Provisional Interconnection Study Report for PI-2023-7

6/24/2024

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1.0 Executive Summary

The PI-2023-7 project is a Provisional Interconnection request for a 150 MW Solar Generating Facility with a Point of Interconnection (POI) at the Pawnee 345 kV substation. PI-2023-7 is the Provisional Interconnection request later submitted as Generation Interconnection Request GI-2024-18.

The total cost of the transmission system improvements required for PI-2023-7 to qualify for Provisional Interconnection Service is estimated to be $10.815 million (Table 9 and Table 10).

The initial maximum permissible output of PI-2023-7 Generating Facility is 150 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 GI-2024-18, in the 2024 Definitive Interconnection System Impact Study (DISIS), selection of Energy Resource Interconnection Service (ERIS), the security associated with the Network Upgrades that might be identified at the conclusion of the GI-2024-18 Large Generation Interconnection Procedure (LGIP) 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.

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[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-2023-7 is the Provisional Interconnection Service[3] request for a 150 MW Solar Generating Facility located in Morgan County, Colorado.

- The POI of this project is Pawnee 345 kV substation. The Pawnee 345 kV substation is part of the Colorado Power Pathway project.
- The requested Commercial Operation Date (COD) of PI-2023-7 is May 1, 2027 and the requested back feed date is April 2, 2027.

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.

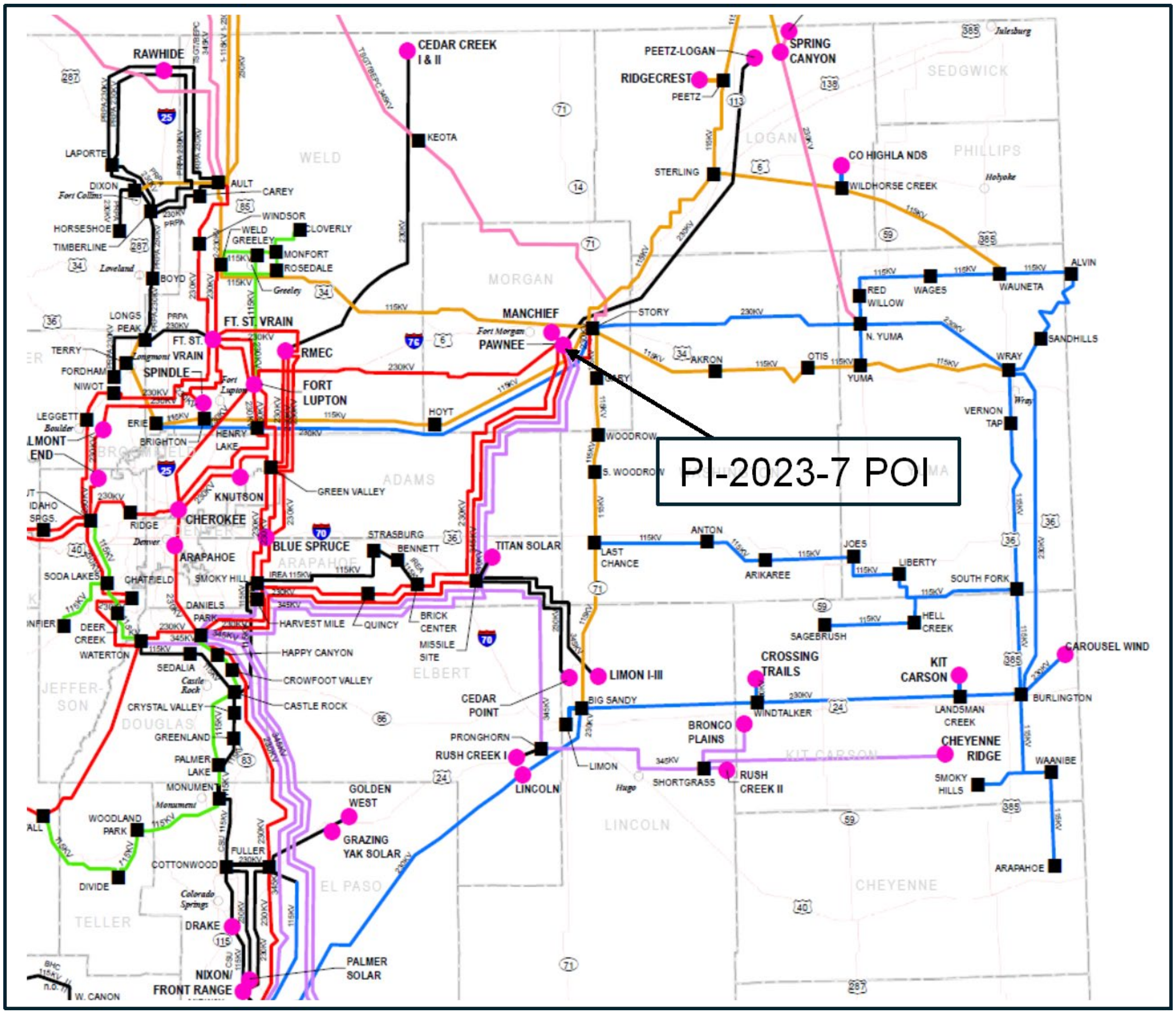

Figure 1 - Point of Interconnection of PI-2023-7

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-2023-7 for Provisional Service. Consistent with the assumption in the study agreement, PI-2023-7 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, generator re-dispatching in the neighbouring areas are applied to alleviate the thermal and voltage violations. If the violations are not resolved via re-dispatch, then 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 Table 1.

Table 1: Transient Stability Contingencies

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)
1	Pawnee 345 kV	P1	Pawnee - Canal Crossing 345 kV CKT 1	4
2	Pawnee 345 kV	P1	Pawnee 345/230 kV Transformer T2	4
3	Pawnee 345 kV	P1	PI-2023-7 Generation	4
4	Missile Site - Canal Crossing 345 kV Line	P1	Missile Site - Canal Crossing 345 kV CKT 1	4
5	FSV - Canal Crossing 345 kV Line	P1	Fort Saint Vrain - Canal Crossing 345 kV CKT 1	4
6	Pronghorn 345 kV	P4	Pronghorn 345 kV Gen Tie Line Rush Creek Generation	12
7	Canal Crossing 345 kV	P4	Canal Crossing - Goose Creek 345 kV CKT 1 Canal Crossing - Goose Creek 345 kV CKT 2 Canal Crossing 345 kV Capacitor 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 2029HS2a WECC case released on May 3, 2023, was selected as the Starting Case. The Base Case was created from the Starting Case by including the following modeling changes.

- Shortgrass to Goose Creek uprate to 1439 MVA – Happening as Part of CPP.
- Poncha – San Luis Valley 115 kV L9811 uprate to 239 MVA – ISD 8/20/2025.
- Daniels Park-Prairie-Greenwood Uprate L5707 to 956 MVA – ISD 6/1/2026.
- Leetsdale-Monroe-Elati line 5283 uprate to 956 MVA – ISD 5/31/2026.
- Uprate Lines 6935/6936 69 kV from Alamosa - Mosca - San Luis Valley to 800 A, 95 MVA – ISD 5/15/2026.
- Daniels Park-Prairie-Greenwood Uprate L5111 to 956 MVA – ISD 10/21/2026.
- Additional Harvest Mile to Smoky Hill 230 kV Line – ISD 5/14/2027.
- Leetsdale to University Line 9338 – ISD 9/9/2026.
- Tollgate Load Shift – ISD 7/7/2026.
- New Arapahoe T6 230/115 kV, 272/319 MVA – ISD 2/10/2027.
- Cherokee-Federal Heights-Broomfield L9558 Line rebuild – ISD 11/18/2026.
- MidwayPS 230/115 T1 Transformer Replacement with 280 MVA – ISD 10/7/2026.
- Leetsdale-Harrison L9955 Uprate to 1900 A – ISD 11/16/2027.
- Uprate Line 9255 115kV from Poncha Junction to Otero Tap 1200A 239 MVA – ISD 5/1/2028.
- Cherokee-Federal Heights-Semper Line 9055 rebuild – ISD 6/1/2029.
- Semper-Broomfield Line 9464 rebuild – ISD 6/1/2029.
- Add Smoky Hill 345/230 T6 Transformer – ISD 9/27/2028.
- San Luis Valley – Blanca Peak Line 9431 115kV uprate to 800A, 159 MVA – ISD 6/20/2028.
- Poncha – San Luis Valley 230 kV L3006 Uprate to 478 MVA – ISD 5/11/2029.
- New Line (second circuit) 115kV from Alamosa Terminal - San Luis Valley 1200 A 239MVA – ISD 6/15/2028.
- Cherokee-Lacombe 230 kV L5057 Uprate to 1900 A, 756 MVA – ISD 9/13/2029.
- Daniels Park 345/230 kV Transformer #4 – ISD 9/13/2029.
- Add Chambers T3 230/115 Transformer – ISD 9/13/2029.
- Capital-Denver Terminal L9007 Uprate to 1900 A – ISD 9/13/2029.
- Havana-Chambers 115 kV L9543 & L9544 Uprate - ISD 9/13/2029.
- New double circuit from Cherokee-Sandown-Chambers-Harvest Mile 230 kV – ISD 9/13/2029.
- Sandown 230/115 kV Transformer #1 Uprate to 560/756 MVA – ISD TBD.
- New Fort Lupton 230/115 kV, 273/319 MVA Transformer #4 – ISD TBD.
- New Alli to Chatfield 230 kV transmission line rated at 283 MVA – ISD TBD.

Additionally, the following segments of the Colorado Power Pathway (CPP) were included in the Base Case:

- Segment #1: Fort St. Vrain – Canal Crossing 345 kV Double Circuit

- Segment #2: Canal Crossing – Goose Creek 345 kV Double Circuit
- Segment #3: Goose Creek – May Valley 345 kV Double Circuit

The Base Case model includes the existing PSCo generation resources and all Affected Systems' existing resources.

While the higher-queued NRIS requests were dispatched at 100%, the higher-queued ERIS requests were modeled offline.

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 generation dispatch given in Table 2. Additionally, 4050 MW of Native Load Priority (NLP) was modeled, as shown in Table 3.

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

Gen Bus Number	Name	ID	Status	Pgen (MW)	Pmax (MW)
70310	PAWNEE	C1	1	526.00	526.00
70314	MANCHEF1	G1	1	118.35	131.50
70315	MANCHEF2	G2	1	117.90	131.00
70767	RUSHCK1_W1	W1	1	161.60	202.00
70770	RUSHCK1_W2	W2	1	142.40	178.00
70771	RUSHCK2_W3	W3	1	176.00	220.00
70739	CHEYRGW_W1	W1	1	109.12	136.40
70742	CHEYRGW_W2	W2	1	105.60	132.00
70733	CHEYRGE_W1	W1	1	43.20	54.00
70736	CHEYRGE_W2	W2	1	88.00	110.00
70775	CHEYRGE_W3	W3	1	52.80	66.00
70818	MTNBRZ_W1	W1	1	126.32	157.90
70817	MTNBRZ_W2	W2	1	11.04	13.80
70670	CEDARPT_W1	W1	1	99.36	124.20
70671	CEDARPT_W2	W2	1	100.80	126.00
70635	LIMON1_W	W1	1	160.80	201.00
70636	LIMON2_W	W2	1	160.80	201.00
70637	LIMON3_W	W3	1	160.80	201.00
70753	BRONCO_W1	W1	1	117.28	146.60

Gen Bus Number	Name	ID	Status	Pgen (MW)	Pmax (MW)
70749	BRONCO_W2	W2	1	128.96	161.20
70710	PTZLOGN1	W1	1	160.80	201.00
70712	PTZLOGN2	W2	1	96.00	120.00
70713	PTZLOGN3	W3	1	63.60	79.50
70714	PTZLOGN4	W4	1	140.00	175.00
70721	SPRNGCAN1_W1	W1	1	51.84	64.80
70715	SPRNGCAN2_W2	W2	1	50.16	62.70
70723	RDGCREST	W1	1	23.76	29.70
70443	Arriba W1	W1	1	80.04	100.05
70442	Arriba W2	W2	1	80.04	100.05
Total (MW)				**3453.37**	**4152.40**

Table 3: NLP Generation Included

Generator Bus Number	Name	ID	Status	Pgen (MW)
700043	5RSC_24_10	B	1	253.60
700057	5RSC_24_15	W2	1	130.00
700060	5RSC_24_15	W3	1	130.00
700063	5RSC_24_15	W4	1	110.00
700067	5RSC_24_15	W1	1	130.00
700076	5RSC_24_16	W1	1	144.00
700077	5RSC_24_16	W2	1	162.00
700078	5RSC_24_16	W3	1	144.00
700079	5RSC_24_17	W1	1	153.00
700085	5RSC_24_17	W3	1	135.00
700088	5RSC_24_17	W4	1	153.00
700095	5RSC_24_18	W	1	310.90
999002	NLP_CACR	1	1	882.50
70920	NLP_MAYV	1	1	1212.00
Total (MW)				**4050.00**

4.2 Study Case Modeling

A Study Case was created from the Benchmark Case by turning on the PI-2023-7 generation. The additional 150 MW output from PI-2023-7 was balanced against PSCo generation outside of the Eastern Colorado study pocket. As described in Section 3.11 of the BPM, this pocket is comprised of the eastern Colorado transmission system with major generation injecting into Pawnee, Beaver Creek and Missile Site substations.

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 150 MW Solar Generating Facility (PI-2023-7) to the Pawnee 345 kV substation. The output will not exceed 150 MW at the POI.

This project assumes the use of forty-eight (48) Power Electronics FS3430M solar inverters rated at 3.43 MVA operating at +/-0.95 pf for PI-2023-7. Each of the solar inverters is connected to a collector transformer, 0.66/34.5kV, rated at 3.51 MVA. A 345/34.5/13.8kV main GSU transformer rated at 102/136/170 MVA steps the voltage up from the collector transformer voltage to the POI voltage. An approximately one-mile-long generation tie line interconnects the project to the Pawnee 345kV 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 CAPE 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-2023-7 GIR is modelled as follows:

Solar Generator: Pmax = 156.48 MW, Pmin = 0 MW, Qmax = 51.19 MVar, Qmin= -51.19 MVar

The summary for the Voltage and Reactive Power Capability Evaluation for PI-2023-7 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-2023-7 are summarized in Table 4. Please note the generator terminal voltage exceeds 1.05 p.u. during the lagging test.

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Table 4: Reactive Capability Evaluation for PI-2023-7

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
153.2	39.6	51.2	-51.2	1.086	152.1	50.5	1.031	0.9491	152.0	51.0	1.030	0.9481
153.2	-30.7	51.2	-51.2	1.000	152.0	-50.5	1.026	-0.9490	151.9	-50.1	1.026	-0.9497
0.0	-39.5	51.2	-51.2	0.995	-0.1	-40.0	1.028	-0.0025	-0.1	-40.0	1.028	-0.0025

5.2 Steady State Analysis

Contingency analysis was performed on the East study pocket Study Case.

- 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 re-dispatch. 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. Note there were a few diverged category P7 contingencies that occurred. 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.

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Table 5: East Pocket - Single Contingency Overloads

Ref. No.	Monitored Facility	Contingency Name	Contingency Description	Area	Owner	Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	STORY (73192) - PAWNEE (70311) 230 kV CKT 1	line_144_SGL_345_001	Smokey Hill - Missile Site #7081	73/70	PSCo	772	98.81	103.98	4.17
2	B.CK_TRI (73015) - B.CK_TRI (73016) 230 kV CKT 1	line_000_SGL_115_001	Beaver Creek East - Story #5265	73	TSGT	224	99.51	100.63	1.12

Table 6: East Pocket - Multiple Contingency Overloads

Ref. No.	Monitored Facility	Contingency Name	Contingency Description	Area	Owner	Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	CLARK (70112) - JORDAN (70241) 230 kV CKT 1	P7_150	Double circuit loss of lines 5167 and 5285	70	PSCo	364	108.91	112.52	3.61
2	STORY (73192) - PAWNEE (70311) 230 kV CKT 1	P7_135	Double circuit loss of lines 7081 and 7109	73/70	PSCo	772	99.81	103.98	4.17

5.3 Transient Stability Results

The transient stability analysis was performed in the east pocket using the case analyzed in the steady-state analysis. The generator re-dispatching was applied in the study case that resolved the overloads observed during the steady state analysis.

The following results were obtained for the disturbances analyzed:

- ✓ 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 response observed during the contingency in Ref. No. 2-3 showed undamped and uneven oscillations occurring between 2-10 seconds which starts damping out at around 10 seconds, and completely damp out at 12 seconds generating flat voltage profile. The responses observed for these contingencies are considered stable per the criteria (a) in the section 3.2 Transient Stability Criteria of the report.

Note the response observed during the contingency in Ref. No. 8, a category P4 contingency at Canal Crossing 345 kV, is not attributable to the Study GIR. However, a Corrective Action Plan (CAP) may be necessary, which could include an Operating Procedure and/or Remedial Action Scheme (RAS).

Table 7: Transient Stability Analysis Result

Ref. No.	Contingency Name	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Flat Run	-	P0	Flat run	-	Stable	Stable
2	Pawnee-CanalXing_345kV	Pawnee 345 kV	P1	Pawnee - Canal Crossing 345 kV CKT 1	4	Stable	Stable
3	Pawnee_Xfmr	Pawnee 345 kV	P1	Pawnee 345/230 kV Transformer T2	4	Stable	Stable
4	PI-2023-7_Gen	Pawnee 345 kV	P1	PI-2023-7 Generation	4	Stable	Stable
5	MS-CanalXing_345kV	Missile Site - Canal Crossing 345 kV Line	P1	Missile Site - Canal Crossing 345 kV CKT 1	4	Stable	Stable
6	FSV-CanalXing_345kV	FSV - Canal Crossing 345 kV Line	P1	Fort Saint Vrain - Canal Crossing 345 kV CKT 1	4	Stable	Stable
7	Rush Creek - BF123a (324)	Pronghorn 345 kV	P4	Pronghorn 345 kV Gen Tie Line Rush Creek Generation	12	Stable	Stable
8	Canal Crossing - BF210 (402)	Canal Crossing 345 kV	P4	Canal Crossing - Goose Creek 345 kV CKT 1 Canal Crossing - Goose Creek 345 kV CKT 2 Canal Crossing 345 kV Capacitor Bank	12	Unstable	Stable

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 8 below, along with the Thevenin impedance at the POI. Both the base case and the case with the GIR added are shown.

Table 8: Short Circuit Parameters at PI-2023-7 POI (Pawnee 345 kV Substation)

	Before the PI Addition	After the PI Addition
Three Phase		
Three Phase Current	20330A	20260 A
Positive Sequence Impedance	0.61736 + j9.80904 ohms	0.61736 + j9.80904 ohms
Negative Sequence Impedance	0.69267 + j9.78060 ohms	0.69267 + j9.78060 ohms
Zero Sequence Impedance	1.33574 + j13.4511 ohms	1.15132 + j12.3358 ohms
Phase-to-Ground		
Single Line to Ground Current	18090 A	18970 A
Positive Sequence Impedance	0.61736 + j9.80904 ohms	2.94172 + j38.0808 ohms
Negative Sequence Impedance	0.69267 + j9.78060 ohms	2.96554 + j38.0763 ohms
Zero Sequence Impedance	1.33574 + j13.4511 ohms	1.15132 + j12.3358 ohms

A breaker duty study on the PSCo transmission system did not identify any circuit breakers that became over-dutied because of adding the solar generation PI-2023-7.

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 150 MW.

6.0 Cost Estimates

The total cost of the required Upgrades for PI-2023-7 to interconnect for Provisional Interconnection Service at the Pawnee 345 kV substation is estimated to be **$10.815 million**.

- **Cost of Transmission Provider's Interconnection Facilities (TPIF) is $4.080 million** (Table 9)
- **Cost of Station Network Upgrades is $6.735 million** (Table 10)
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the Provisional Interconnection of PI-2023-7 are given in Table 9 and Table 10.

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

Table 9: Transmission Provider's Interconnection Facilities

Element	**Description**	**Cost Est. (Million)**
PSCo's Pawnee 345 kV Substation	Interconnection of PI-2023-7 at the Pawnee 345 kV Substation. 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 for metering • (1) 345 kV 3-phase CCVT • Yard expansion including grading, ground grid, access road relocation, surfacing and fencing • Dual fiber communication equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing	$4.030
PSCo's Pawnee 345 kV Substation	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		**$4.080**

Table 10: Station Network Upgrades

Element	Description	Cost Est. (Million)
PSCo's Pawnee 345 kV Substation	Interconnection of PI-2023-7 at Pawnee 345 kV Substation. The new equipment includes: • (2) 345 kV dead end structures • (5) 345 kV 3000A SF6 circuit breakers • (6) 345 kV 3000A disconnect switches • (2) 345 kV 3-phase CCVTs • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$6.735
Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities		**$6.735**

PSCo has developed cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of PI-2023-7 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-2023-7 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 is April 2, 2027. This is 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 11.

Table 11: Proposed Milestones for PI-2023-7

Milestone	Responsible Party	Estimated Completion Date
PLGIA Execution	Interconnection Customer and Transmission Provider	August 30, 2024
In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection	Transmission Provider	April 2, 2027
In-Service Date & Energization of Interconnection Customer's Interconnection Facilities	Interconnection Customer	April 2, 2027
Initial Synchronization Date	Interconnection Customer	April 10, 2027
Begin trial operation & testing	Interconnection Customer and Transmission Provider	April 10, 2027
Commercial Operation Date	Interconnection Customer	May 1, 2027

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-2023-7 to qualify for Provisional Interconnection Service would be $10.815 million.

The initial maximum permissible output of PI-2023-7 Generating Facility is 150 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 the GI-2024-18, in the 2024 Definitive Interconnection System Impact Study (DISIS), selection of Energy Resource Interconnection Service (ERIS), the security associated with the Network Upgrades that might be identified at the conclusion of the GI-2024-18 Large Generation Interconnection Procedure (LGIP) 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-2023-7 include the TPIF and Station Network Upgrades identified in Table 9 and Table 10, respectively.

9.0 Preliminary One-Line Diagram and General Arrangement for PI-2023-7

Figure 2 - Preliminary One-Line for PI-2023-7 at Pawnee 345 kV substation

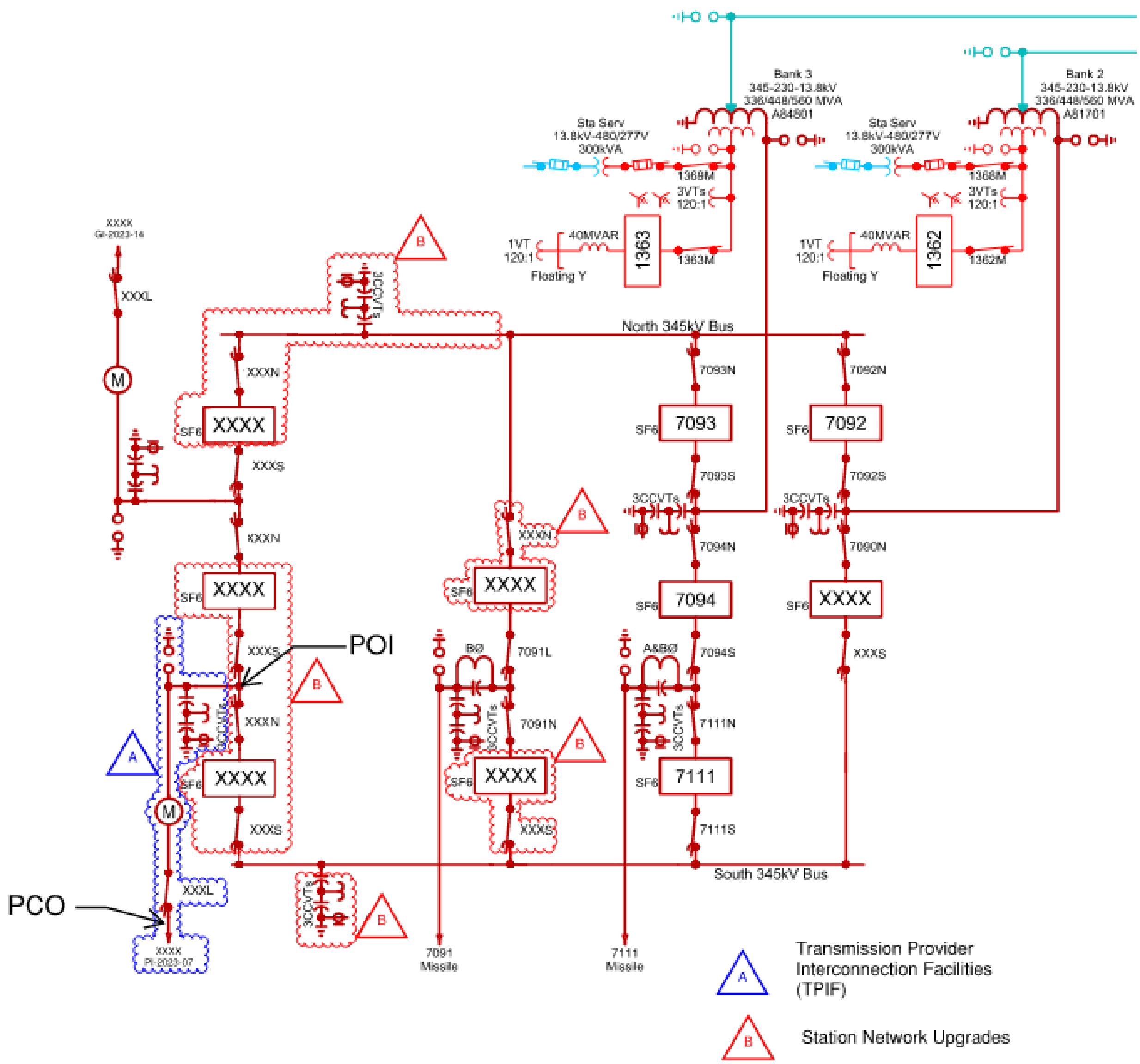
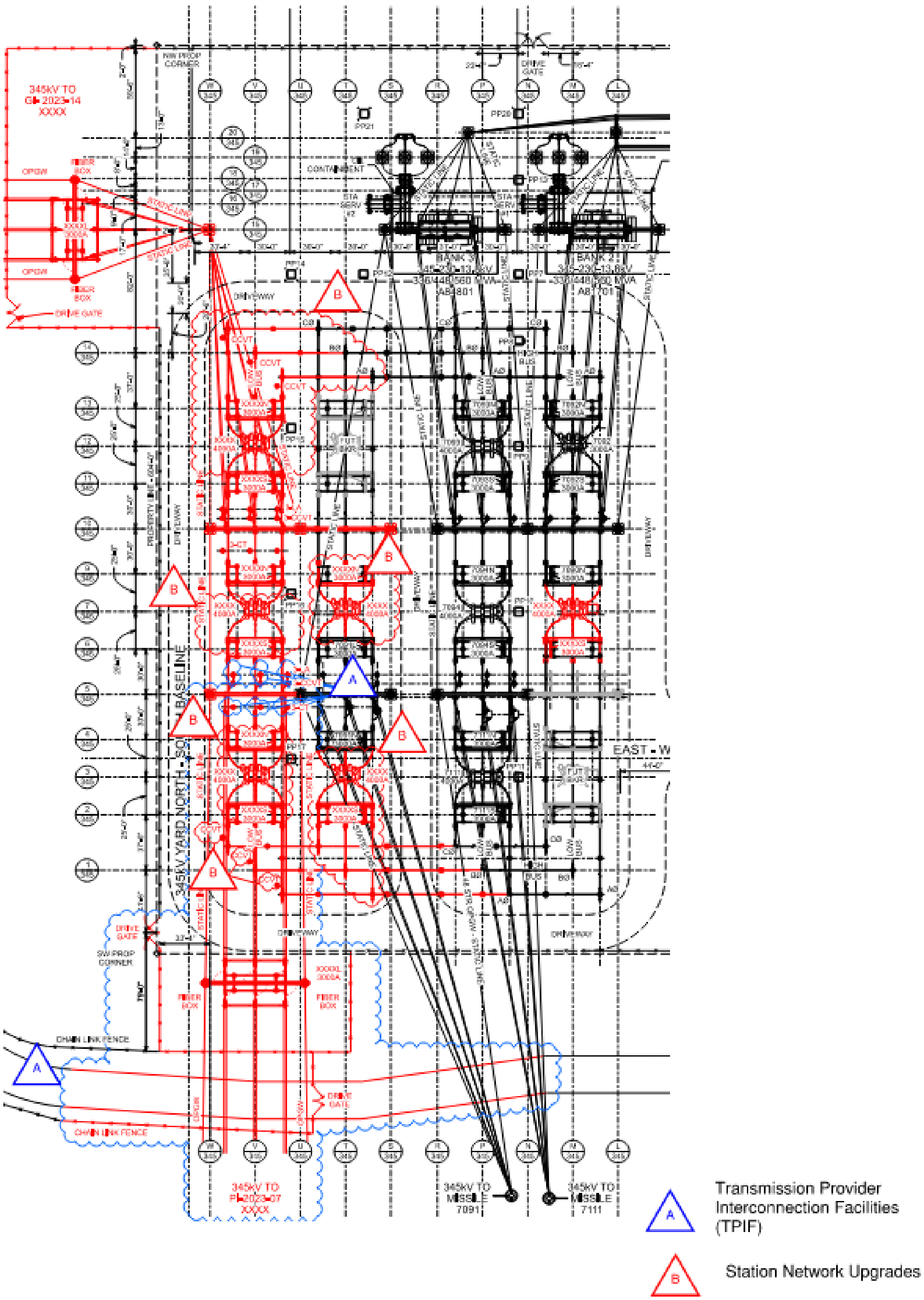


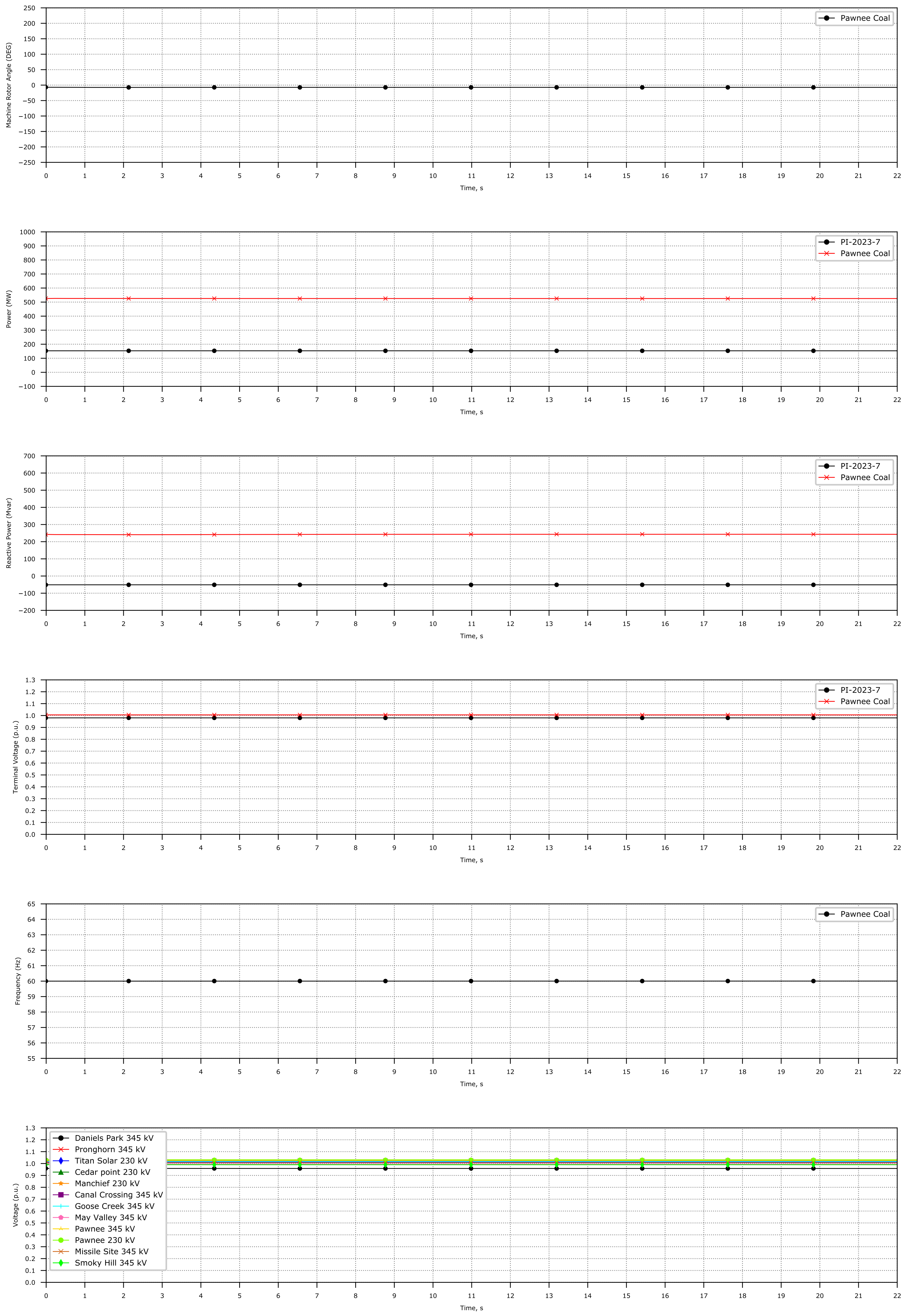
Figure 3 - Preliminary General Arrangement for PI-2023-7 Interconnection Facilities at Pawnee 345 kV



10.0 Appendices

Appendix A: Transient Stability Plots	PI-2023-7_Study_Results.pdf

PI-2023-7_Study_East_flatrun



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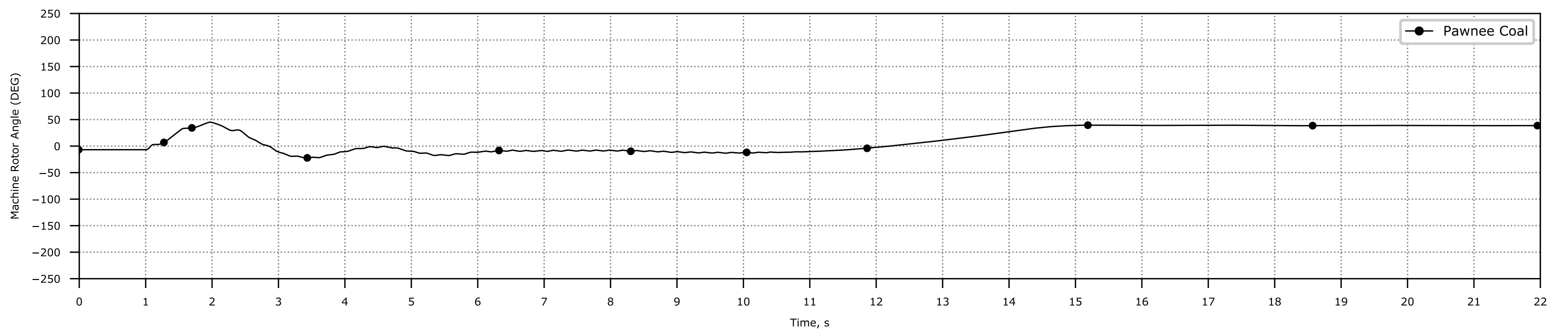

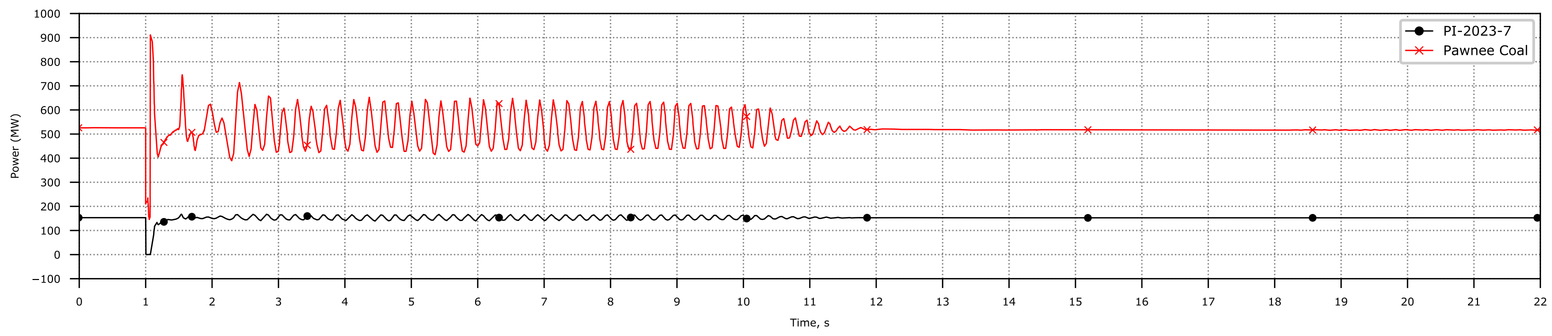

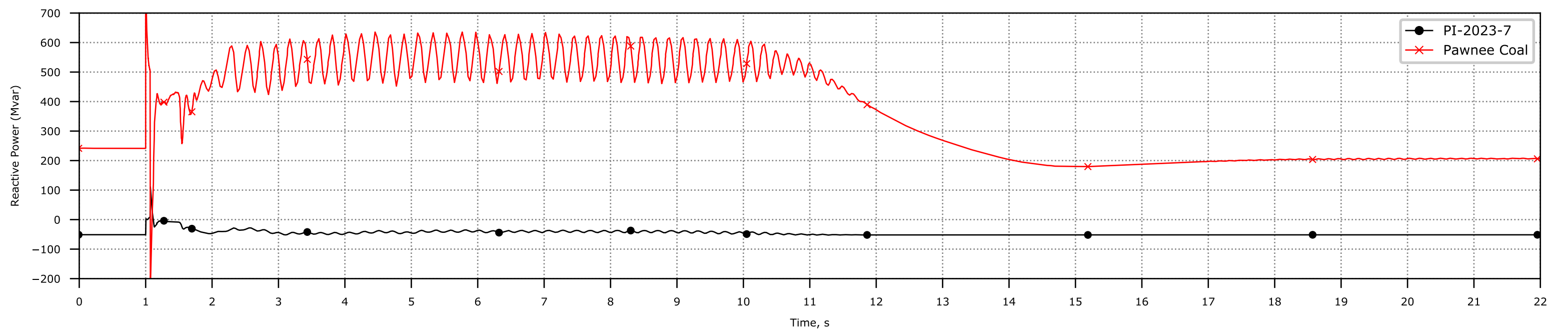

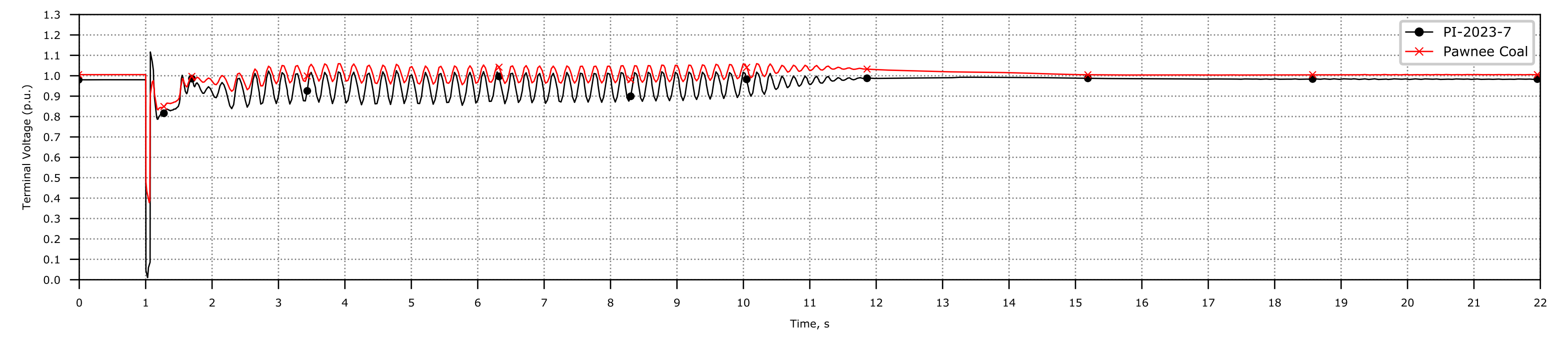

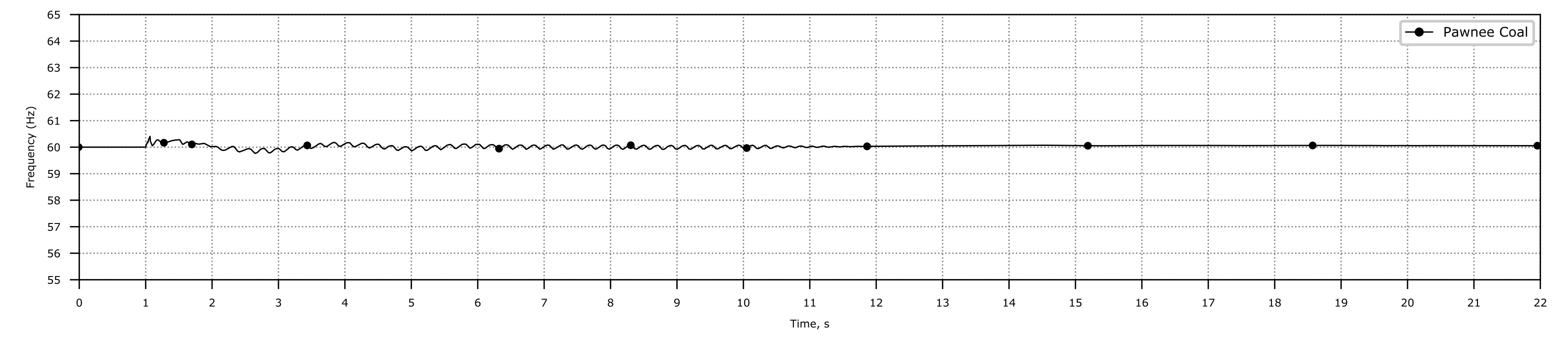

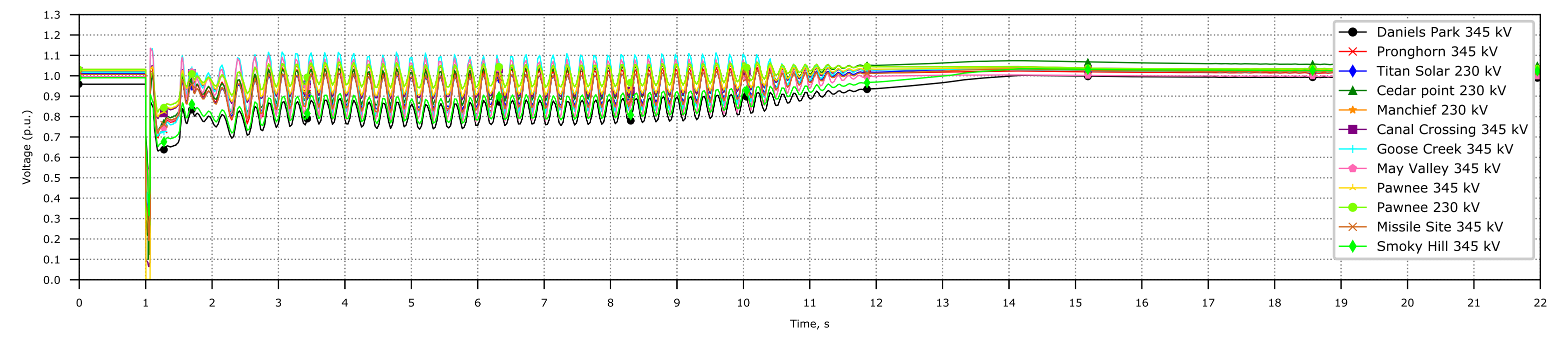

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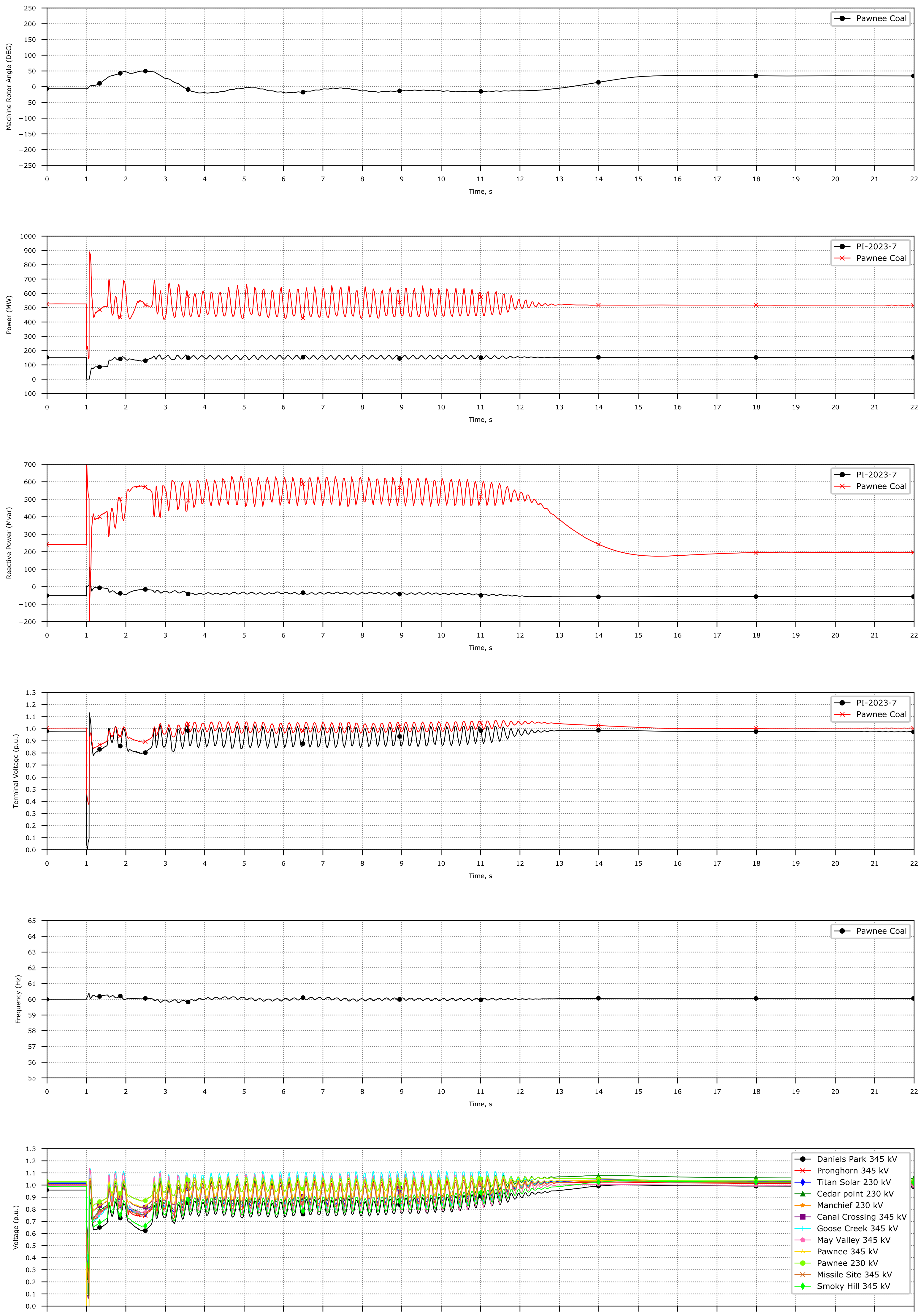

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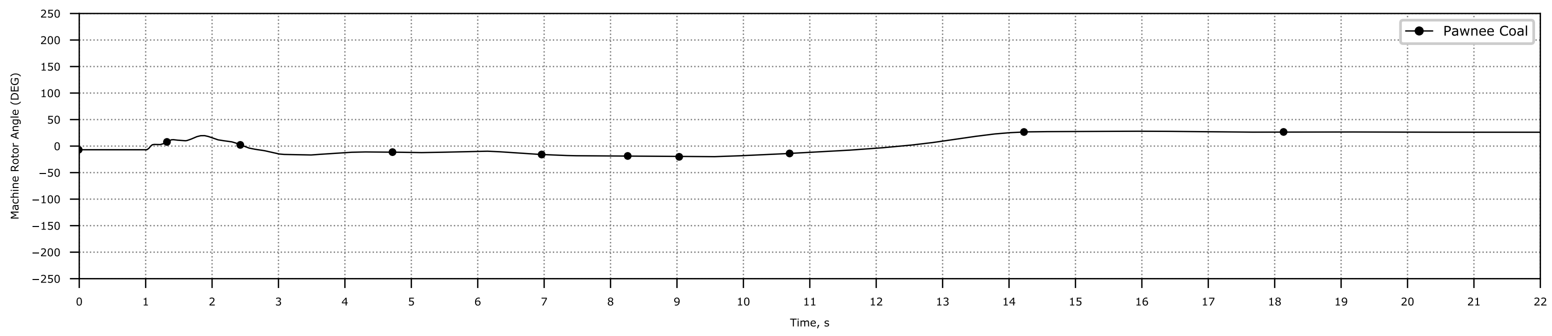
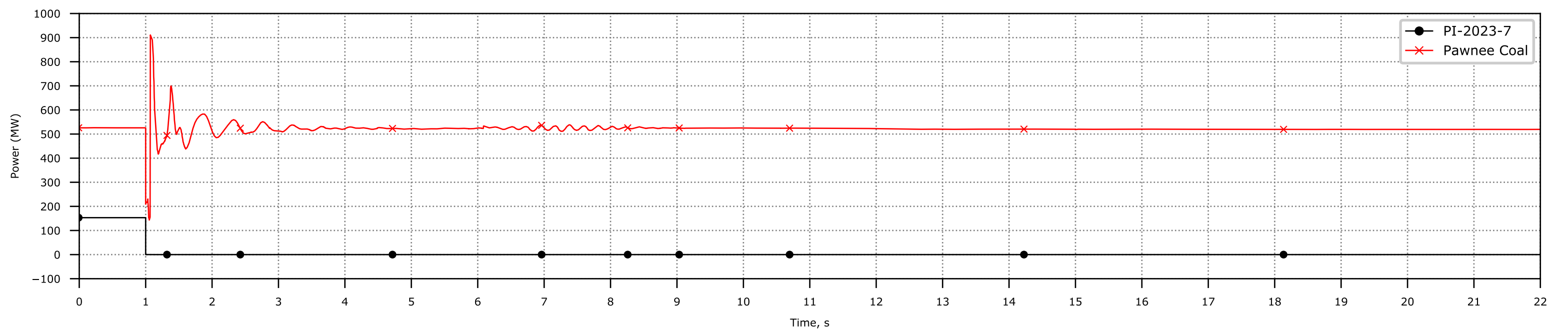
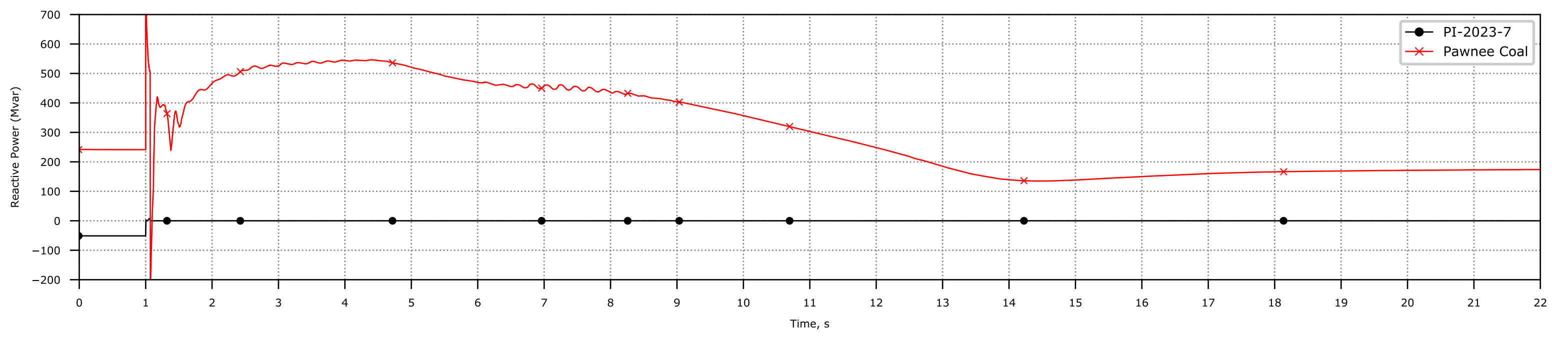
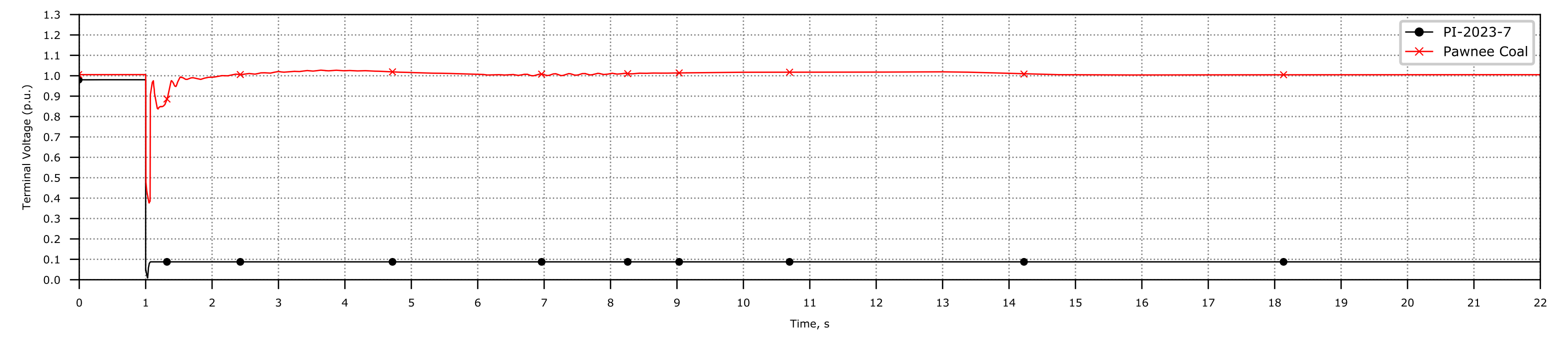
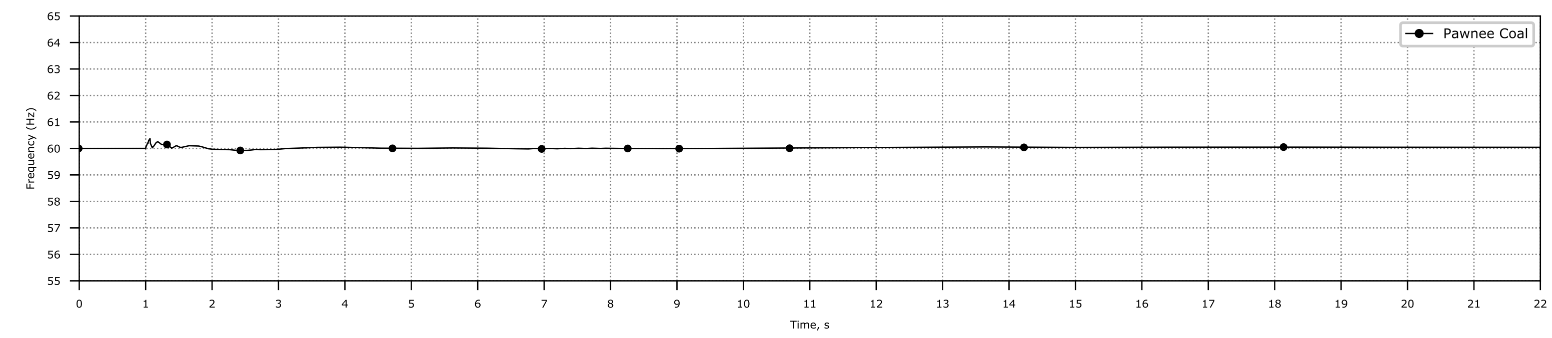
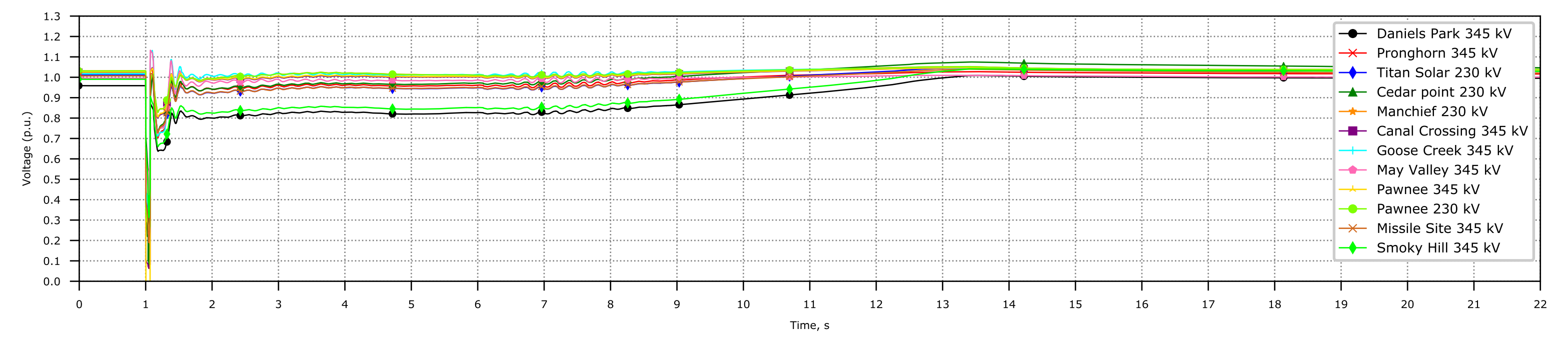




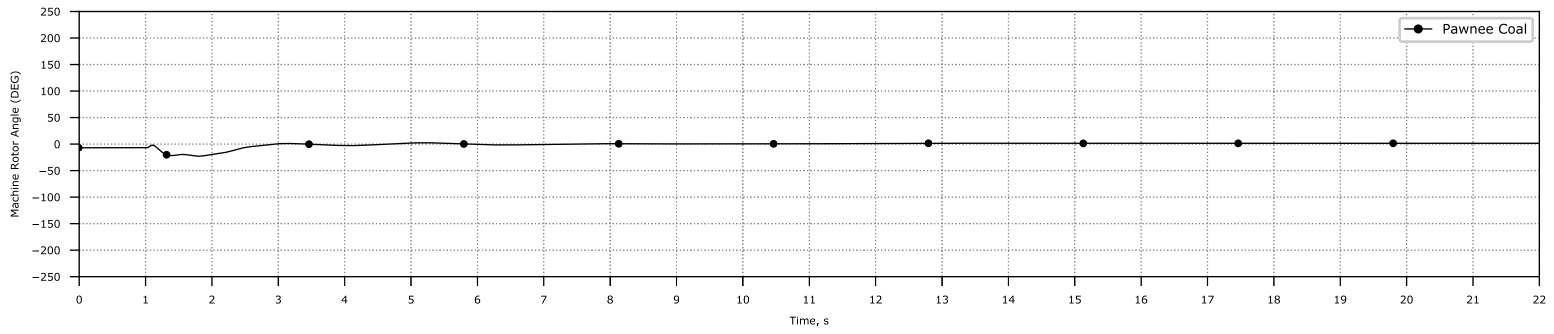


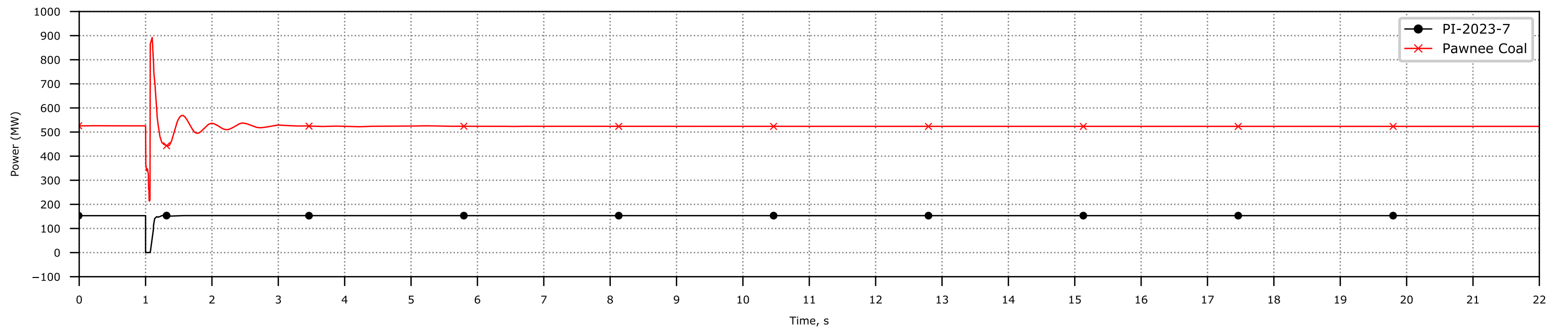


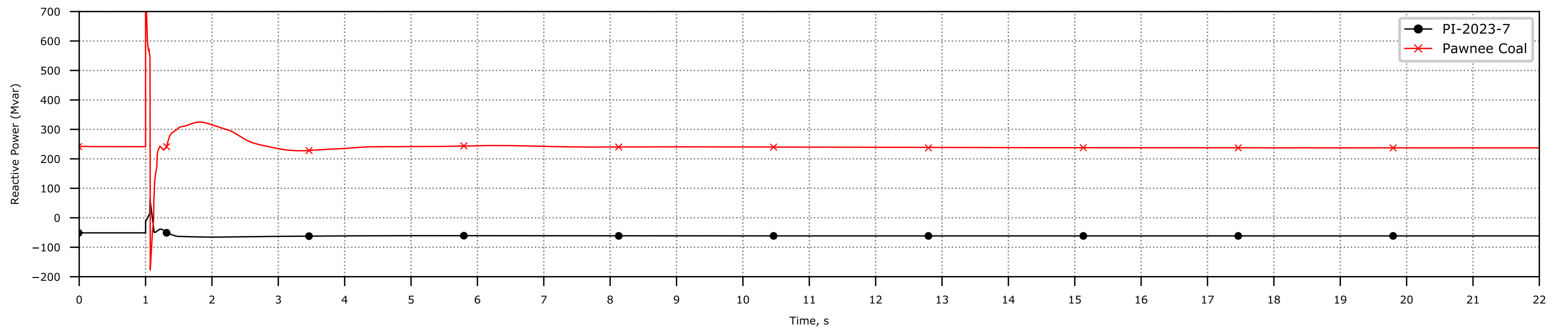


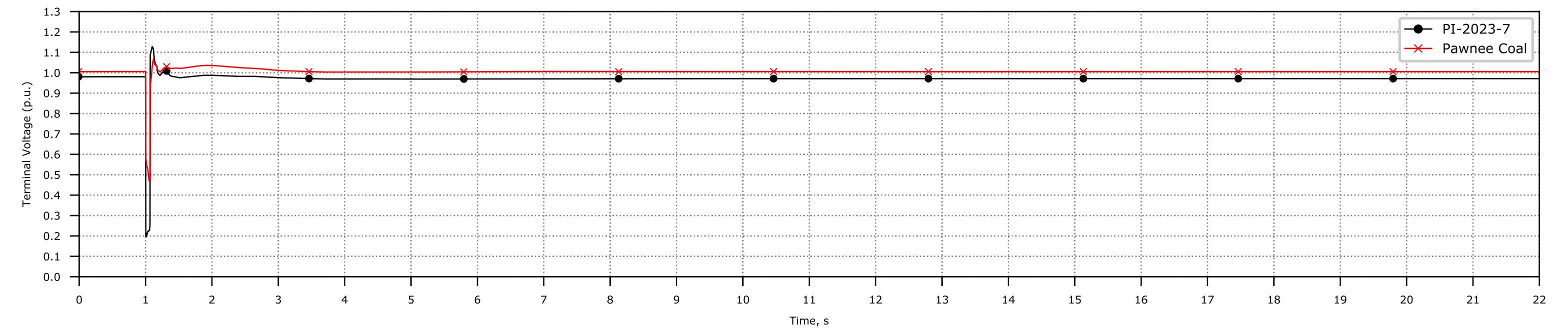


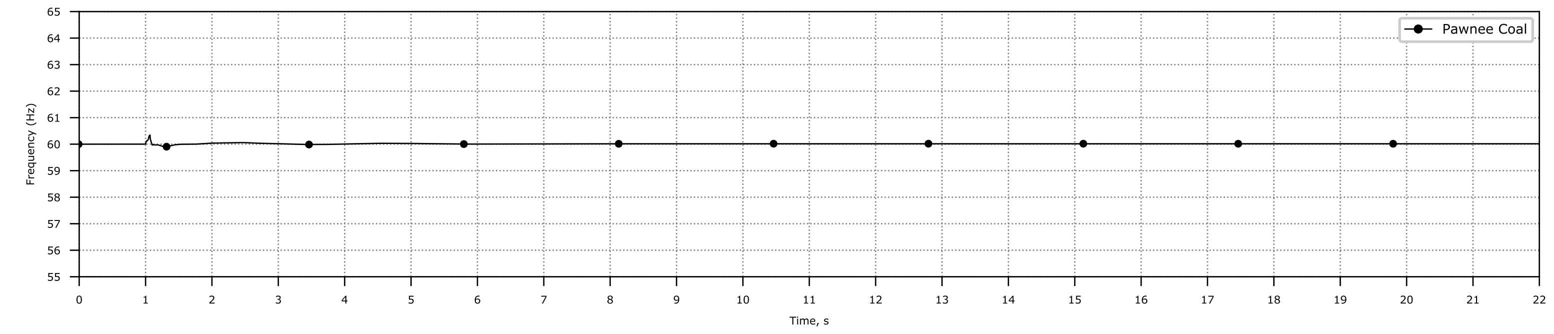
PI-2023-7_Study_East_MS-CanalXing_345kV

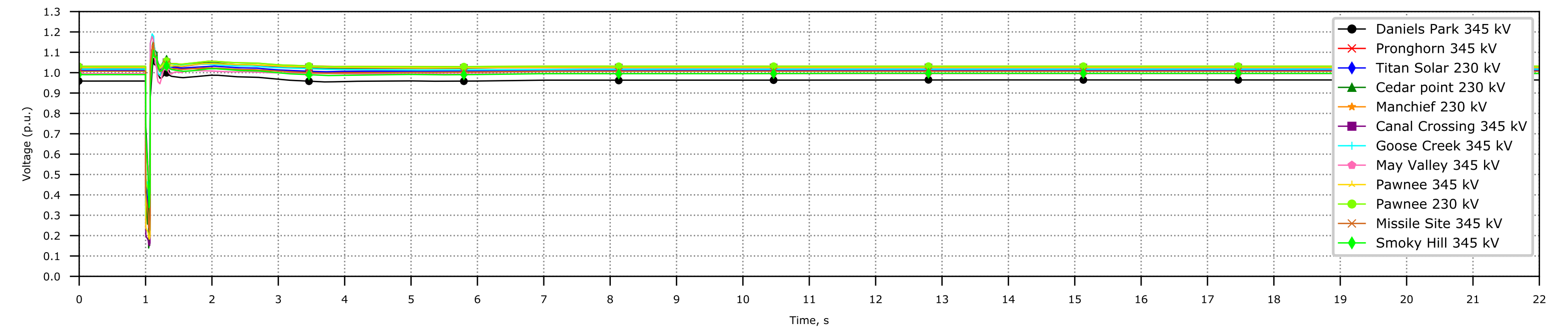




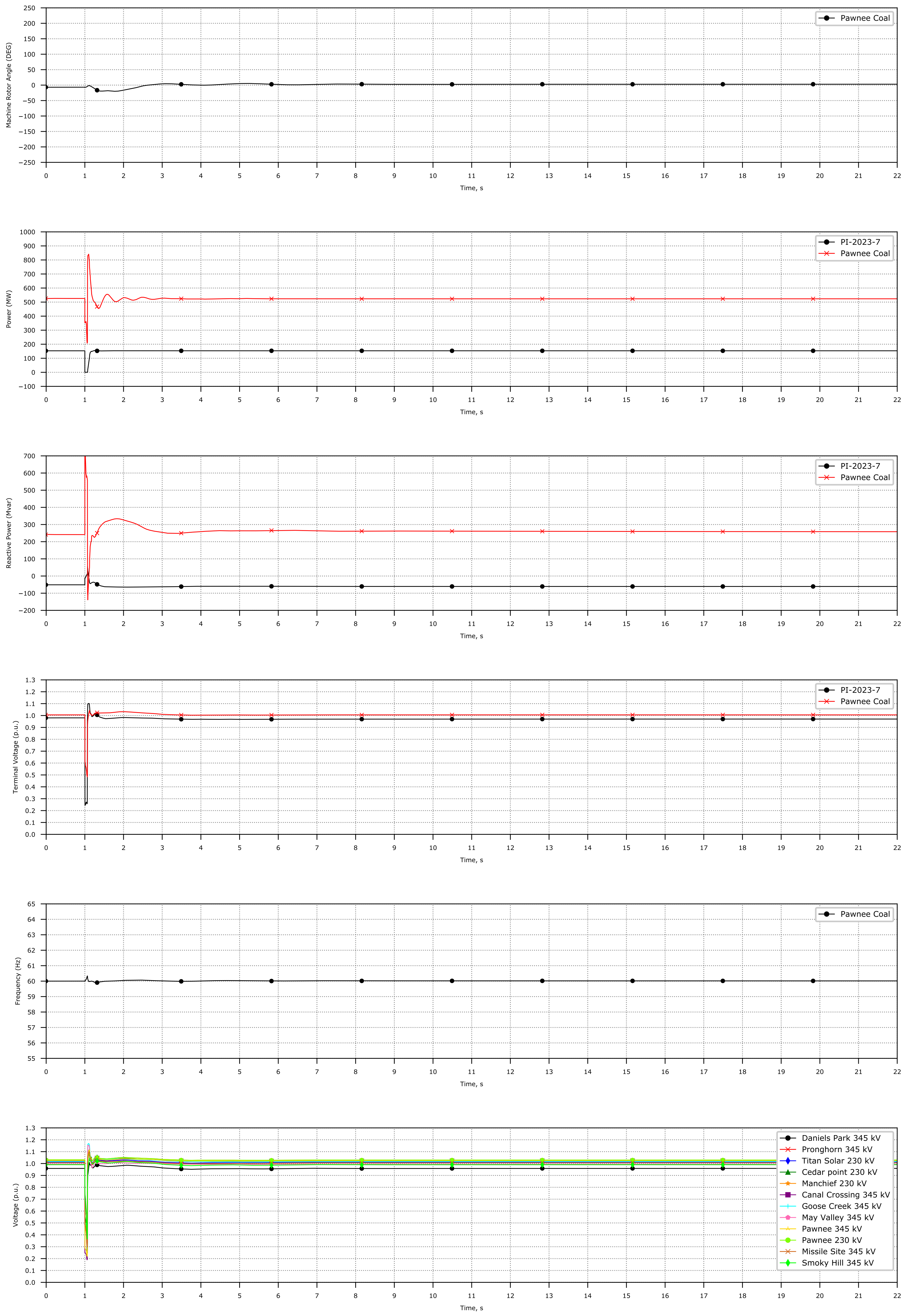








PI-2023-7_Study_East_FSV-CanalXing_345kV



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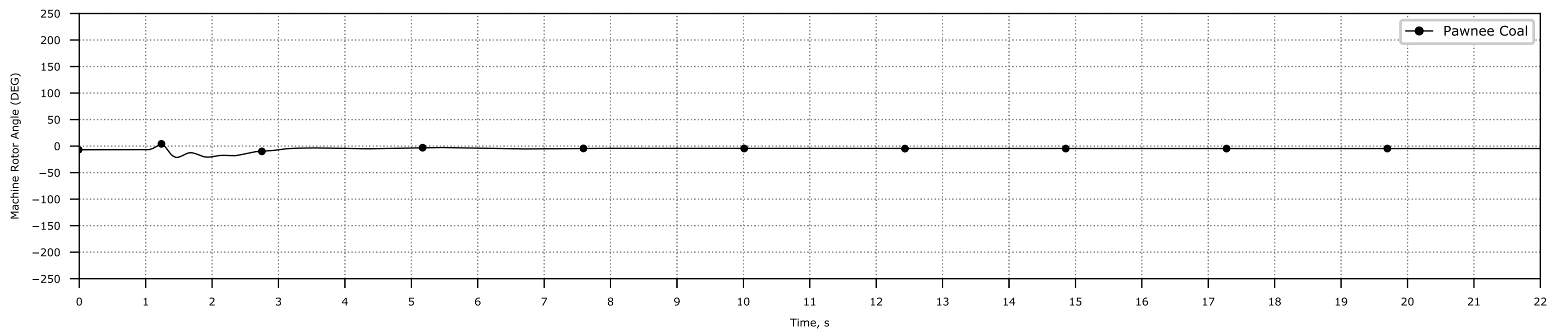

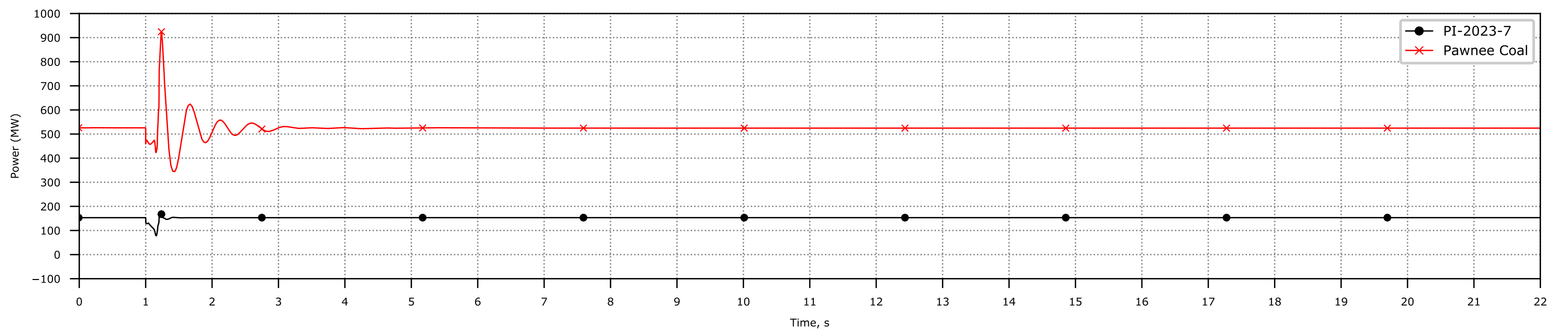

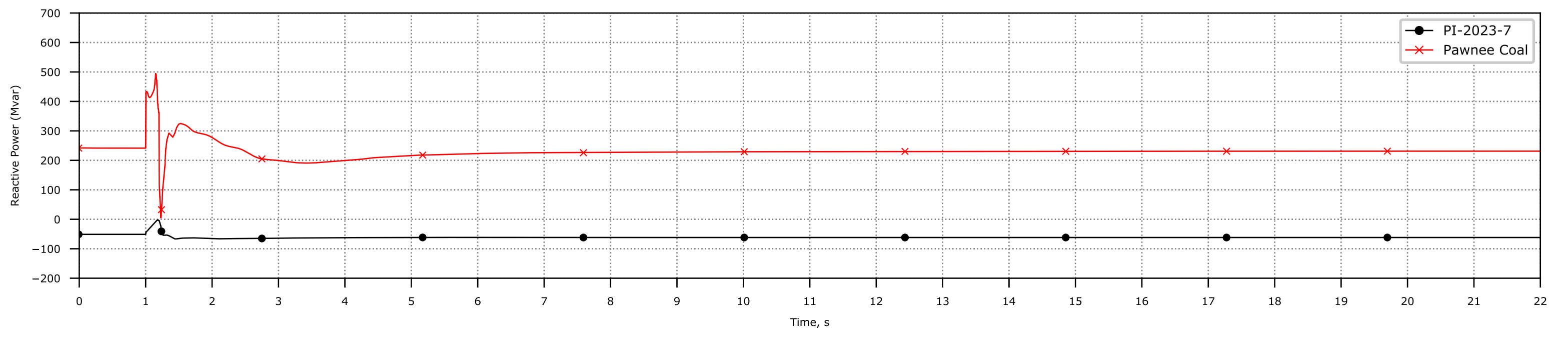

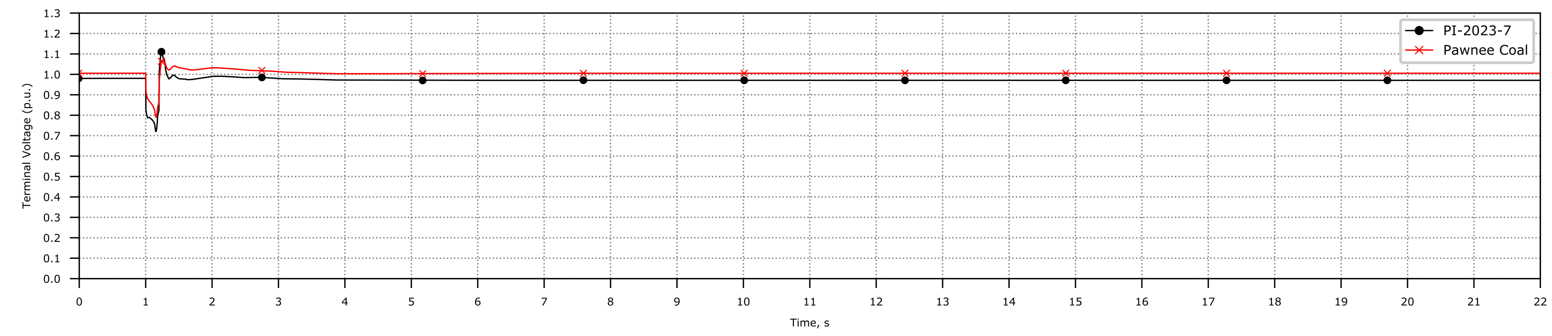

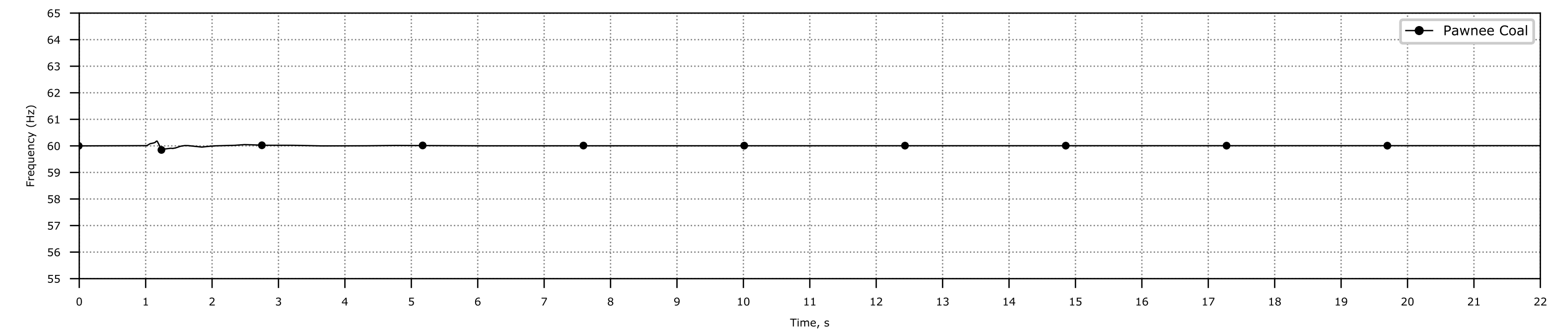

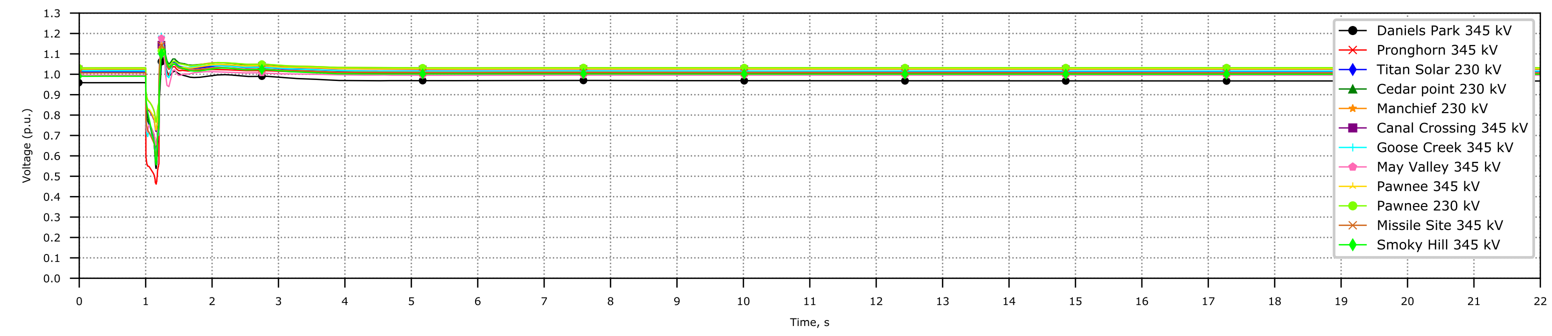

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