Provisional Interconnection Study Report for PI-2024-06

8/26/2024

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1.0 Executive Summary

The PI-2024-06 project is a Provisional Interconnection request for a 400 MW Solar Photovoltaic (PV) Generating Facility with a Point of Interconnection (POI) tapping the May Valley – Sandstone – Tundra 345 kV circuit 1. PI-2024-06 is the Provisional Interconnection request as associated with Generation Interconnection Request 5RSC-2024-21 in the 5RSC cluster.

The total cost of the transmission system improvements required for PI-2024-06 to qualify for Provisional Interconnection Service is estimated to be $32.865 million (Table 13 and Table 14).

The initial maximum permissible output of the PI-2024-06 Generating Facility is 400 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-2024-21 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-2024-21 Large Generation Interconnection Procedure (LGIP) in the 5RSC cluster is $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-2024-06 is the Provisional Interconnection Service[3] request for a 400 MW Solar PV Generating Facility located in Crowley County, Colorado.

- The POI of this project is a new 345 kV switching station tapping May Valley – (Sandstone) – Tundra 345 kV circuit 1.
- The Commercial Operation Date (COD) to be studied for PI-2024-06 as noted on the Provisional Interconnection request for is June 1, 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.

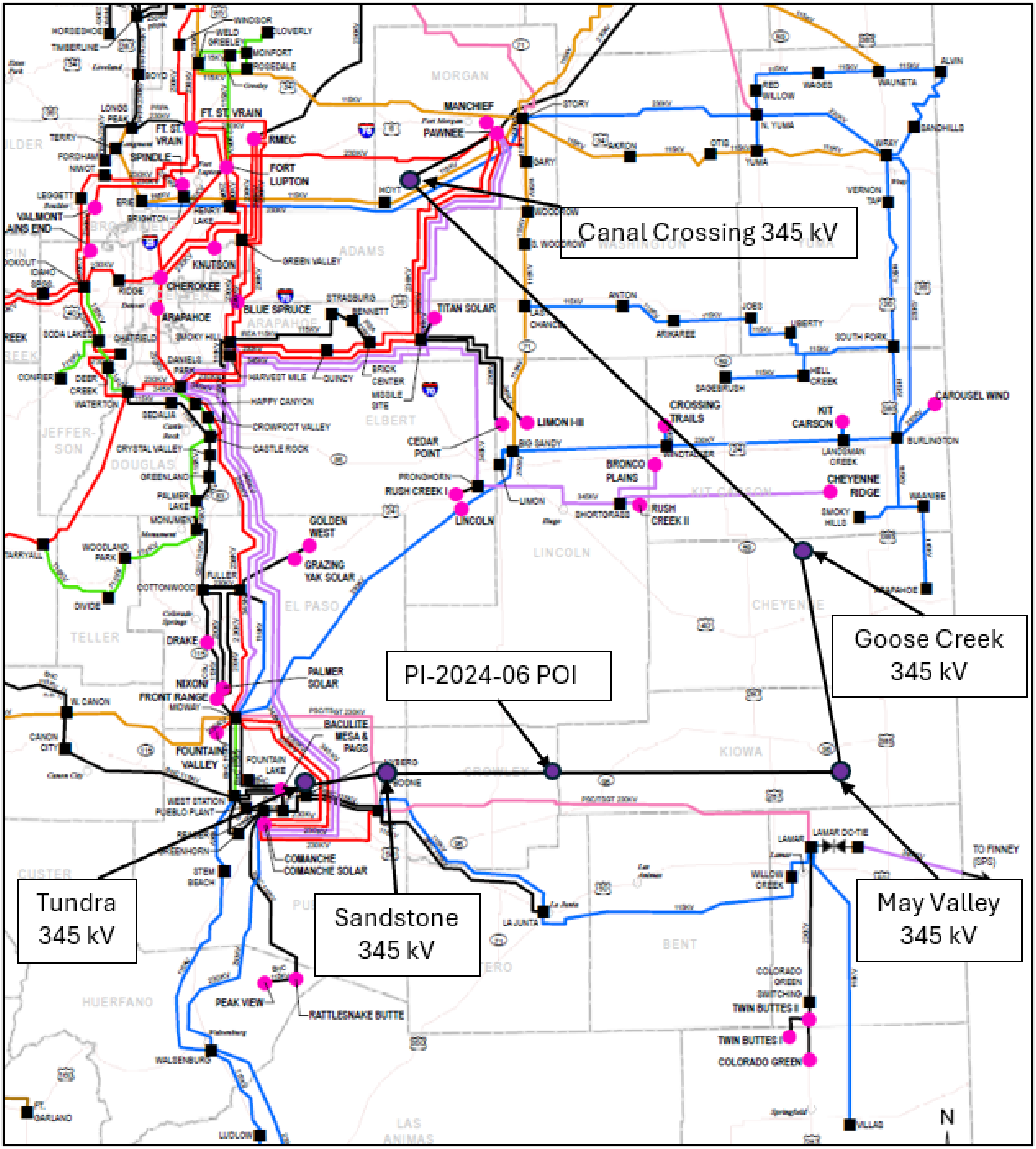

Figure 1: Approximate Point of Interconnection of PI-2024-06

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-2024-06 for Provisional Interconnection Service. Consistent with the assumption in the study agreement, PI-2024-06 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 3.2. 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	Outage(s)	Clearing Time (Cycles)
1	-	Flat Run	-
2	PI-2024-06 POI 345 kV	PI-2024-06 Generation	4
3	PI-2024-06 POI - Sandstone 345 kV CKT 1	PI-2024-06 POI - Sandstone 345 kV CKT 1	4
4	PI-2024-06 POI - May Valley 345 kV CKT 1	PI-2024-06 POI - May Valley 345 kV	4
5	May Valley - Goose Creek 345 kV CKT 1	May Valley - Goose Creek 345 kV CKT 1	4
6	May Valley - Sandstone 345 kV CKT 2	May Valley - Sandstone 345 kV CKT 1	4
7	Tundra - Sandstone 345 kV CKT 1	Tundra - Sandstone 345 kV CKT 1	4
8	Harvest Mile - Sandstone 345 kV CKT 1	Harvest Mile - Sandstone 345 kV CKT 1	4

Ref. No.	Fault Location	Outage(s)	Clearing Time (Cycles)
9	May Valley - PI-2024-06 POI 345 kV CKT 1	May Valley - PI-2024-06 POI 345 kV CKT 1 Sandstone - PI-2024-06 POI 345 kV CKT 1 PI-2024-06 Generation	12

3.6 Study Area

The southern Colorado study area includes WECC designated zone 704. As described in Section 3.11 of the BPM, this pocket is comprised of South-central Colorado and Southeast Colorado transmission system. The transmission corridors impacted are Comanche - Daniels Park, I Midway - Waterton (345kV), and Midway - Fuller - Daniels Park (230kV). Below is the current generation in the southern Colorado study area:

- Comanche: Golden West Wind at Fuller, Fountain Valley Gas at Midway, Comanche Coal, Community Solar at Comanche, Mirasol, Tundra
- Lamar: Colorado Green Wind, Twin Buttes Wind, DC Tie

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 – ISD TBD
- 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 Allison 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 southern Colorado study pocket. This was accomplished by adopting the stressed 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 to Create the Southern Colorado Benchmark Case (MW is Gross Capacity)

Ref. No.	Generator Bus No.	Bus Name	Base kV	ID	Status	Pgen (MW)	Max Power (MW)
1	70120	COMAN_2	24.00	C2	1	365.00	365.00
2	70577	FTNVL1&2	13.80	G1	1	36.00	40.00
3	70577	FTNVL1&2	13.80	G2	1	36.00	40.00
4	70578	FTNVL3&4	13.80	G3	1	36.00	40.00
5	70578	FTNVL3&4	13.80	G4	1	36.00	40.00
6	70579	FTNVL5&6	13.80	G5	1	36.00	40.00
7	70579	FTNVL5&6	13.80	G6	1	36.00	40.00
8	70777	COMAN_3	27.00	C3	1	804.90	804.90
9	70934	COMAN_S1	0.42	S1	1	102.00	120.00
10	70017	SI_GEN 0	0.60	1	1	25.59	30.10
11	70878	BIGHORN_S	0.63	S1	1	210.38	247.50
12	70756	NEPTUNE_B1	0.48	B1	1	106.25	125.00
13	70758	NEPTUNE_S1	0.66	S1	1	212.93	250.50
14	70761	THNDWLF_B1	0.48	B1	1	85.00	100.00
15	70763	THNDWLF_S1	0.66	S1	1	170.00	200.00

Ref. No.	Generator Bus No.	Bus Name	Base kV	ID	Status	Pgen (MW)	Max Power (MW)
16	70859	SUN_MTN_S1	0.66	S1	1	172.30	202.70
17	700142	GI_2020_10	0.63	S1	1	154.10	154.10
18	700146	GI_2020_10	0.63	S2	1	154.10	154.10
19	70256	CO_GRN_W	0.58	W2	1	64.80	81.00
20	70708	CO_GRN_E	0.58	W1	1	64.80	81.00
21	70704	TBI_GEN	0.58	W1	1	60.00	75.00
22	70663	GLDNWST_W1	0.69	W1	1	199.52	249.40
23	70010	TBII_GEN	0.69	W	1	62.40	78.00
24	700119	REPL_21_1	0.66	S1	1	103.02	121.20
25	700120	REPL_21_1	0.66	S2	1	103.02	121.20
26	700121	REPL_21_1	0.66	S3	1	103.02	121.20
27	70725	SPANPKS2_GEN	0.60	PV	1	34.17	40.20
28	70994	SP_GEN	0.62	PV	1	85.17	100.20
29	700104	3RSC_23_1	0.66	S1	1	102.30	102.30
30	700107	3RSC_23_1	0.66	S2	1	102.30	102.30
31	700111	3RSC_23_2	0.66	B	1	102.30	102.30
32	700115	3RSC_23_3	0.69	W1	1	105.40	105.40
33	700118	3RSC_23_3	0.69	W3	1	102.00	102.00
34	700172	GI_2014_6	0.63	S	1	100.90	100.90
Total (MW)						**4273.65**	**4677.50**

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-2024-06 generation. The additional 400 MW output from PI-2024-06 was balanced against PSCo generation outside of the southern Colorado study pocket.

4.3 Short-Circuit Modeling

The Integrated System Planning - OATT Department has requested Fault Studies for a Provisional Interconnection request. This request is for the Interconnection of a 400 MW PV Generating Facility (PI-2024-06) tapping the May Valley – Sandstone 345 kV circuit 1. The output will not exceed 400 MW at the POI.

This project assumes the use of five hundred and twenty-eight (528) TMEIC PVU-L0840GR-2 inverters rated at 0.84 MVA operating at +/-0.92 pf for PI-2024-06. Each set of six (6) inverters is connected to a collector transformer, 0.63/34.5 kV, rated at 5.04 MVA. Two 345/34.5/13.8 kV main GSU transformers rated at 134/178/223 MVA step the voltage up from the collector transformer voltage to the POI voltage. The fault current from the interconnection is assumed to be shared equally between the two GSUs. An approximately 0.1-mile-long generation tie line interconnects the project to the new PSCo 345 kV station near the May Valley to Sandstone to Tundra 345 kV line.

All connected generating facilities were assumed capable of producing maximum fault current. As such, all generation was modeled at full capacity, whether 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

Per Section 4.1.1.1 of the BPM, 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.

Per Section 4.1.1.2 in the BPM, the following voltage regulation and reactive power capability requirements are applicable to synchronous generators:

- Xcel Energy's OATT requires all synchronous Generator Interconnection Customers to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the POI.
- The reactive power analysis performed in this report is an indicator of the reactive power requirements at the POI and the capability of the generator to meet those requirements. The Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and the regulating voltage of the POI.

Per Section 4.4.1 in the BPM, the following steps shall be followed to perform the reactive power capability evaluation for synchronous generators:

a. The reactive power evaluation of the Synchronous generators is done by dispatching the generator at Pmax and changing the POI voltage till Qmax and Qmin are reached.
b. This step is repeated for Pmin.
c. The POI voltage and power factor for the two evaluations are noted. If the POI power factor of 0.95 is reached and the POI voltage stays under the voltage guidance values noted (1-1.04 p.u. for the 230kV system, 1-1.05 for the 345kV system and 1-1.03 for 115kV system), the GIR is considered to meet reactive power requirements. If not, additional dynamic reactive support would be identified.

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

All summary tables representing GIRs' 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 of 0.95 – 1.05 p.u. are highlighted in yellow to provide additional information.

The PI-2024-06 GIR is modeled as follows:

Wind Generator: Pgen = 413.30 MW, Pmin = 0.0 MW, Qmax = 173.82 MVar, Qmin= -173.82 MVar

The summary for the Voltage and Reactive Power Capability Evaluation for PI-2024-06 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-2024-06 are summarized in Table 4. Please note the POI and high side of the main power transformer reach 0.94 p.u. voltage during the 0.95 leading power factor assessment.

Table 4 – Reactive Power Capability Evaluation for PI-2024-06

Generator Terminals						High Side of Main Transformer				POI			
Pgen (MW)	Qgen (Mvar)	Qmax (Mvar)	Qmin (Mvar)	V (p.u.)	PF	P (MW)	Q (Mvar)	V (p.u.)	PF	P (MW)	Q (Mvar)	V (p.u.)	PF
413.3	173.8	173.8	-173.8	1.03	0.9218	400.0	134.4	0.99	0.9479	400.0	134.4	0.99	0.9479
413.3	-50.4	173.8	-173.8	1.00	-0.9218	400.8	-137.3	0.94	-0.9460	400.8	-137.3	0.94	-0.9460
0.0	-6.0	173.8	-173.8	0.99	0.0000	-4.0	-8.7	0.97	-0.4177	-4.0	-8.6	0.97	-0.4217

5.2 Steady-State Analysis

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

The power flow analysis showed that the category P1 contingency outage of Goose Creek – Shortgrass 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, 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 southern Colorado study pocket. The following single and multiple contingency analyses are conducted with the dispatch presented in the last column of Table 5.

- System Intact analysis showed no thermal or voltage violations attributable to PI-2024-06.
- Single Contingency analysis showed the following thermal and voltage violations attributable to PI-2024-06 in Table 6 and Table 7.
    - All single contingency violations were alleviated via redispatch.
- Multiple Contingency analysis showed the following thermal or voltage violations attributable to PI-2024-06 in Table 8 and Table 9. Per TPL-001-5, multiple contingency violations 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.
    - Note a total of seven P7 contingencies were divergent as shown in Table 10. Multiple contingency issues are resolved using system adjustments, including generation redispatch (includes GIRs under study) and/or operator actions. Therefore, they are not attributable to the study GIR.

Table 5 – Generation Dispatch to Resolve the Diverged P1 Contingency

Bus No.	Bus Name	Base kV	ID	Original Pgen (MW)	Modified Pgen (MW)
700076	5RSC_24_16	0.72	W1	144.00	0.00
700077	5RSC_24_16	0.72	W2	162.00	0.00

Table 6 – Single Contingency Overloads

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Daniels Park 345/230 kV Transformer T4	DanielsPark T3_P1-3_15	230/345	70	560	128.55	131.93	3.38
2	Daniels Park 345/230 kV Transformer T5	DanielsPark T3_P1-3_15	230/345	70	560	128.55	131.93	3.38
3	Greenwood_1 (70212) - Tech Center (70428) 230 kV Circuit 2	Greenwood - Monaco - Sullivan (#5717)	230	70	405	122.52	124.8	2.28
4	Leetsdale (70260) - Sullivan_2 (70365) 230 kV Circuit 1	Smoky Hill - Buckley - Jewell - Leetsdale (#5285)	230	70	425	117.53	122.92	5.39
5	Pueblo N. Tap (70339) - Reader (70352) 115 kV Circuit 1	Comanche-Walsenberg Auto Trip Scheme	115	70	160	94.03	118.18	24.15
6	Midway_PS (70286) - Mirasol (70652) 230 kV Circuit 1	DanielsPark-Tundra-1_P1-2_14	230	70	505	101.75	106.04	4.29
7	Monaco_12 (70481) - Sullivan_2 (70365) 230 kV Circuit 1	Sullivan - Greenwood (#5705)	230	70	445	102.91	105.15	2.24
8	Daniels Park 345/230 kV Transformer T3	Smokey Hill - Missile Site #7081	230/345	70	560	101.68	103.98	2.30
9	Harrison_P1 (70215) - Harrison_P2 (70182) 115 kV Circuit 1	Leetsdale - Elati (#5283)	115	70	239	95.95	103.13	7.18
10	Hyde Park (70236) - Pueblo N. Tap (70339) 115 kV Circuit 1	Comanche-Walsenberg Auto Trip Scheme	115	70	159	78.7	102.94	24.24
11	Daniels Park (70139) - Prairie_1 (70331) 230 kV Circuit 1	Daniels Park - Prairie - Greenwood (#5707)	230	70	956	99.49	100.88	1.39
12	Greenwood_2 (70189) - Monaco_12 (70481) 230 kV Circuit 1	Sullivan - Greenwood (#5705)	230	70	503	98.79	100.72	1.93

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Table 7 – Single Contingency Voltage Violations

Ref. No.	Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
1	DANIEL_PK	70601	345	70	line_144_SGL_345_001	0.9107	0.8964	-0.0143
2	WATERTON	70466	345	70	DanielsPark-Tundra-1_P1-2_14	0.9003	0.8975	-0.0028

Table 8 – Multiple Contingency Overloads

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Pueblo N. Tap (70339) - Reader (70352) 115 kV Circuit 1	P7_53 - Lines 5411 55255	115	70	160	125.26	150.75	25.49
2	Leetsdale (70260) - Sullivan_2 (70365) 230 kV Circuit 1	BF_004a - Arapahoe 230 kV	230	70	425	139.99	146.33	6.34
3	Hyde Park (70236) - Pueblo N. Tap (70339) 115 kV Circuit 1	P7_53 - Lines 5411 55255	115	70	159	110.03	135.48	25.45
5	Greenwood_1 (70212) - Tech Center (70428) 230 kV Circuit 2	BF_064a - Greenwood Bus 2 230 kV	230	70	470	116.22	118.86	2.64
6	Monaco_12 (70481) - Sullivan_2 (70365) 230 kV Circuit 1	P7_104 - Lines 5705 5167	230	70	445	107.05	110.12	3.07
7	Sullivan_1 (70417) - Tech Center (70428) 230 kV Circuit 1	BF_064a - Greenwood Bus 2 230 kV	230	70	452	107.12	109.96	2.84
8	Daniels Park (70139) - Sante Fe (70527) 230 kV Circuit 1	P7_58 - Lines 5707 5111	230	70	553	107.04	109.29	2.25
9	Daniels Park (70139) - Marcy (70278) 230 kV Circuit 1	P7_65 - Lines 5109 7051	230	70	478	98.81	103.26	4.45

Ref. No.	Monitored Facility	Contingency Name	kVs	Areas	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
10	Chatfield (70100) - Waterton (70464) 230 kV Circuit 1	BF_064c - Greenwood Bus Tie	230	70	553	98.78	101.88	3.10
11	Daniels Park (70601) - Tundra (70653) 345 kV Circuit 1	BF_045c - Daniels Park 345 kV Bkr 7036	345	70	1183	97.69	101.28	3.59
12	Midway_PS (70286) - Mirasol (70652) 230 kV Circuit 1	P7_52 - Lines 5415 5411	230	70	555	97.25	101.17	3.92
13	Daniels Park (70139) - Prairie_1 (70331) 230 kV Circuit 1	BF_045s - Daniels Park Bkr 5707	230	70	956	99.49	100.88	1.39
14	Daniels Park (70139) - Prairie_3 (70323) 230 kV Circuit 1	BF_045t - Daniels Park Bkr 5111	230	70	956	98.86	100.33	1.47

Table 9 – Multiple Contingency Voltage Violations

Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
ARAPAHOE	70038	230	70	line_154_BF_045g	0.9099	0.8997	-0.0102
BLACKFOR	73452	115	73	line_154_BF_045g	0.9137	0.8997	-0.0140
CALHAN	72104	69	73	line_154_BF_045g	0.9104	0.8962	-0.0142
CALHANTP	72105	115	73	line_154_BF_045g	0.9127	0.8986	-0.0141
CROWFT_VLY	70117	115	70	line_154_BF_045g	0.9175	0.8995	-0.0180
CRSTL_VA_CR	70584	115	70	line_154_BF_045g	0.9114	0.8959	-0.0155
DAKOTA	70141	230	70	line_154_BF_045g	0.9098	0.8996	-0.0102
DANIEL_PK	70601	345	70	line_152_BF_045c	0.8920	0.8769	-0.0151
ELATI1	70163	230	70	line_154_BF_045g	0.9095	0.8993	-0.0102
EMIL_AND	73400	115	73	line_154_BF_045g	0.9106	0.8974	-0.0132
FORESTLK	73476	115	73	line_154_BF_045g	0.9115	0.8985	-0.0130

Bus Name	Bus Number	Base kV	Area	Contingency Name	Benchmark Case Bus Voltage (p.u.)	Study Case Bus Voltage (p.u.)	Voltage Difference (p.u.)
FOWLER	70178	69	70	line_042_BF_019a	0.7992	0.8676	0.0684
FOXRUN	73414	115	73	line_154_BF_045g	0.9116	0.8975	-0.0141
FOXRUN69	72902	69	73	line_154_BF_045g	0.9056	0.8914	-0.0142
GREENLND_CR	70582	115	70	line_154_BF_045g	0.9072	0.8923	-0.0149
GRESHAM	73445	115	73	line_154_BF_045g	0.9123	0.8983	-0.0140
HAPPY_CNYN	70115	115	70	line_154_BF_045g	0.9193	0.8980	-0.0213
LA_SECPA	70243	69	70	line_042_BF_019a	0.8759	0.8924	0.0165
LAJUNTAT	70247	115	70	line_042_BF_019a	0.8787	0.8936	0.0149
LAJUNTAW	70249	115	70	line_042_BF_019a	0.8453	0.8991	0.0538
LEMON_GLCH	70533	230	70	line_154_BF_045g	0.9108	0.8991	-0.0117
MANZANOL	70275	69	70	line_042_BF_019a	0.7991	0.8674	0.0683
MARCY	70278	230	70	line_154_BF_045g	0.9094	0.8973	-0.0121
MONROEPS	70291	230	70	line_154_BF_045g	0.9083	0.8982	-0.0101
ORDWAY	70303	69	70	line_042_BF_019a	0.7954	0.8640	0.0686
PALMER_LK	70308	115	70	line_154_BF_045g	0.9071	0.8923	-0.0148
PALMRDIV	72419	69	73	line_154_BF_045g	0.8974	0.8831	-0.0143
ROCKYFRD	70366	69	70	line_042_BF_019a	0.8088	0.8763	0.0675
S.FOWLR	71027	115	70	line_042_BF_019a	0.8017	0.8699	0.0682
S_FWL_TP	70372	69	70	line_042_BF_019a	0.8017	0.8699	0.0682
SANTA_FE	70527	230	70	line_154_BF_045g	0.9083	0.8972	-0.0111
SODA_LAKES	70018	230	70	P7_154	0.8734	0.8906	0.0172
SULPHUR	70524	230	70	line_154_BF_045g	0.9104	0.8987	-0.0117
WATE_DST	70959	230	70	line_154_BF_045g	0.9099	0.8975	-0.0124
WATERTON	70466	345	70	line_152_BF_045c	0.8934	0.8791	-0.0143

Table 10 – Diverged P7 Contingencies

Diverged Contingency	Contingency Description	Benchmark Case	Study Case
P7_51	Daniels Park - Tundra 345 kV circuits 1 and 2	Diverged	Diverged
P7_129	Daniels Park - Fuller 230 kV circuit 1 Midway - Waterton 345 kV circuit 1	Diverged	Diverged
P7_136	Pawnee - Brick Center 230 kV circuit 1 Smoky Hill - Missile Site 345 kV circuit 1	Converged	Diverged
P7_160	Canal Crossing - Goose Creek 345 kV circuits 1 and 2	Diverged	Diverged
P7_161	Canal Crossing - FSV 345 kV circuits 1 and 2	Converged	Diverged
P7_162	Harvest Mile - Sandstone 345 kV circuits 1 and 2	Diverged	Diverged
P7_163	May Valley - Goose Creek 345 kV circuits 1 and 2	Diverged	Diverged

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.

Please note to resolve an instability observed during the contingency in Ref. No. 3, nearby generation was redispatched until the contingency was stable. This redispatch solution is shown in Table 11.

The results of the contingency analysis are shown in Table 12. The transient stability plots are shown in Appendix A in Section 10.0 of this report.

Table 11 – Generation Dispatch to Resolve the Unstable P1 Contingency

Bus No.	Bus Name	Base kV	ID	Original Pgen (MW)	Modified Pgen (MW)
700115	3RSC_23_3	0.72	W1	105.40	0.00
700118	3RSC_23_3	0.72	W3	102.00	0.00

Table 12 – Transient Stability Analysis Results

Ref. No.	Fault Location	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
1	-	Flat Run	-	Stable	Stable
2	PI-2024-06 POI 345 kV	PI-2024-06 Generation	4	Stable	Stable
3	PI-2024-06 POI - Sandstone 345 kV CKT 1	PI-2024-06 POI - Sandstone 345 kV CKT 1	4	Stable	Stable
4	PI-2024-06 POI - May Valley 345 kV CKT 1	PI-2024-06 POI - May Valley 345 kV	4	Stable	Stable
5	May Valley - Goose Creek 345 kV CKT 1	May Valley - Goose Creek 345 kV CKT 1	4	Stable	Stable
6	May Valley - Sandstone 345 kV CKT 2	May Valley - Sandstone 345 kV CKT 1	4	Stable	Stable
7	Tundra - Sandstone 345 kV CKT 1	Tundra - Sandstone 345 kV CKT 1	4	Stable	Stable
8	Harvest Mile - Sandstone 345 kV CKT 1	Harvest Mile - Sandstone 345 kV CKT 1	4	Stable	Stable
9	May Valley - PI-2024-06 POI 345 kV CKT 1	May Valley - PI-2024-06 POI 345 kV CKT 1 Sandstone - PI-2024-06 POI 345 kV CKT 1 PI-2024-06 Generation	12	Stable	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 13 below, along with the Thevenin impedance at the POI. Both the base case and the case with the GIR added are shown.

Table 13 – Short-Circuit Parameters at PI-2024-06 POI (PI-2024-06 POI 345 kV Switching Station)

	Before the PI Addition	After the PI Addition
Three Phase		
Three Phase Current	7150A	6750A
Positive Sequence Impedance	2.21520 + j27.5415 ohms	2.21520 + j27.5415 ohms
Negative Sequence Impedance	2.23968 + j27.5334 ohms	2.23968 + j27.5334 ohms
Zero Sequence Impedance	11.7839 + j66.8327 ohms	2.20086 + j23.6141 ohms
Phase-to-Ground		
Single Line to Ground Current	4840 A	8300 A
Positive Sequence Impedance	2.21520 + j27.5415 ohms	2.21520 + j27.5415 ohms
Negative Sequence Impedance	2.23968 + j27.5334 ohms	2.23968 + j27.5334 ohms
Zero Sequence Impedance	11.7839 + j66.8327 ohms	2.20086 + j23.6141 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-2024-06.

5.5 Affected Systems

The study did not identify any impacts to Affected Systems.

5.6 Summary of Provisional Interconnection Analysis

The maximum allowable output of the GIR without requiring any additional System Network Upgrades is 400 MW.

During the 0.95 leading power factor test, as shown in Section 5.1, the generating facility POI and high side of the main power transformer each reach 0.94 p.u. voltage. This under voltage will need to be corrected by the generator owner.

6.0 Cost Estimates

The total cost of the required Upgrades for PI-2024-06 to interconnect for Provisional Interconnection Service at the new 345 kV switching station tapping May Valley – Sandstone 345 kV circuit 1 is estimated to be **$32.865 million**.

- **Cost of Transmission Provider's Interconnection Facilities (TPIF) is $3.148 million** (Table 14)
- **Cost of Station Network Upgrades is $29.717 million** (Table 15)
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the Provisional Interconnection of PI-2024-06 are given in Table 14, and Table 15.

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

Table 14 – Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Million)
PSCo's New 5RSC-2024-21 345 kV Switching Station	Interconnection of 5RSC-2024-21 (PI-2024-6) at the new 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 disconnect switch • (3) 345 kV 1-phase CT's for metering • (3) 345 kV CCVTs • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying	$3.098
PSCo's New 5RSC-2024-21 345 kV Switching Station	Transmission line into substation from customer's dead-end structure on gen-tie. Single span, 3 conductors, insulators, hardware and labor.	$0.050
Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities		**$3.148**

Table 15 – Station Network Upgrades

Element	Description	Cost Est. (Million)
PSCo's New 5RSC-2024-21 345 kV Switching Station	Install new PI-2024-6 345 kV Switching Station tapping the May Valley – Sandstone 345 kV line. The new equipment includes: • (3) 345 kV dead-end structures • (3) 345 kV 3000A circuit breakers • (8) 345 kV 3000A disconnect switches • (6) 345 kV CCVTs • (2) 345 kV SSVTs • (6) 345 kV Surge Arresters • (1) Electrical Equipment Enclosure (EEE) • Site grading and fencing • Associated electrical equipment, bus, wiring and grounding • Station controls and wiring • Associated foundations and structures	$24.190
PSCo's New 5RSC-2024-21 345 kV Switching Station	Install required communication in the EEE at the PI-2024-6 345 kV Switching Station	$0.872
PSCo's May Valley 345 kV Switching Station	Remote end upgrade at May Valley 345 kV Substation, removal of wave traps and Line tuners and update to line protection	$0.557
PSCo's Sandstone 345 kV Switching Station	Remote end upgrade at Sandstone 345 kV Substation, removal of wave traps and Line tuners and update to line protection	$0.557
PSCo's circuit 7273	Circuit 7273 - Removal of 1 OPGW and (3) tangent structure arms	$0.039
PSCo's circuit 7411	Circuit 741 - Removal of hardware, insulators, and conductor and adding (2) single-pole dead-end structures for conductor and OPGW into new Colt Creek 345 kV Switching Station	$1.637
PSCo's New circuit	New circuit - Work on the new circuit out of the new Colt Creek 345 kV Switching Station adding (2) single-pole dead-end structures, conductor, and OPGW	$1.615
PSCo's New 5RSC-2024-21 345 kV Switching Station	Siting and Land Rights land acquisition and permitting, no land purchase costs included	$0.250
Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities		**$29.717**

PSCo has developed cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of PI-2024-06 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.
- Land for new switching station can be acquired at fair market value.
- 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 facilitate the fee simple ownership of the property required for the new switching station, approximately 15 acres, to interconnect the Colt Creek solar development.
- Customer will install two (2) redundant fiber optic circuits (one primary circuit with a redundant backup) 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-2024-06 to the Transmission Provider's Transmission System. The customer did not provide a back-feed date (In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection) for the Provisional Interconnection Service, therefore it was estimated at March 1, 2027, three months prior to the requested Commercial Operation

Date of June 1, 2027. 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 16.

Table 16 – Proposed Milestones for PI-2024-06

Milestone	Responsible Party	Estimated Completion Date
PLGIA Execution	Interconnection Customer and Transmission Provider	October 2024
In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection	Transmission Provider	February 28, 2028
In-Service Date & Energization of Interconnection Customer's Interconnection Facilities	Interconnection Customer	February 28, 2028
Initial Synchronization Date	Interconnection Customer	April 3, 2028
Begin trial operation & testing	Interconnection Customer and Transmission Provider	April 3, 2028
Commercial Operation Date	Interconnection Customer	May 31, 2028

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 24 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.
- A Certificate of Public Convenience and Necessity (CPCN) may be required for the construction of the Interconnection Facilities and Station Network Upgrades. The expected time to obtain a CPCN approval is 18 months, which could impact the start of construction for the interconnection facilities.

7.0 Summary of Provisional Interconnection Service Analysis

The total estimated cost of the PSCo transmission system improvements required for PI-2024-06 to qualify for Provisional Interconnection Service would be $32.865 million.

The initial maximum permissible output of PI-2024-06 Generating Facility is 400 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-2024-21 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-2024-21 Large Generation Interconnection Procedure (LGIP) in the 5RSC cluster is $5 million.

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

8.0 Contingent Facilities

The Contingent Facilities identified for PI-2024-06 include the TPIF and Station Network Upgrades identified in Table 14 and Table 15, respectively.

9.0 Preliminary One-Line Diagram and General Arrangement for PI-2024-06

Figure 2: Preliminary One-Line for PI-2024-06 Tapping May Valley – Sandstone 345 kV Circuit

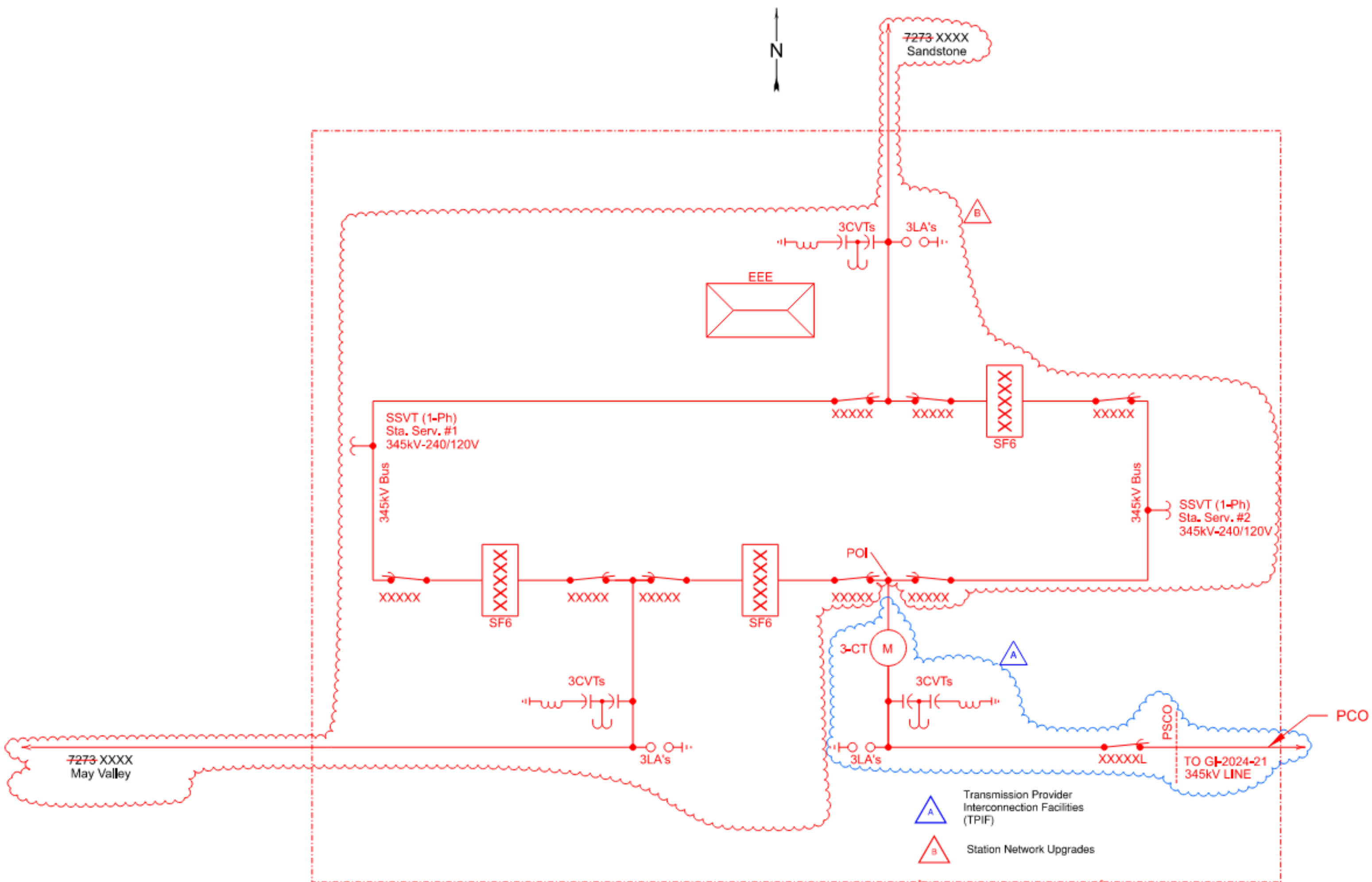

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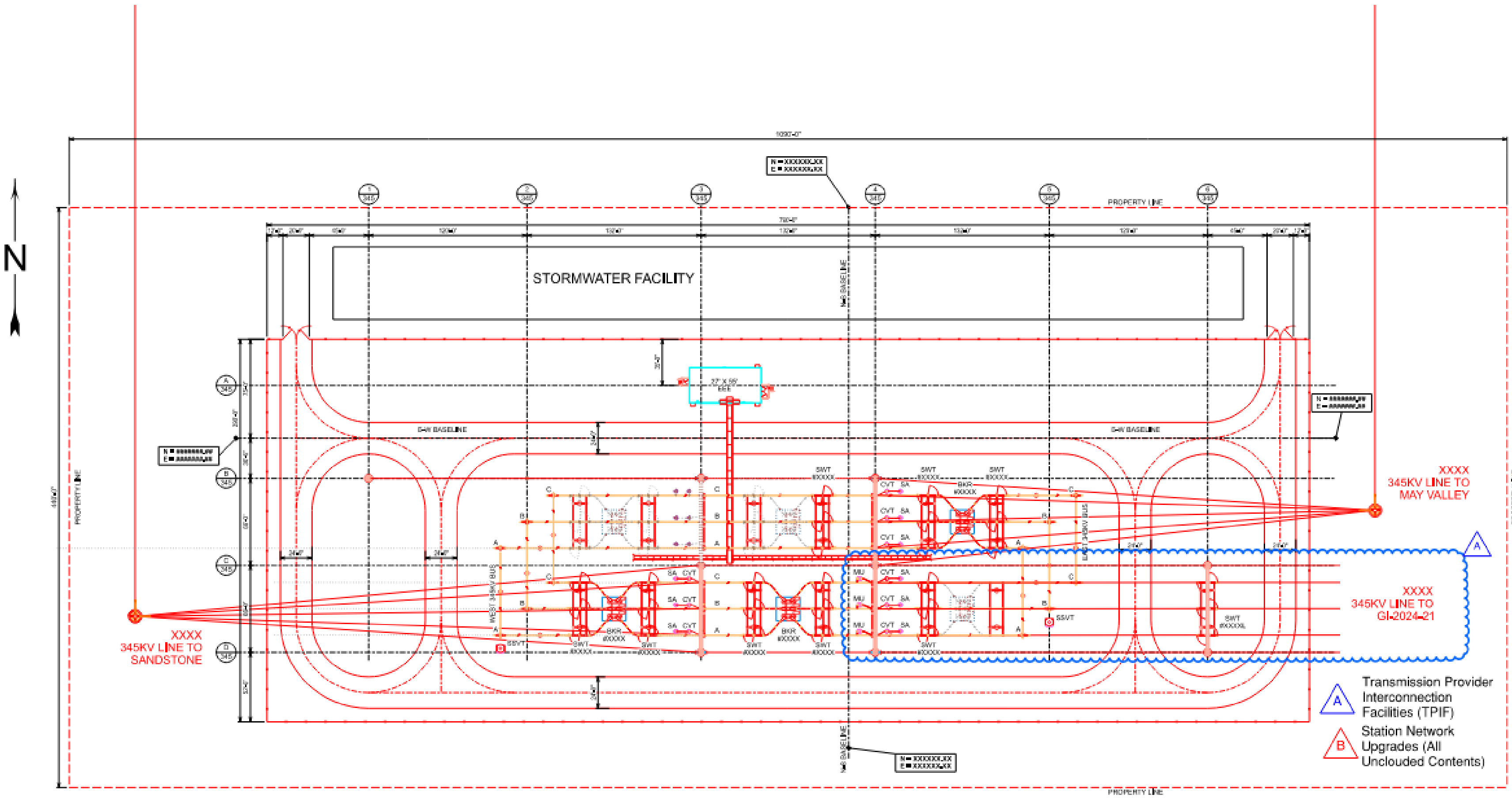
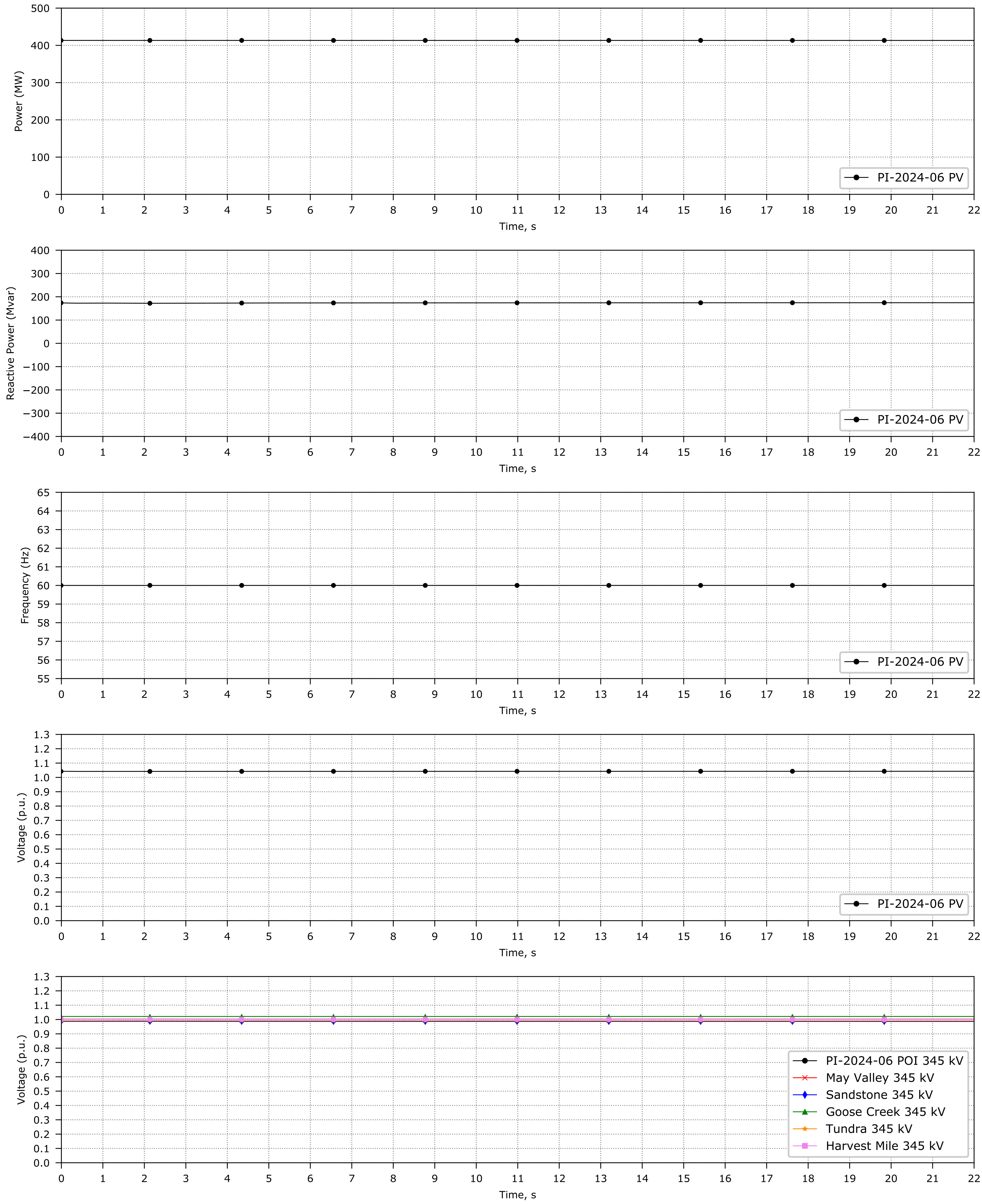
Figure 3: Preliminary General Arrangement for PI-2024-04 Tapping May Valley – (Sandstone) – Tundra 345 kV



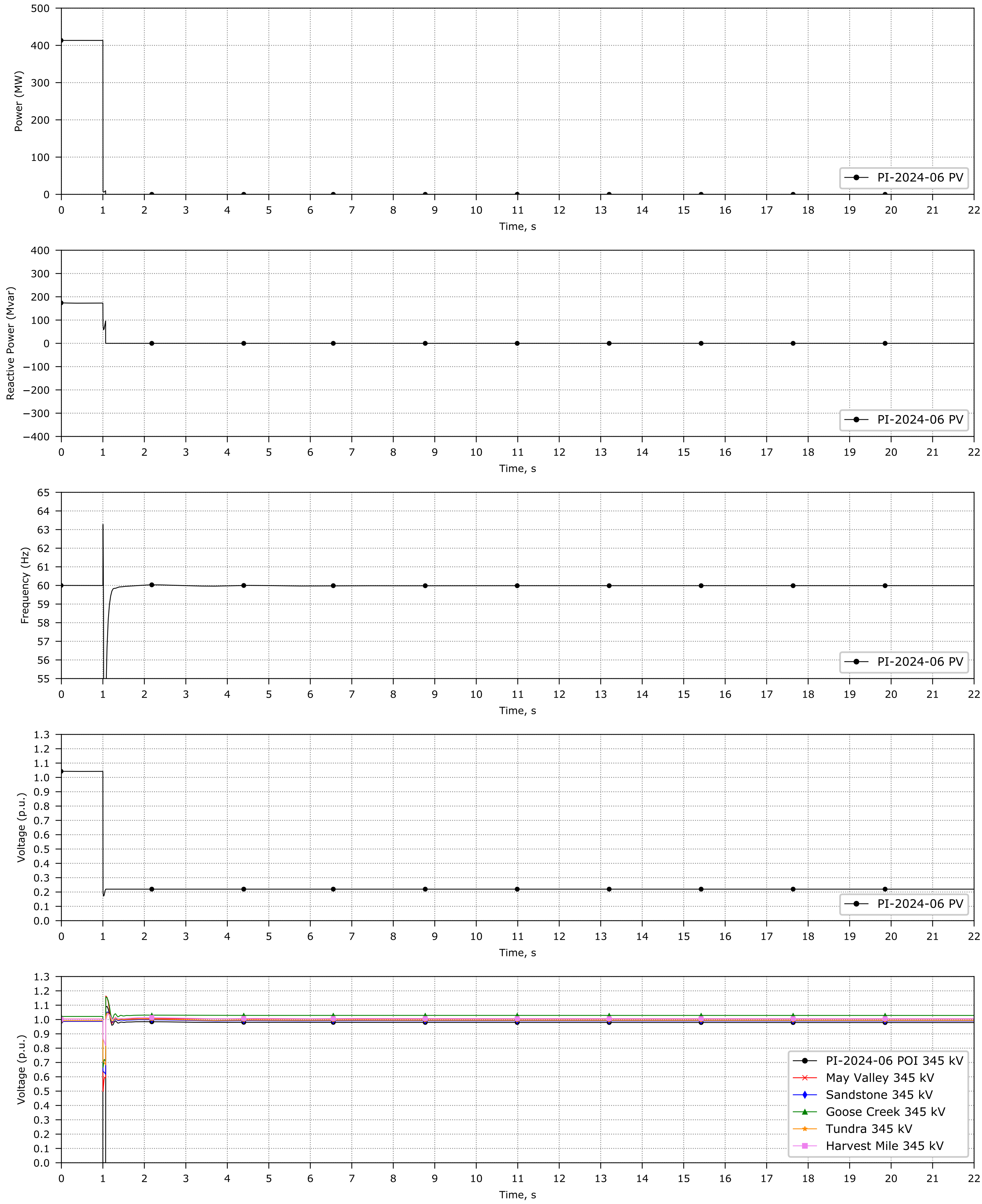
10.0 Appendices

Appendix A: Transient Stability Plots	PDF PI-2024-06_Transient Stability Analysis.pdf

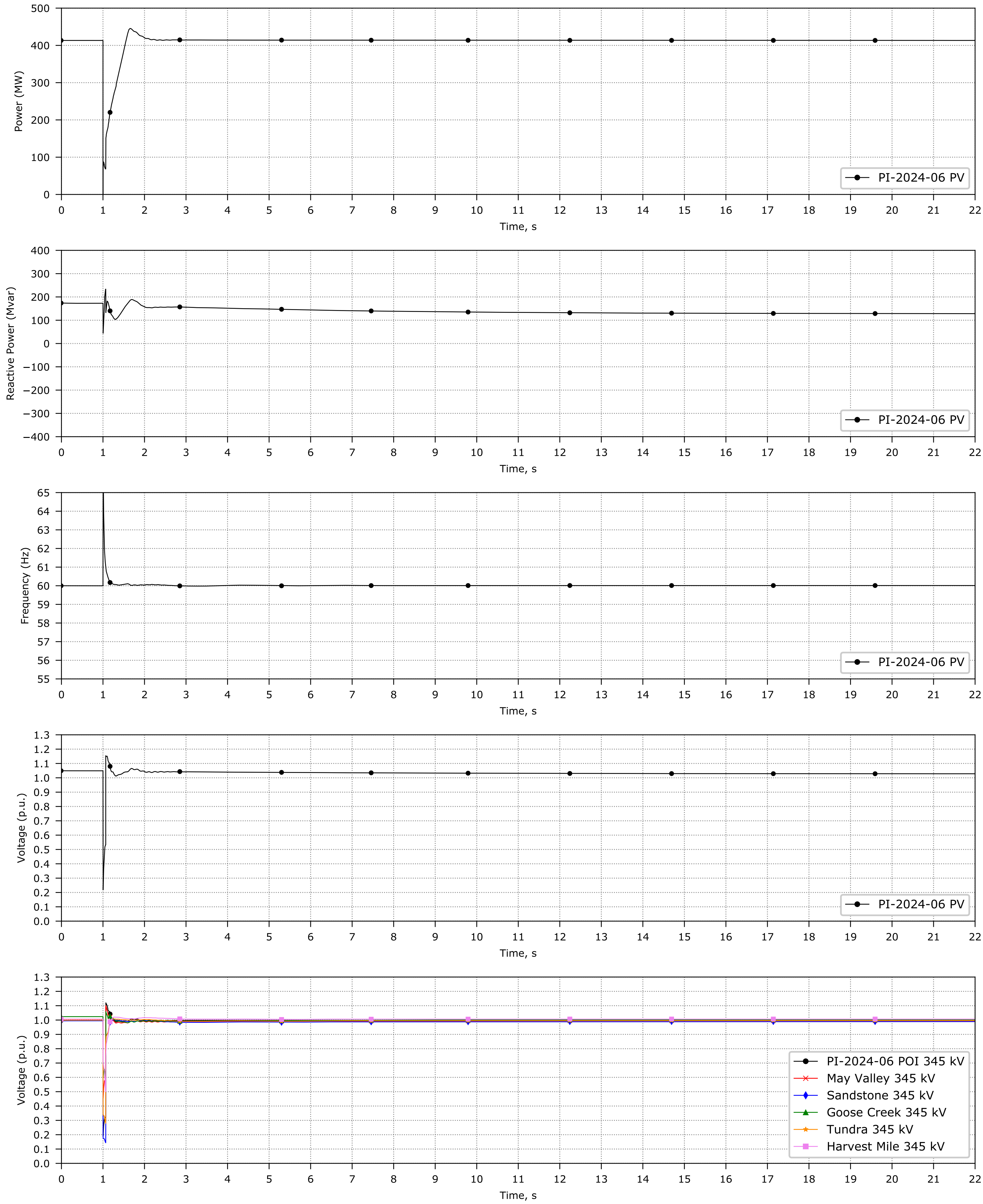
PI-2024-06_Study_South_flatrun



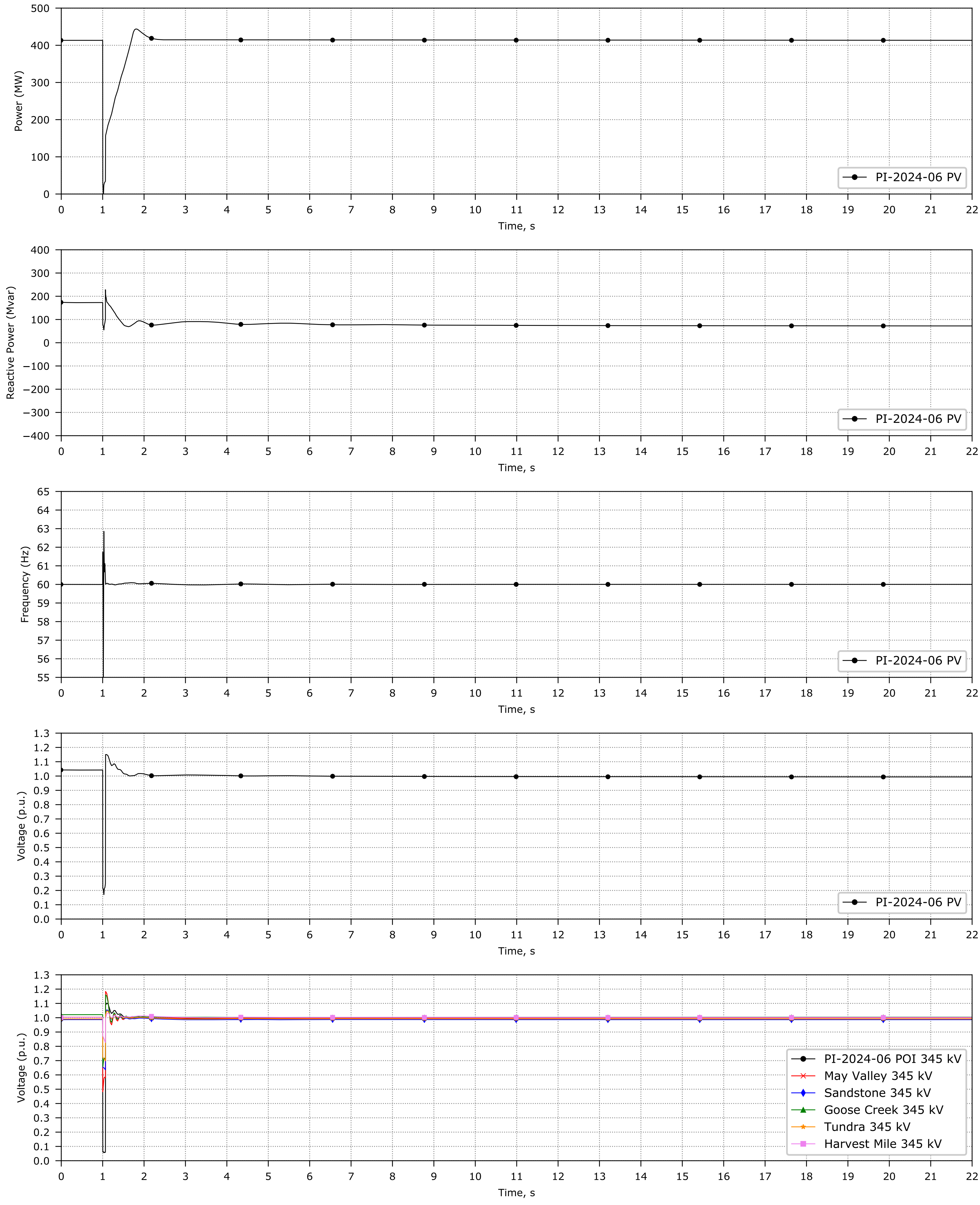
PI-2024-06_Study_South_PI-2024-06_Gen



PI-2024-06_Study_South_PI-06_POI-Sandstone



PI-2024-06_Study_South_PI-06_POI-MayValley



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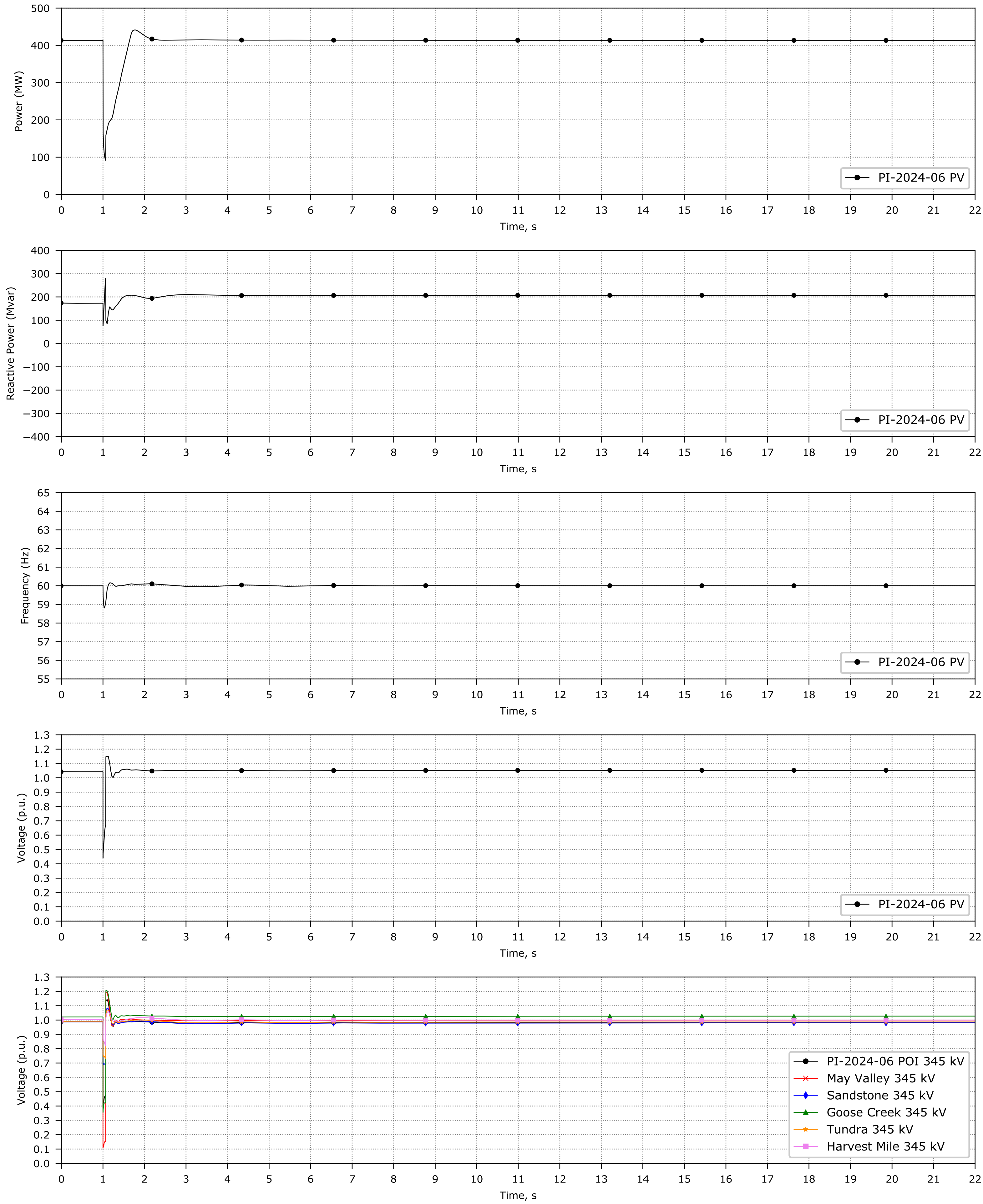

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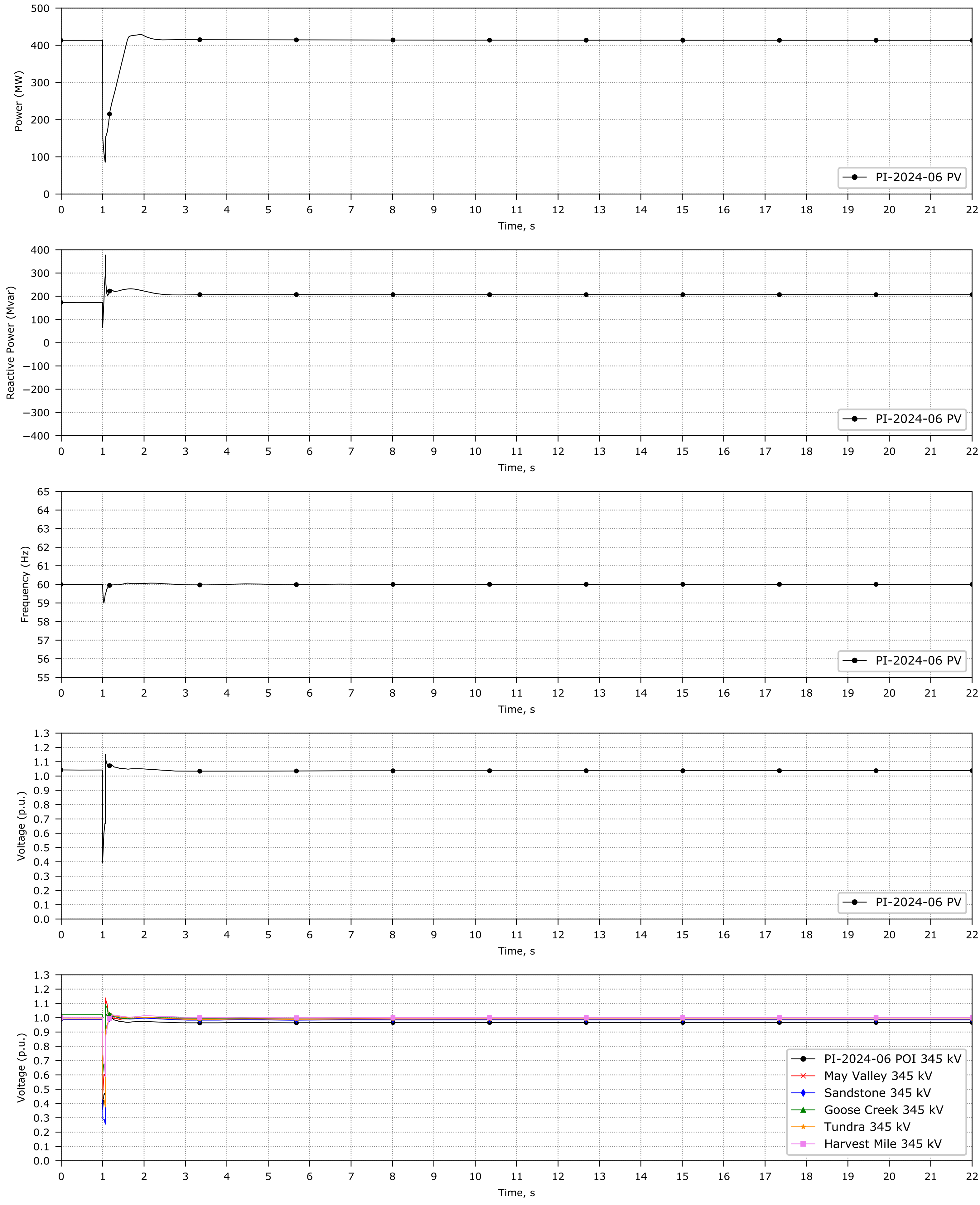
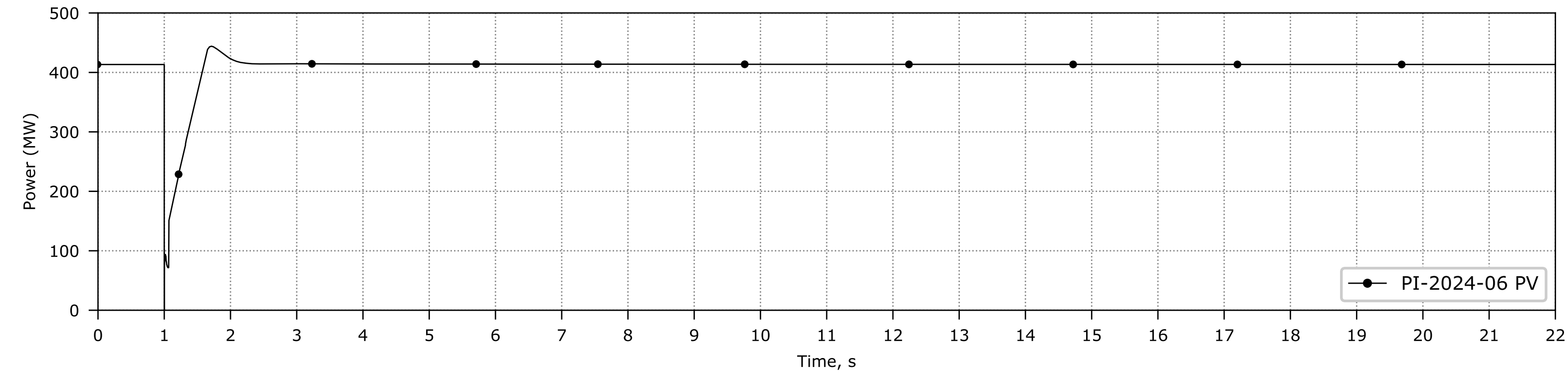
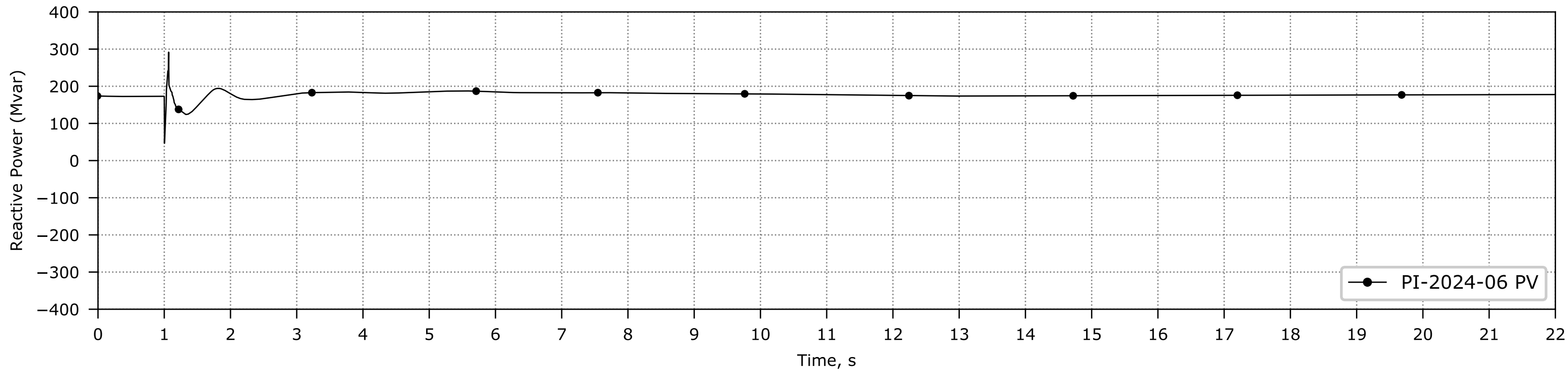
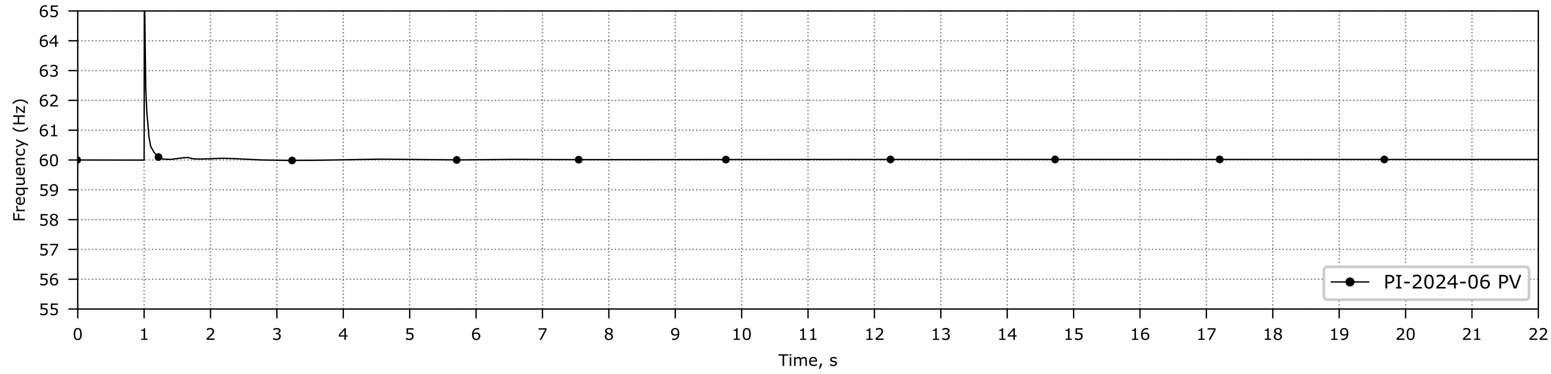
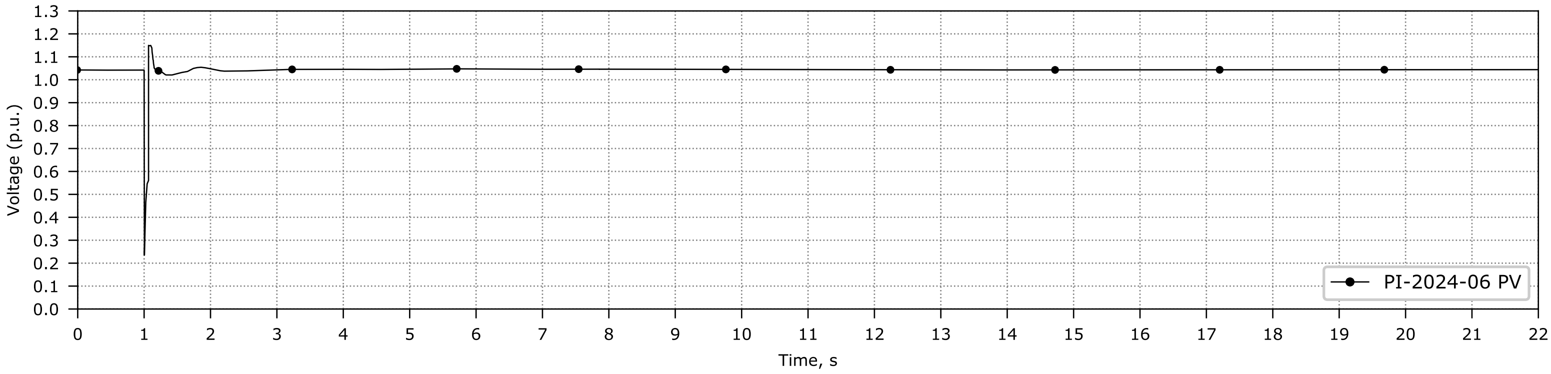


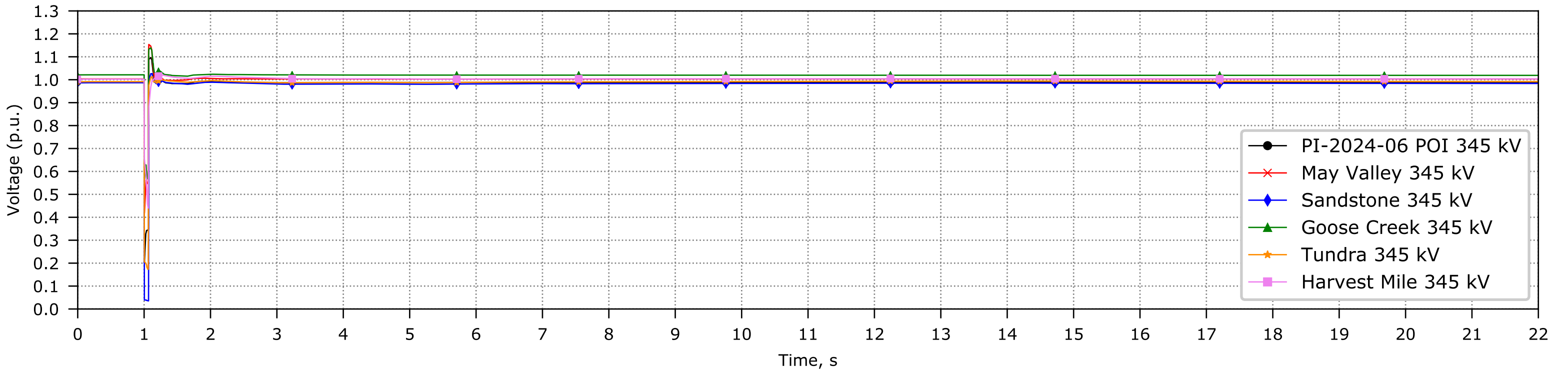
PI-2024-06_Study_South_Sandstone-Tundra



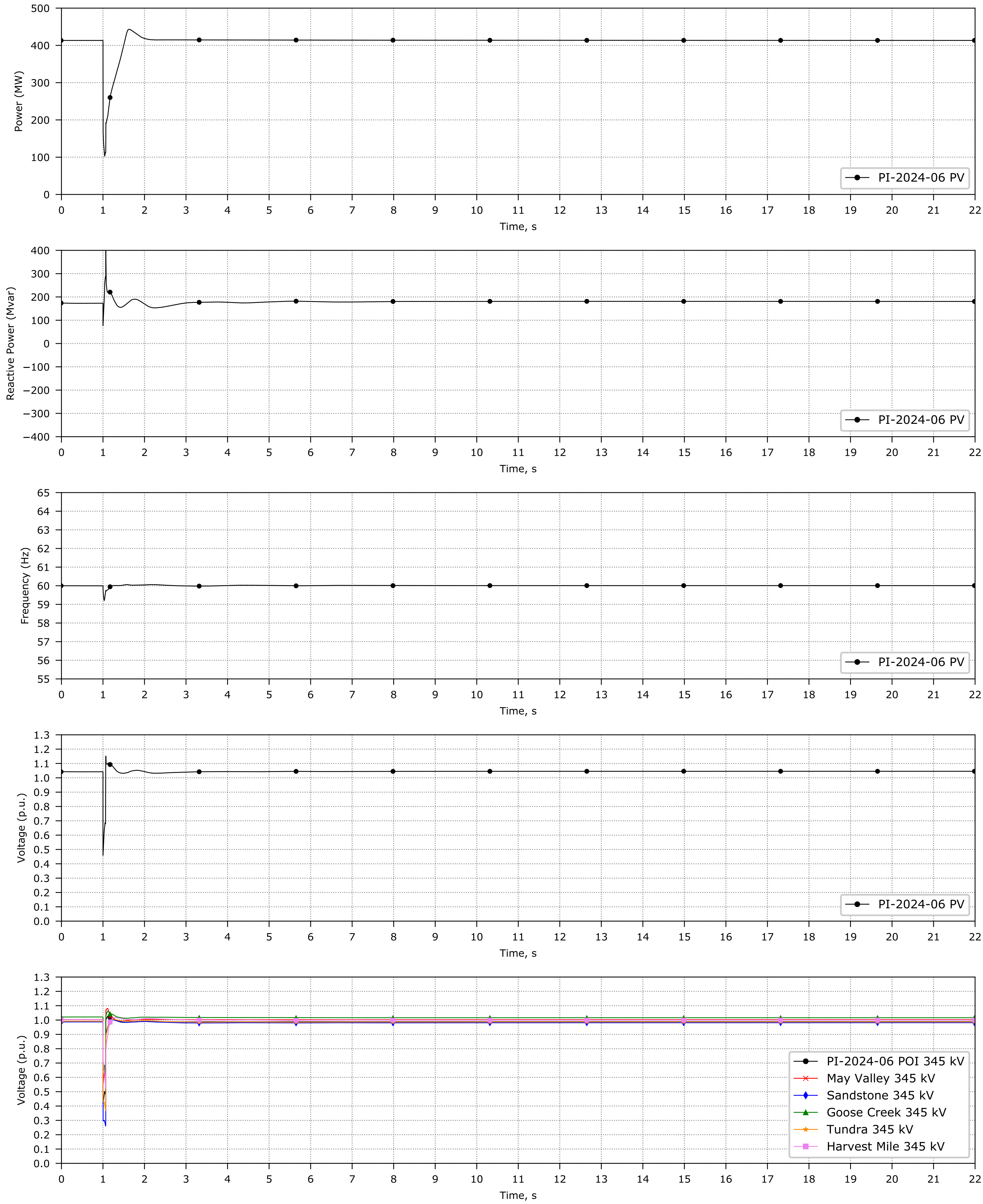








PI-2024-06_Study_South_Sandstone-HMIL



PI-2024-06_Study_South_PI-06_P4