEF1	16	G1	1	118.40	131.50
70315	MANCHEF2	16	G2	1	117.90	131.00
70721	SPRNGCAN1_W1	0.57	W1	1	51.80	64.80
70710	PTZLOGN1	34.5	W1	1	160.80	201.00

Bus No.	Bus Name	Base kV	ID	Status	Pgen (MW)	Pmax (MW)
70712	PTZLOGN2	34.5	W2	1	96.00	120.00
70713	PTZLOGN3	34.5	W3	1	63.60	79.50
70714	PTZLOGN4	34.5	W4	1	140.00	175.00
70715	SPRNGCAN2_W2	0.69	W2	1	50.20	62.70
70733	CHEYRGE_W1	0.69	W1	1	43.20	54.00
70736	CHEYRGE_W2	0.69	W2	1	88.00	110.00
70739	CHEYRGW_W1	0.69	W1	1	109.12	136.40
70742	CHEYRGW_W2	0.69	W2	1	105.60	132.00
70670	CEDARPT_W1	0.69	W1	1	99.36	124.20
70671	CEDARPT_W2	0.69	W2	1	100.80	126.00
70767	RUSHCK1_W1	0.69	W1	1	161.12	201.40
70770	RUSHCK1_W2	0.69	W2	1	130.32	162.90
70771	RUSHCK2_W3	0.69	W3	1	166.40	208.00
70635	LIMON1_W	34.5	W1	1	160.80	201.00
70636	LIMON2_W	34.5	W2	1	160.80	201.00
70637	LIMON3_W	34.5	W3	1	160.80	201.00
70753	BRONCO_W1	0.69	W1	1	117.28	146.64
70749	BRONCO_W2	0.69	W2	1	128.96	161.18
70443	ARRIBA_W1	0.69	W1	1	80.80	100.05
70442	ARRIBA_W2	0.69	W2	1	80.80	100.05
Total					3218.86	3857.32

4.2 Study Case Modeling

A Study Case was created from the Benchmark Case by turning on the PI-2023-6 generation. The additional 500 MW output from PI-2023-6 was balanced against PSCo generation outside of the Eastern Colorado study pocket.

4.3 Short-Circuit Modeling

The Transmission Planning Department has requested Fault Studies for a Provisional Interconnection request. This request is for the Interconnection of a 500 MW Wind Generating Facility (PI-2023-6) to the Goose Creek 345 kV substation. The output will not exceed 500 MW at the POI.

This project assumes the use of one hundred eighty-two (182) GE 2.8-127 Type III wind turbine generators (WTGs) rated at 3.133 MVA operating at +/-0.90 pf for PI-2023-6. Each of the WTGs is connected to a collector transformer, 0.69/34.5kV, rated at 2.9 MVA. Two 345/34.5/13.8 kV

main GSU transformers rated at 168/224/280 MVA step the voltage up from the collector transformer voltage to the POI voltage. An approximate 13.8-mile-long generation tie line interconnects the project to the Goose Creek 345 kV substation.

All connected generating facilities were assumed capable of producing maximum fault current. As such, all generation was modeled at full capacity, whether Network Resource Interconnection Service (NRIS) or ERIS is requested. Generation is modeled as a separate generating resource in PSS CAPE software and included at full capacity in the short circuit study, regardless of any limitations to the output that would be imposed otherwise.

5.0 Provisional Interconnection Service Analysis

5.1 Voltage and Reactive Power Capability Evaluation

The following voltage regulation and reactive power capability requirements are applicable to non-synchronous generators:

- Xcel Energy's OATT requires all non-synchronous generator Interconnection Customers to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the high side of the generator substation. Furthermore, Xcel Energy requires every Generating Facility to have dynamic voltage control capability to assist in maintaining the POI voltage schedule specified by the Transmission Operator.
- It is the responsibility of the Interconnection Customer to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (MVar), and the locations (on the Interconnection Customer's facility) of any additional static reactive power compensation needed within the generating plant in order to have adequate reactive capability to meet the +/- 0.95 power factor at the high side of the main step-up transformer.
- It is the responsibility of the Interconnection Customer to compensate their generation tie line to ensure minimal reactive power flow under no load conditions.

All proposed reactive devices in customer provided models are switched favourably to provide appropriate reactive compensation in each test, therefore identified deficiencies are in addition to any proposed reactive compensation.

All the summary tables representing the GIR's Voltage and Reactive Power Capability tests adhere to the following color formatting representing the different aspects of the tests:

- Values highlighted in red indicate a failed reactive power requirement.
- Voltages outside the range of 0.95 p.u. to 1.05 p.u. are highlighted in yellow to provide additional information.

The PI-2023-6 GIR is modeled as follows:

Wind Generator: Pmax = 513.24 MW, Pmin = 0 MW, Qmax = 248.57 MVar, Qmin= -248.57 MVar

The summary for the Voltage and Reactive Power Capability Evaluation for PI-2023-6 is:

- The GIR is capable of meeting ±0.95 pf at the high side of the main step-up transformer while maintaining a normal operating voltage at the POI.
- The GIR is capable of meeting ±0.95 pf at its terminals while meeting the interconnection service request.
- The reactive power exchange and voltage change across the gen-tie are acceptable under no load conditions.

The Voltage and Reactive Power Capability tests performed for PI-2023-6 are summarized in Table 3. Please note the generator terminal voltage exceeds 1.10 p.u. while the high side of main transformer voltage exceeds 1.05 p.u. during the lagging test.

Table 3 – Reactive Capability Evaluation for PI-2023-6

Generator Terminals					High Side of Main Transformer				POI			
Pgen (MW)	Qgen (MVar)	Qmax (MVar)	Qmin (MVar)	V (p.u.)	P (MW)	Q (MVar)	V (p.u.)	PF	P (MW)	Q (MVar)	V (p.u.)	PF
513.2	238.6	248.6	-248.6	1.13	503.7	165.7	1.06	0.9499	500.3	149.8	1.03	0.9580
513.2	-94.3	248.6	-248.6	0.96	502.6	-165.6	0.99	-0.9498	498.7	-185.2	1.00	-0.9374
0.0	-42.2	248.6	-248.6	1.00	-2.5	-31.3	1.02	-0.0796	-2.5	-22.8	1.02	-0.1090

5.2 Steady State Analysis

Contingency analysis was performed on the Eastern Colorado pocket using the Study Case model.

The power flow analysis showed that the category P1 contingency outage of Missile Site – Pronghorn 345 kV was divergent in the Study Case. As described in Section 7.4 of the BPM, single contingency issues should be mitigated using redispatch. Therefore, to resolve the divergence without requiring network upgrades or curtailment of the Study GIR's output, two PSCo units located near the Study GIR were re-dispatched until the diverged contingency was resolved. The change in output of both units was balanced against PSCo generation outside of the Eastern Colorado study pocket. The following single and multiple contingency analyses are conducted with the dispatch presented in the last column of Table 4.

- The results of the system intact analysis showed no violations.
- The results of the single contingency analysis on the Study Case are shown in Table 5. All the single contingency overloads identified in Table 5 are alleviated through generation redispatch. Single contingency analysis showed no voltage violations attributed to the Study GIR.
- The results of the multiple contingency analysis on the Study Case are shown in Table 6.
- Per TPL-001-5, multiple contingency overloads are mitigated using system adjustments, including generation redispatch (includes GIRs under study) and/or operator actions. None of the multiple contingency overloads are attributed to the Study GIR. Multiple contingency analysis showed no voltage violations attributed to the Study GIR.

Table 4 – Generation Dispatch Used to Resolve the Diverged P1 Contingency

Bus No.	Bus Name	Base kV	ID	Original Pgen (MW)	Modified Pgen (MW)
70767	RUSHCK1_W1	0.69	W1	161.12	101.12
70770	RUSHCK1_W2	0.69	W2	130.32	90.32

Table 5 – East Pocket - Single Contingency Overloads

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Normal Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Story (73192) – Pawnee (70311) 230 kV ckt 1	Smokey Hill – Missile Site #7081	230	73/70	PSCo	581.00	103.84	123.82	19.98
2	Buckley 2 (70046) – Smoky Hill (70396) 230 kV ckt 1	Greenwood – Monaco – Sullivan (#5717)	230	70	PSCo	478.00	122.00	123.34	1.34
3	Buckley 2 (70046) – Tollgate (70491) 230 kV ckt 1	Greenwood – Monaco – Sullivan (#5717)	230	70	PSCo	484.00	120.51	121.82	1.31
4	Capitol Hill (70087) – Denver TM 1 (70148) 230 kV ckt 1	Argo – Cherokee SW (#9413)	115	70	PSCo	131.00	114.35	116.12	1.77
5	Fort Lupton (70192) – Pawnee (70311) 230 kV ckt 1	Smokey Hill – Missile Site #7081	230	70	PSCo	478.00	94.15	103.33	9.18
6	Jewell 2 (70239) – Tollgate (70491) 230 kV ckt 1	Greenwood – Monaco – Sullivan (#5717)	230	70	PSCo	484.00	101.33	102.69	1.36

Table 6 – East Pocket - Multiple Contingency Overloads

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Emergency Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Story (73192) – Pawnee (70311) 230 kV ckt 1	P7_136: Lines 5467, 7081	230	73/70	PSCo	589	129.70	155.15	25.45
2	Buckley 2 (70046) – Smoky Hill (70396) 230 kV ckt 1	BF_064c: Greenwood Bus Tie	230	70	PSCo	478	147.35	149.41	2.06
3	Buckley 2 (70046) – Tollgate (70491) 230 kV ckt 1	BF_064c: Greenwood Bus Tie	230	70	PSCo	554	127.14	128.92	1.78
4	Fort Lupton (70192) – Pawnee (70311) 230 kV ckt 1	P7_136: Lines 5467, 7081	230	70	PSCo	478	110.33	122.51	12.18
5	Clark (70112) – Jordan (70241) 230 kV ckt 1	P7_58: Lines 5707, 5111	230	70	PSCo	364	118.73	120.75	2.02
6	Jewell 2 (70239) – Leetsdale (70260) 230 kV ckt 1	BF_064c: Greenwood Bus Tie	230	70	PSCo	478	116.66	118.83	2.17
7	Capitol Hill (70087) – Denver TM 1 (70148) 115 kV ckt 1	P7_11: Lines 9413, 9541	115	70	PSCo	145	110.58	112.16	1.58
8	Jewell 2 (70239) – Tollgate (70491) 230 kV ckt 1	BF_064c: Greenwood Bus Tie	230	70	PSCo	555	110.16	111.98	1.82
9	Smoky Hill (70599) – Missile Site (70624) 345 kV ckt 1	P7_61: Lines 5113, 7109	345	70	PSCo	1775	95.15	108.16	13.01

5.3 Transient Stability Results

The following results were obtained for the disturbances analysed:

- ✓ No machines lost synchronism with the system.
- ✓ No transient voltage drop violations were observed.
- ✓ Machine rotor angles displayed positive damping.

The results of the contingency analysis are shown in Table 7. The transient stability plots are shown in Appendix A in Section 10.0 of this report.

The transient stability analysis showed that the original dynamic model for the Study GIR presented momentary cessation and/or unstable behavior in P1 contingencies Ref. Nos. 3, 4, 5, and 6, and in P4 contingencies Ref. Nos. 8, 9, and 10. The internal Business Practice Manual (BPM) states that inverter-based generation should ensure that momentary cessation is eliminated and, therefore, the Voltage-Dependent current Limit tables (VDL1 and VDL2) from the REEC_A dynamic model were updated for compliance with the BPM. Furthermore, the REEC_A dynamic model was also updated to ensure the Study GIR was capable of voltage and reactive power control, meaning that parameters “vflag” and “qflag” were set to 1.0. Upon receiving this Provisional study report, the generator owner will need to confirm the changes to the submitted dynamics data for VDL1 and VDL2 as shown below are within the capability of the inverter specifications.

The results displayed in Table 7 and the plots shown in Appendix A were obtained with the updated dynamic model of the Study GIR, meaning those model updates resolved the unsatisfactory response originally observed in the transient stability analysis.

Table 7 – Transient Stability Analysis Results

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Canal Crossing 345 kV	P1	Canal Crossing – Missile Site 345 kV ckt 1	4	Stable	Stable
2	Canal Crossing 345 kV	P1	Canal Crossing – Pawnee 345 kV ckt 1	4	Stable	Stable
3	Goose Creek 345 kV	P1	Goose Creek – Canal Crossing 345 kV ckt 1	4	Stable	Stable
4	Goose Creek 345 kV	P1	Goose Creek - Cheyenne Ridge 345 kV ckt 1 Cheyenne Ridge Wind Generation	4	Stable	Stable
5	Goose Creek 345 kV	P1	Goose Creek – Shortgrass 345 kV ckt 1	4	Stable	Stable
6	Shortgrass 345 kV	P1	Shortgrass – Pronghorn 345 kV ckt 1	4	Stable	Stable
7	Goose Creek 345 kV	P1	PI-2023-6 Generation	4	Stable	Stable
8	Daniels Park 345 kV	P4	Daniels Park - Missile Site 345 kV ckt 1 Daniels Pak 345 kV Cap Bank	12	Stable	Stable
9	Pronghorn 345 kV	P4	Pronghorn - Rush Creek 345 kV ckt Rush Creek Wind Generation Daniels Park 345 kV Cap Bank	12	Stable	Stable
10	Canal Crossing 345 kV	P4	Goose Creek - Canal Crossing 345 kV ckt 1 Goose Creek - Canal Crossing 345 kV ckt 2 Canal Crossing 345 kV Cap Bank	12	Stable	Stable

Table 8 – Transient Stability Analysis Result Comparison Summary

Ref. No.	Benchmark		Study with Original DYD		Study with Modified DYD		Observations
	Post-Fault Voltage Recovery	Angular Stability	Post-Fault Voltage Recovery	Angular Stability	Post-Fault Voltage Recovery	Angular Stability	
1	Stable	Stable	Stable	Stable	Stable	Stable	
2	Stable	Stable	Stable	Stable	Stable	Stable	
3	Stable	Stable	Unstable	Unstable	Stable	Stable	
4	Stable	Stable	Unstable	Unstable	Stable	Stable	
5	Stable	Stable	Unstable	Unstable	Stable	Stable	
6	Stable	Stable	Unstable	Unstable	Stable	Stable	
7	-	-	Stable	Stable	Stable	Stable	
8	Stable	Stable	Stable[1]	Stable[1]	Stable	Stable	[1] Study unit shows momentary cessation over approximately 1 second.
9	Stable	Stable	Stable[2]	Stable[2]	Stable	Stable	[2] Study unit shows momentary cessation over more than 1 second.
10	Stable	Stable	Unstable	Unstable	Stable	Stable	

Table 9 – Comparison of parameters used in REEC_A model for Transient Stability Analysis

Parameter in REEC_A (short description)	Study with Original DYD	Study with Modified DYD
vflag (voltage control flag)	0.000	1.000
qflag (Q control flag)	0.000	1.000
vq1 (table VDL1)	0.400	0.500
iq1 (table VDL1)	1.250	0.990
vq2 (table VDL1)	0.800	0.900
iq2 (table VDL1)	1.250	0.540
vq3 (table VDL1)	1.100	1.100
iq3 (table VDL1)	1.250	0.540
vq4 (table VDL1)	0.000	1.250
iq4 (table VDL1)	0.000	1.260
vp1 (table VDL2)	0.400	0.000
ip1 (table VDL2)	1.250	0.000
vp2 (table VDL2)	0.800	0.500
ip2 (table VDL2)	1.250	0.000
vp3 (table VDL2)	1.100	0.900
ip3 (table VDL2)	1.250	1.230
vp4 (table VDL2)	0.000	1.000
ip4 (table VDL2)	0.000	1.107

5.4 Short-Circuit and Breaker Duty Analysis Results

The fault currents at the POI for three-phase and phase-to-ground faults can be found in Table 10 – below, along with the Thevenin impedance at the POI. Both the base case and the case with the GIR added are shown.

Table 10 – Short-Circuit Parameters at PI-2023-6 POI (Goose Creek 345 kV substation)

	Before the PI Addition	After the PI Addition
Three Phase		
Three Phase Current	9330A	10760 A
Positive Sequence Impedance	1.81051+ j21.2753 ohms	1.81051+ j21.2753 ohms
Negative Sequence Impedance	1.83420 + j21.2708 ohms	1.83420 + j21.2708 ohms
Zero Sequence Impedance	5.62728 + j34.7574 ohms	3.35865+ j21.9417 ohms
Phase-to-Ground		
Single Line to Ground Current	7680 A	10610 A
Positive Sequence Impedance	1.81051+ j21.2753 ohms	1.81051+ j21.2753 ohms
Negative Sequence Impedance	1.83420 + j21.2708 ohms	1.83420 + j21.2708 ohms
Zero Sequence Impedance	5.62728 + j34.7574 ohms	3.35865+ j21.9417 ohms

A breaker duty study on the PSCo transmission system did not identify any circuit breakers that became over-dutied because of adding the wind generation PI-2023-6.

5.5 Affected Systems

The study did not identify any impacts to Affected Systems.

5.6 Summary of Provisional Interconnection Analysis

All single contingency thermal violations were alleviated through generation redispatch, therefore, the maximum allowable output of the GIR without requiring any additional System Network Upgrades is 500 MW.

6.0 Cost Estimates

The total cost of the required Upgrades for PI-2023-6 to interconnect for Provisional Interconnection Service at the Goose Creek 345 kV substation is estimated to be **$15.148 million**.

- **Cost of Transmission Provider's Interconnection Facilities (TPIF) is $3.699 million** (Table 11)

Cost of Station Network Upgrades is $11.448 million (

- Table 12)
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the Provisional Interconnection of PI-2023-6 are given in Table 11, and

Table 12.

Since the POI is a new substation, a CPCN would be required to accommodate the interconnection.

Table 11 – Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Million)
PSCo's Goose Creek 345 kV Switching Station	Interconnection of PI-2023-6 at the Goose Creek 345 kV Switching Station. The new equipment includes: • (1) 345 kV single bay dead end structure • (1) 345 kV 3-phase arrester • (1) 345 kV 3000A line disconnect switch • (3) 345 kV 1-phase CT/PT for metering • Dual fiber communication equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing	$3.649
PSCo's Goose Creek 345 kV Switching Station	Transmission line into substation from customer's dead-end structure on gen-tie. Three spans, conductor, insulators, hardware and labor.	$0.050
Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities		**$3.699**

Table 12 – Station Network Upgrades

Element	Description	Cost Est. (Million)
PSCo's Goose Creek 345 kV Switching Station	Interconnection of PI-2023-6 at Goose Creek 345 kV Switching Station. The new equipment includes: • (3) 345 kV dead end structures • (2) 345 kV 3000A SF6 circuit breakers • (5) 345 kV 3000A disconnect switches • Yard expansion including grading, ground grid, surfacing and fencing • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$11.090
PSCo's Goose Creek 345 kV Switching Station	Install required communication in the EEE at the Pawnee 345 kV Substation	$0.358
Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities		**$11.448**

PSCo has developed cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of PI-2023-6 for Provisional Interconnection Service. The estimated costs provided in this report are based upon the following assumptions:

- The estimated costs are in 2024 dollars with escalation and contingencies applied.
- Allowances for Funds Used During Construction (AFUDC) is not included.
- The estimated costs include all applicable labor and overheads associated with the siting, engineering, design, and construction of these new PSCo facilities.
- The estimated costs do not include the cost for any Customer owned equipment and associated design and engineering.
- Labor is estimated for straight time only—no overtime included.
- PSCo (or its Contractor) will perform all construction, wiring, testing, and commissioning for PSCo owned and maintained facilities.

The customer requirements include:

- Customer will install two (2) redundant fiber optic circuits (one primary circuit with a redundant backup) 48-fiber single mode OPGW cables into the Transmission Provider's substation as part of its interconnection facilities construction scope.
- Power Quality Metering (PQM) will be required on the Customer's generation tie-line terminating into the POI.

- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer substation. PSCo will be provided with indications, readings, and data from the LF/AGC RTU.
- The Interconnection Customer will comply with the Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW, as amended from time to time, and available at: XEL-POL-Transmission Interconnection Guideline Greater 20MW

6.1 Schedule

This section provides proposed milestones for the interconnection of PI-2023-6 to the Transmission Provider's Transmission System. The customer requested a back-feed date (In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection) for the Provisional Interconnection of September 2025. This is not attainable by the Transmission Provider, based upon the current schedule developed for this interconnection request. The Transmission Provider proposes the milestones provided below in Table 13.

Table 13 – Proposed Milestones for PI-2023-6

Milestone	Responsible Party	Estimated Completion Date
PLGIA Execution	Interconnection Customer and Transmission Provider	September 2024
In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection	Transmission Provider	May 4, 2026
In-Service Date & Energization of Interconnection Customer's Interconnection Facilities	Interconnection Customer	May 4, 2026
Initial Synchronization Date	Interconnection Customer	May 4, 2026
Begin trial operation & testing	Interconnection Customer and Transmission Provider	May 4, 2026
Commercial Operation Date	Interconnection Customer	June 4, 2026

Some schedule elements are outside of the Transmission Provider's control and could impact the overall schedule. The following schedule assumptions provide the basis for the schedule milestones:

- Construction permitting (if required) for new facilities will be completed within 12 months of PLGIA execution.
- The Transmission Provider is currently experiencing continued increases to material lead times which could impact the schedule milestones. The schedule milestones are based upon material lead times known at this time.
- Availability of line outages to interconnect new facilities to the transmission system.

7.0 Summary of Provisional Interconnection Service Analysis

The total estimated cost of the PSCo transmission system improvements required for PI-2023-6 to qualify for Provisional Interconnection Service would be $15.148 million.

The initial maximum permissible output of PI-2023-6 Generating Facility is 500 MW. The maximum permissible output of the Generating Facility in the PLGIA would be reviewed quarterly and updated if there are changes to system conditions compared to the system conditions previously used to determine the maximum permissible output.

Security: Based on 5RSC-2024-28 in the 5RSC selection of Energy Resource Interconnection Service (ERIS), the security associated with the Network Upgrades that might be identified at the conclusion of the 5RSC-2024-28 Large Generation Interconnection Procedure (LGIP) in the 5RSC cluster is estimated to be approximately $5 million.

Note that Provisional Interconnection Service in and of itself does not convey transmission service.

8.0 Contingent Facilities

The portions of Colorado Power Pathway outlined in Section 4.0 are assumed to be completed prior to this GIR COD. Any capacity or lack thereof is based on these segments being completed. In the event these facilities are delayed, not constructed, reconfigured, redesigned, or otherwise changed from the manner and timing currently modeled for this study, the ability to provide Provisional Interconnection Service would need to be re-evaluated.

Additional Contingent Facilities identified for PI-2023-6 include the TPIF and Station Network Upgrades identified in Table 11 and

Table 12, respectively.

9.0 Preliminary One-Line Diagram and General Arrangement for PI-2023-6

Figure 2: Preliminary One-Line of PI-2023-6 at the Goose Creek 345 kV Switching Station

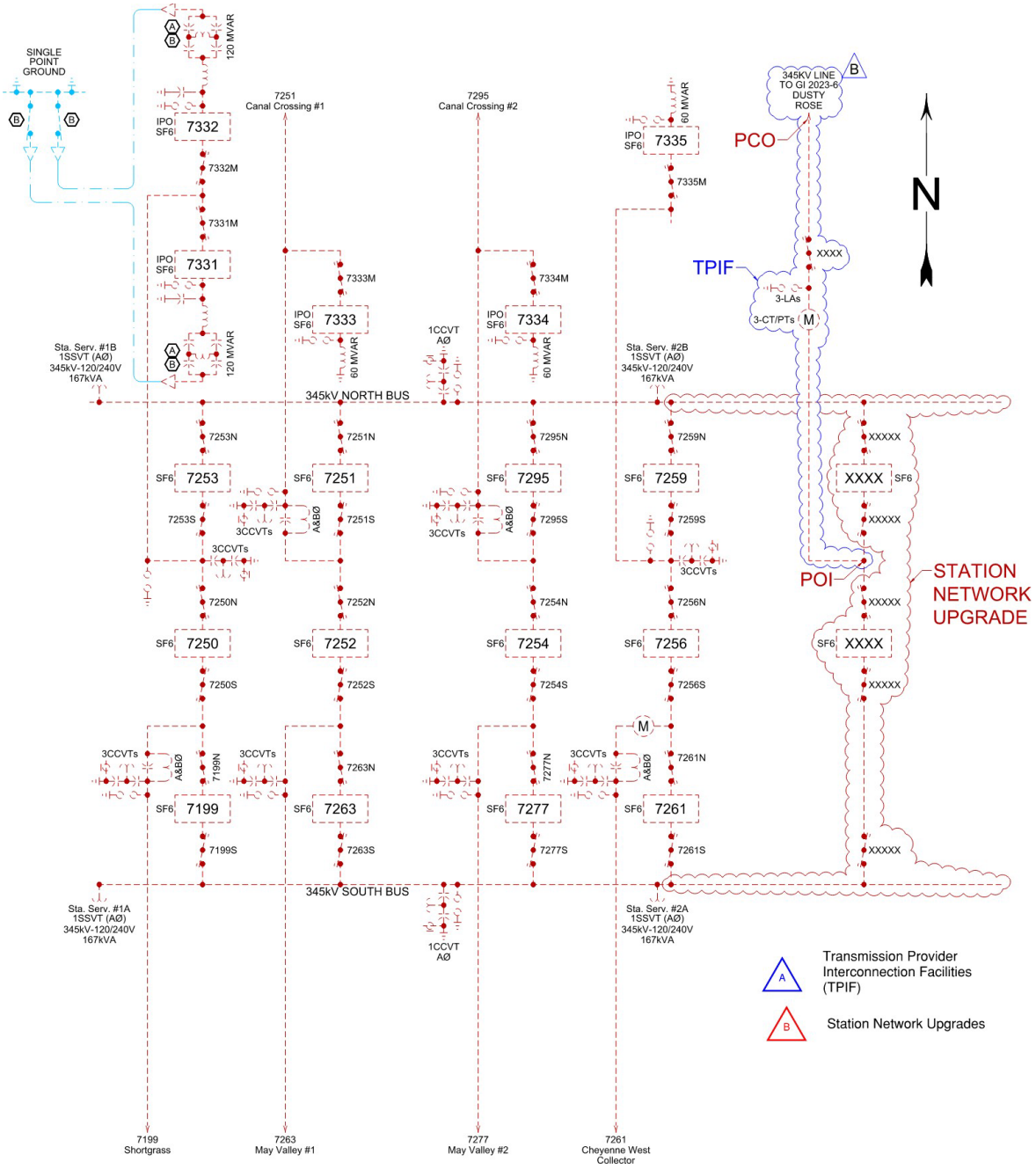
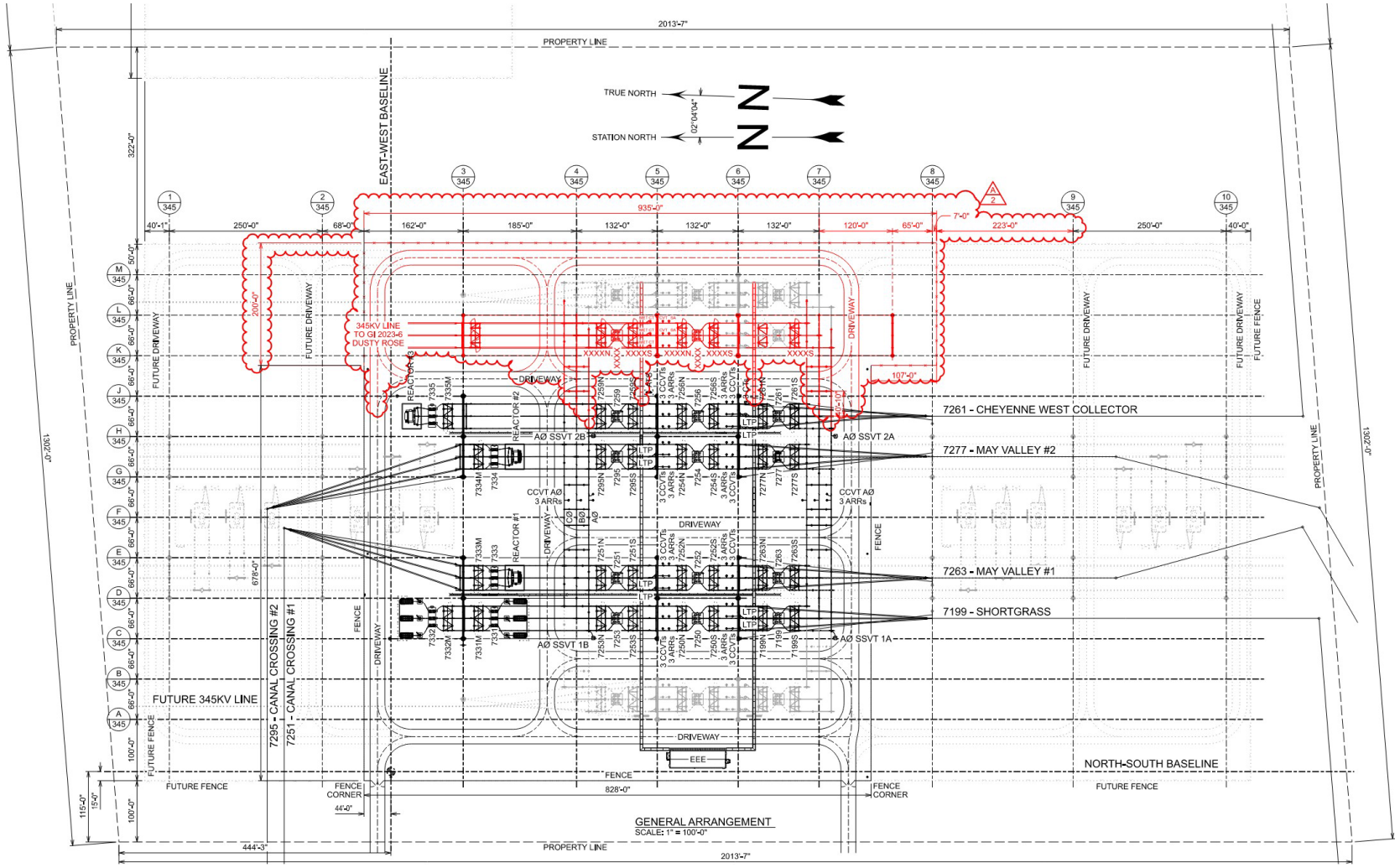


Figure 3: Preliminary General Arrangement for PI-2023-6 at the Goose Creek 345 kV Switching Station



10.0 Appendices

Appendix A: Transient Stability Plots	PI-2023-6_Transient Stability Plots.pdf