Provisional Interconnection Study Report
for PI-2024-07

10/4/2024

Xcel Energy®

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1.0 Executive Summary

The PI-2024-07 project is a Provisional Interconnection request for a 200 MW Battery Energy Storage System (BESS) with a Point of Interconnection (POI) at the Comanche 345 kV substation. PI-2024-07 is the Provisional Interconnection associated with Generation Interconnection Request 5RSC-2024-12 in the 5RSC cluster.

The total estimated cost of the transmission system improvements required for PI-2024-07 to qualify for Provisional Interconnection Service is $6.710 million (Table 16 and Table 17).

The initial maximum permissible output of PI-2024-07 Generating Facility is 200 MW in discharging mode and 200 MW in grid charging mode. The maximum permissible output of the Generating Facility in the PLGIA[1] will 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-2024-12 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-2024-12 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.

The 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-2024-07 is the Provisional Interconnection Service[3] request for a 200 MW Battery Energy Storage System (BESS) located in Pueblo County, Colorado.

- The POI of this project is the Comanche 345 kV substation.
- The Commercial Operation Date (COD) to be studied for PI-2024-07 as noted on the Provisional Interconnection Service request for is May 1, 2027.

The geographical location of the transmission system near the POI is shown in Figure 1.

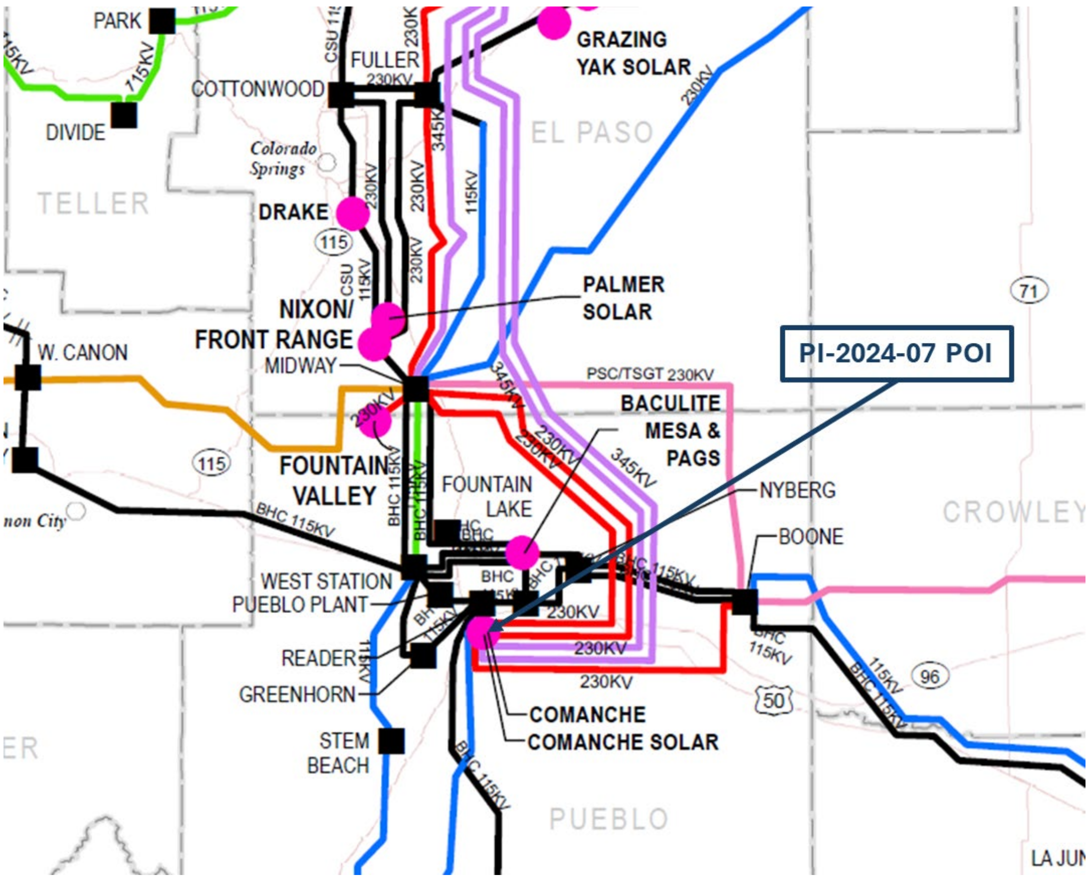

Figure 1: Point of Interconnection of PI-2024-07

[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.

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-2024-07 for Provisional Interconnection Service. Consistent with the assumption in the study agreement, PI-2024-07 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

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[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	Fault Category	Outage(s)	Clearing Time (Cycles)
1	-	P0	Flat run	-
2	Comanche 345 kV	P1	Comanche – Tundra 345 kV ckt 1	4
3	Comanche 345 kV	P1	Comanche ‘C3’ generation	4
4	Comanche 345 kV	P1	Comanche 345/230 kV transformer ‘T3’	4
5	Comanche 345 kV	P1	PI-2024-07 ‘B’ generation	4
6	Tundra 345 kV	P1	Loss of Neptune ‘S1’ and ‘B1’ generation	4
7	Tundra 345 kV	P1	Tundra – Daniels Park 345 kV ckt 1	4
8	Tundra 345 kV	P1	Tundra – Sandstone 345 kV ckt 1	4
9	Comanche 230 kV	P1	Comanche – Bighorn 230 kV ckt 1 Bighorn ‘S1’ generation	5
10	Comanche 230 kV	P1	Comanche – Huckleberry 230 kV ckt 1 Huckleberry – Walsenberg 230 kV ckt 1 Walsenberg – Valent 230 kV ckt 1	5
11	Comanche 230 kV	P1	Comanche – Boone 230 kV ckt 1	5
12	Comanche 345 kV	P4	Comanche – Tundra 345 kV ckt 1 Comanche 345/230 kV transformer ‘T3’	12
13	Comanche 230 kV	P4	Comanche – CF&I Furnace 230 kV ckt 1 Comanche – GI 2020 10 230 kV ckt 1 CF&I Furnace load ‘IN’	17
14	Comanche 230 kV	P4	Comanche – Boone 230 kV ckt 1 Comanche – Huckleberrry 230 kV ckt 1	17

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, Midway - Waterton (345 kV), and Midway - Fuller - Daniels Park (230 kV). Below is the current generation in the southern Colorado study area:

- Comanche area: Comanche Solar, Sun Mountain Solar, Bighorn Solar, Rocky Mountain Solar, Comanche Units 2 & 3 (coal), Golden West Wind at Fuller, Fountain Valley Gas at Midway, Comanche Coal, Community Solar at Comanche, Mirasol, Tundra.
- Lamar area: Colorado Green Wind, Twin Buttes Wind, DC Tie.

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.

- 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.

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 Network Resource Interconnection Service (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 was modeled, as shown in Table 3.

Table 2 – Generation Dispatch Used 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
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 Grid Charging Benchmark Case Modeling

The Grid Charging Benchmark Case was created from Base Case described in Section 4.0 by changing the study pocket generation dispatch to reflect a Grid Charging scenario as outlined in Section 3.16 of the BPM. This was accomplished by adopting the stressed generation dispatch given in Table 4.

Table 4 – Generation Dispatch Used to Create the Southern Colorado Grid Charging 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	0.00	120.00

Ref. No.	Generator Bus No.	Bus Name	Base kV	ID	Status	Pgen (MW)	Max Power (MW)
10	70017	SI_GEN 0	0.60	1	1	0.00	30.10
11	70878	BIGHORN_S	0.63	S1	1	0.00	247.50
12	70756	NEPTUNE_B1	0.48	B1	1	-112.86	125.00
13	70758	NEPTUNE_S1	0.66	S1	1	0.00	250.50
14	70761	THNDWLF_B1	0.48	B1	1	-50.00	100.00
15	70763	THNDWLF_S1	0.66	S1	1	0.00	200.00
16	70859	SUN_MTN_S1	0.66	S1	1	0.00	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	17.01	81.00
20	70708	CO_GRN_E	0.58	W1	1	17.01	81.00
21	70704	TBI_GEN	0.58	W1	1	15.75	75.00
22	70663	GLDNWST_W1	0.69	W1	1	52.37	249.40
23	70010	TBII_GEN	0.69	W	1	16.38	78.00
24	700119	REPL_21_1	0.66	S1	1	0.00	121.20
25	700120	REPL_21_1	0.66	S2	1	0.00	121.20
26	700121	REPL_21_1	0.66	S3	1	0.00	121.20
27	70725	SPANPKS2_GEN	0.60	PV	1	0.00	40.20
28	70994	SP_GEN	0.62	PV	1	0.00	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)						**2264.96**	**4677.50**

4.3 Study Case Modeling

A Study Case was created from the Benchmark Case by turning on the PI-2024-07 BESS Generating Facility. The additional 200 MW output from PI-2024-07 was balanced against PSCo generation outside of the Southern Colorado study pocket.

A Grid Charging Study Case was created from the Grid Charging Benchmark Case by adding the PI-2024-07 BESS Generating Facility modeled as a load.

4.4 Short-Circuit Modeling

This request is for the Interconnection of a 200 MW BESS Generating Facility (PI-2024-07) to the Comanche 345 kV substation. The output will not exceed 200 MW at the POI.

This project assumes the use of 45 SUNGROW SC5000UD-MV-US inverters rated at 5.0 MVA operating at +/- 0.93 pf. Each of the 5 MVA inverters is connected to a collector transformer, 0.9/34.5 kV, rated at 5 MVA. A single 345/34.5/13.8 kV main GSU transformer rated at 132/176/220 MVA steps the voltage up from the collector transformer voltage to the POI voltage. Single 1.3-mile generation tie line connects the project to the Comanche 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 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

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 230 kV system, 1-1.05 for the 345 kV system and 1-1.03 for 115 kV 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. range are highlighted in yellow to provide additional information.

The PI-2024-07 GIR is modeled as follows:

Generator gross capacity: Pmax = 209.25 MW, Pmin = -209.25 MW, Qmax = 82.70 MVar, Qmin= -82.70 MVar

The summary for the Voltage and Reactive Power Capability Evaluation for PI-2024-07 is:

- The GIR is capable of meeting 0.95 lagging pf at the POI at either operating point. However, the POI voltage exceeds the limit of 1.05 p.u. during lagging pf test.
- The GIR is capable of meeting 0.95 leading pf at the POI at either operating point. However, the POI voltage is less than the limit of 0.95 p.u. during leading pf test.

The Voltage and Reactive Power Capability tests performed for PI-2024-07 are summarized in Table 5.

Table 5 – Reactive Capability Evaluation for PI-2024-07

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
207.3	70.2	82.7	-82.7	1.08	200.2	65.8	0.98	0.9500	200.1	66.7	0.98	0.9487
207.5	-14.3	82.7	-82.7	0.94	200.2	-65.9	0.98	-0.9500	200.1	-65.0	0.98	-0.9511
0.0	-27.1	82.7	-82.7	0.95	-5.0	-28.2	0.98	-0.1746	-5.0	-27.2	0.98	-0.1808

5.2 Steady State Analysis

Contingency analysis was performed on the South study pocket using the Study Case model. Both Discharging and Grid Charging scenarios are summarized below.

The power flow analysis of the Discharging scenario showed that four contingencies of the category P1 were divergent in the Study Case. The contingencies are described in Table 6. 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 the units was balanced against PSCo generation outside of the South study pocket. The following single and multiple contingency analyses for the Discharging scenario are conducted with the dispatch presented in Table 7.

Table 6 – Diverged P1 Contingencies for Discharging Scenario

Diverged Contingency	Contingency Description	Case
Line_077_SGL_115_085	P1: Loss of Cherokee generation	Study
GseCrk-Shortgrass-1_P1-2_4	P1: Goose Creek – Shortgrass 345 kV circuit 1	Study
DanielsPark-Tundra-1_P1-2_14	P1: Daniels Park – Tundra 345 kV circuit 2	Study
DanielsPark-Tundra-2_P1-2_14	P1: Daniels Park – Tundra 345 kV circuit 2	Study

Table 7 – Generation Dispatch to Resolve the Diverged P1 Contingency

Generator Bus Number	Generator Name	ID	Initial Pgen (MW)	Modified Pgen (MW)
70777	COMAN_3	C3	804.90	704.90

The results for the Grid Charging scenario are summarized below:

- System Intact analysis:

  Thermal results: No thermal overload violations attributed to PI-2024-07 were identified.

  Voltage results: No voltage violations attributed to PI-2024-07 were identified.

- Single Contingency analysis:

  Thermal results: No thermal overload violations attributed to PI-2024-07 were identified.

  Voltage results: No voltage violations attributed to PI-2024-07 were identified.

- Multiple Contingency analysis:

  Thermal results: No thermal overload violations attributed to PI-2024-07 were identified.

  Voltage results: No voltage violations attributed to PI-2024-07 were identified. Note two P7 contingencies were divergent as shown in Table 8. Contingency P7_160 was divergent in the Benchmark case, while contingency P7_167 was divergent in both Benchmark and Study cases. Therefore, the divergence, in both instances, is not attributable to the study GIR. Per TPL-001-5, multiple contingency overloads are mitigated using system adjustments, including generation re-dispatch (includes GIRs under study) and/or operator actions. None of the multiple contingency overloads are attributed to the study GIRs.

The results for the Discharging scenario are summarized below.

- System Intact analysis:

  Thermal results: Table 9 lists overloads attributed to PI-2024-07 for system intact conditions. All identified violations in Table 9 were alleviated through generation redispatch.

  Voltage results: Table 10 lists voltage violations attributed to PI-2024-07 for system intact conditions. All identified violations in Table 10 were alleviated through generation redispatch.

- Single Contingency analysis:

  Thermal results: Table 11 lists overloads attributed to PI-2024-07 for contingency conditions. All identified violations in Table 11 were alleviated through generation redispatch. The maximum allowable output of this project, without requiring system network upgrades, is 200 MW.

  Voltage results: No voltage violations attributed to PI-2024-07 were identified.

- Multiple Contingency analysis:

Thermal results: No thermal overload violations attributed to PI-2024-07 were identified. Note eight P7 contingencies were divergent as shown in Table 12. Contingencies P7_129, P7_136, and P7_161 were divergent only in the Benchmark case. Contingencies P7_51, P7_160, P7_162, P7_163 and P7_167 were divergent in both Benchmark and Study cases. Therefore, the divergence, in all instances, is not attributable to the study GIR. Per TPL-001-5, multiple contingency overloads are mitigated using system adjustments, including generation re-dispatch (includes GIRs under study) and/or operator actions. None of the multiple contingency overloads are attributed to the study GIRs.

Voltage results: Table 13 lists voltage violations attributed to PI-2024-07 for multiple contingency conditions. Per TPL-001-5, multiple contingency voltage violations are mitigated using system adjustments, including generation re-dispatch (includes GIRs under study) and/or operator actions. None of the multiple contingency voltage violations are attributed to the study GIRs.

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Table 8 – Diverged P7 Contingencies for Grid Charging Scenario

Diverged Contingency	Contingency Description	BM Case	Study Case
P7_160	Canal Crossing – Goose Creek 345 kV circuit 1 Canal Crossing – Goose Creek 345 kV circuit 2	Diverged	Converged
P7_167	May Valley – Sandstone 345 kV circuit 1 May Valley – Sandstone 345 kV circuit 2	Diverged	Diverged

Table 9 – South Pocket - System Intact Thermal Overloads for Discharging Scenario

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Normal Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	FOXRUN (73414) – FLYHORSE N2 (73738) 115 kV ckt 1	System Intact	115	73	CSU	142.00	132.15	134.25	2.10
2	FLYHORSE S (73576) – KETTLENECK N (73711) 115 kV ckt 1	System Intact	115	73	CSU	162.00	128.53	130.37	1.84
3	CTTNWD N (73391) – KETTLENECK S (73410) 115 kV ckt 1	System Intact	115	73	CSU	162.00	120.64	121.87	1.23

Table 10 – South Pocket - System Intact Voltage Violations for Discharging Scenario

Bus #	Bus Name	Base kV	Area	Zone	Zone Name	Contingency Name	Min Volt Limit (p.u.)	Max Volt Limit (p.u.)	Benchmark Case Contingency Voltage (p.u.)	Study Case Contingency Voltage (p.u.)	Voltage Difference (p.u.)
70291	MONROEPS	230	70	700	ZoneRD	System Intact	0.95	1.05	0.9450	0.9281	-0.0169
70524	SULPHUR	230	70	700	ZoneRD	System Intact	0.95	1.05	0.9499	1.0537	0.1038
70239	JEWELL2	230	70	700	ZoneRD	System Intact	0.95	1.05	0.9500	1.0537	0.1037

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Table 11 – South Pocket - Single Contingency Thermal Overloads for Discharging Scenario

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	FOXRUN (73414) – FLYHORSE N2 (73738) 115 kV CKT 1	Daniels Park – Jackson Fuller #5119	115	73	CSU	142	175.96	178.79	2.83
2	FLYHORSE S (73576) – KETTLENECK N (73711) 115 kV CKT 1	Daniels Park – Jackson Fuller #5119	115	73	CSU	162	166.70	169.20	2.50
3	CTTNWD N (73391) – KETTLENECK S (73410) 115 kV CKT 1	Daniels Park – Jackson Fuller #5119	115	73	CSU	162	143.31	144.89	1.58
4	PALMER LK (70308) – FOXRUN (73414) 115 kV CKT 1	Daniels Park – Jackson Fuller #5119	115	70/73	PSCo/ WAPA	156	140.93	143.42	2.49
5	DANIEL PK 230/345 kV (70139/70601) Transformer T5	Daniels Park 230/345 kV T3	230/ 345	70	PSCo	560	128.26	130.01	1.75
6	DANIEL PK 230/345 kV (70139/70601) Transformer T4	Daniels Park 230/345 kV T3	230/ 345	70	PSCo	560	128.26	130.01	1.75
7	GREENWOOD 1 (70212) – TECH CENTER (70428) 230 kV CKT 2	Greenwood – Monaco – Sullivan #5717	230	70	PSCo	405	122.97	124.61	1.64
8	DANIEL PK (70139) – FULLER (73477) 230 kV CKT 1	Daniels Park – Tundra 345 kV ckt 2	230	70/73	PSCo/ WAPA	478	106.98	109.03	2.05
9	TUNDRA (70653) – COMANCHE (70654) 345 kV CKT 2	Comanche – Tundra 345 kV ckt 1	345	70	PSCo	1195	102.88	108.25	5.37
10	TUNDRA (70653) – COMANCHE (70654) 345 kV CKT 1	Comanche – Tundra 345 kV ckt 2	345	70	PSCo	1195	102.88	108.25	5.37
11	MONACO 12 (70481) – SULLIVAN 2 (70365) 230 kV CKT 1	Sullivan – Greenwood #5705	230	70	PSCo	445	103.27	104.92	1.65

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Rate Cont (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
12	DANIEL PK 230/345 kV (70139/70601) transformer T3	Daniels Park – Tundra 345 kV ckt 2	230	70	PSCo	505	102.82	104.47	1.65
13	DANIEL PK (70139) – PRAIRIE 1 (70331) 230 kV CKT 1	Smoky Hill – Missile Site #7081	230/ 345	70	PSCo	560	101.19	102.66	1.47
14	GREENWOOD 2 (70189) – MONACO 12 (70481) 230 kV CKT 1	Daniels Park – Prairie – Greenwood #5707	230	70	PSCo	956	99.84	101.64	1.80
15	DANIEL PK (70139) – PRAIRIE 3 (70323) 230 kV CKT 2	Sullivan – Greenwood #5705	230	70	PSCo	503	99.15	100.55	1.40
16	DANIEL PK 230/345 kV (70139/70601) transformer T3	Daniels Park – Prairie - Greenwood #5111	230	70	PSCo	956	98.68	100.49	1.81

Table 12 – Diverged P7 Contingencies for Discharging Scenario

Diverged Contingency	Contingency Description	BM Case	Study Case
P7_51	Daniels Park – Comanche 345 kV circuit 2 Daniels Park – Tundra 345 kV circuit 1 Daniels Park – Tundra 345 kV circuit 2	Diverged	Diverged
P7_129	Daniels Park – Fuller 230 kV circuit 1 Midway PS – Waterton 345 kV circuit 1	Diverged	Converged
P7_136	Pawnee – BricCTR 230 kV circuit 1 Smoky Hill – Missile Site 345 kV circuit 1	Diverged	Converged
P7_160	Canal Crossing – Goose Creek 345 kV circuit 1 Canal Crossing – Goose Creek 345 kV circuit 2	Diverged	Diverged
P7_161	Canal Crossing – Ft. St. Vrain 345 kV circuit 1 Canal Crossing – Ft. St. Vrain 345 kV circuit 2	Diverged	Converged

Diverged Contingency	Contingency Description	BM Case	Study Case
P7_162	Harvest Mile – Sandstone 345 kV circuit 1 Harvest Mile – Sandstone 345 kV circuit 2	Diverged	Diverged
P7_163	May Valley – Goose Creek 345 kV circuit 1 May Valley – Goose Creek 345 kV circuit 2	Diverged	Diverged
P7_167	May Valley – Sandstone 345 kV circuit 1 May Valley – Sandstone 345 kV circuit 2	Diverged	Diverged

Table 13 – South Pocket - Multiple Contingency Voltage Violations for Discharging Scenario

Bus #	Bus Name	Base kV	Area	Zone	Zone Name	Contingency Name	Min Volt Limit (p.u.)	Max Volt Limit (p.u.)	Benchmark Case Contingency Voltage (p.u.)	Study Case Contingency Voltage (p.u.)	Voltage Difference (p.u.)
70423	BOULDER CN1	115	70	703	ZoneRB	P7_90 (Lines 5307, 5385, 5953)	0.90	1.10	0.9106	0.8983	-0.0123
70440	VALMONT 2	115	70	703	ZoneRB	P7_90 (Lines 5307, 5385, 5953)	0.90	1.10	0.9119	0.8991	-0.0128
70444	VALMONT 1	115	70	703	ZoneRB	P7_90 (Lines 5307, 5385, 5953)	0.90	1.10	0.9120	0.8991	-0.0129
70295	NCAR	115	70	703	ZoneRB	P7_90 (Lines 5307, 5385, 5953)	0.90	1.10	0.9181	0.8991	-0.0190
70170	NREL	115	70	703	ZoneRB	P7_90 (Lines 5307, 5385, 5953)	0.90	1.10	0.9263	0.8992	-0.0271
70164	ELDORADO	115	70	703	ZoneRB	P7_90 (Lines 5307, 5385, 5953)	0.90	1.10	0.9275	0.8999	-0.0276

5.3 Transient Stability Results

The following results were obtained for all disturbances analysed except for the P4 contingencies shown in Ref. Nos. 13 and 14 in Table 14:

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

A total of ten P1s and three P4s were simulated. The results of the contingency analysis for both Discharging and Grid Charging scenarios are shown in Table 14. The transient stability plots for Discharging scenario are shown in Appendix A. The transient stability plots for Grid Charging scenario are shown in Appendix B. Both appendices are in Section 10.0 of this report.

Contingencies Ref. Nos. 13 and 14 shown in Table 14 resulted in unstable/unsatisfactory results in both Benchmark cases. Therefore, the unstable results are not attributable to the Study GIR.

The response observed during the contingencies of category P4 shown in Ref. Nos. 13 and 14 in Table 14 may require either a Remedial Action Scheme (RAS) or Corrective Action Plan (CAP). Mitigation has not been determined at this time.

Table 14 – Transient Stability Analysis Results

Ref. No.	Fault Location	Fault Category	Outage(s)	Clearing Time (Cycles)	Discharging		Grid Charging	
					Post-Fault Voltage Recovery	Angular Stability	Post-Fault Voltage Recovery	Angular Stability
1	-	P0	Flat run	-	Stable	Stable	Stable	Stable
2	Comanche 345 kV	P1	Comanche – Tundra 345 kV ckt 1	4	Stable	Stable	Stable	Stable
3	Comanche 345 kV	P1	Comanche ‘C3’ generation	4	Stable	Stable	Stable	Stable
4	Comanche 345 kV	P1	Comanche 345/230 kV transformer ‘T3’	4	Stable	Stable	Stable	Stable
5	Comanche 345 kV	P1	PI-2024-07 ‘B’ generation	4	Stable	Stable	Stable	Stable
6	Tundra 345 kV	P1	Loss of Neptune ‘S1’ and ‘B1’ generation	4	Stable	Stable	Stable	Stable
7	Tundra 345 kV	P1	Tundra – Daniels Park 345 kV ckt 1	4	Stable	Stable	Stable	Stable
8	Tundra 345 kV	P1	Tundra – Sandstone 345 kV ckt 1	4	Stable	Stable	Stable	Stable
9	Comanche 230 kV	P1	Comanche – Bighorn 230 kV ckt 1 Bighorn ‘S1’ generation	5	Stable	Stable	Stable	Stable
10	Comanche 230 kV	P1	Comanche – Huckleberry 230 kV ckt 1 Huckleberry – Walsenberg 230 kV ckt 1 Walsenberg – Valent 230 kV ckt 1	5	Stable	Stable	Stable	Stable
11	Comanche 230 kV	P1	Comanche – Boone 230 kV ckt 1	5	Stable	Stable	Stable	Stable
12	Comanche 345 kV	P4	Comanche – Tundra 345 kV ckt 1 Comanche 345/230 kV transformer ‘T3’	12	Stable	Stable	Stable	Stable
13	Comanche 230 kV	P4	Comanche – CF&I Furnace 230 kV ckt 1 Comanche – GI 2020 10 230 kV ckt 1 CF&I Furnace load ‘IN’	17	Unsatisfactory	Unstable	Unsatisfactory	Unstable
14	Comanche 230 kV	P4	Comanche – Boone 230 kV ckt 1 Comanche – Huckleberrry 230 kV ckt 1	17	Unsatisfactory	Unstable	Unsatisfactory	Unstable

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

Table 15 – Short-Circuit Parameters at PI-2024-07 POI (Comanche 345 kV substation)

	Before the PI Addition	After the PI Addition
Three Phase		
Three Phase Current	12170 A	12400 A
Positive Sequence Impedance	1.28419 + j18.1464 ohms	1.28419 + j18.1464 ohms
Negative Sequence Impedance	1.31612 + j18.0850 ohms	1.31612 + j18.0850 ohms
Zero Sequence Impedance	0.58630 + j10.9460 ohms	0.50147 + j9.82411 ohms
Phase-to-Ground		
Single Line to Ground Current	12720 A	13470 A
Positive Sequence Impedance	1.28419 + j18.1464 ohms	1.28419 + j18.1464 ohms
Negative Sequence Impedance	1.31612 + j18.0850 ohms	1.31612 + j18.0850 ohms
Zero Sequence Impedance	0.58630 + j10.9460 ohms	0.50147 + j9.82411 ohms

Breakers previously identified as needing replacement will be replaced under the breaker replacement program. A breaker duty study on the PSCo transmission system did not identify any circuit breakers that became over-dutied because of adding the BESS generation PI-2024-07 (5RSC-2024-12).

5.5 Affected Systems

The study identified CSU and WAPA as Affected Systems.

5.6 Summary of Provisional Interconnection Analysis

The maximum allowable output of the GIR without requiring any additional System Network Upgrades is 200 MW in discharging mode and 200 MW in grid charging mode.

Note during the Voltage and Reactive Capability Evaluation, the GIR terminal voltage reaches 1.08 p.u. during the lagging test, and 0.94 p.u. during the leading test. These out-of-range voltages should be addressed by the generator owner.

6.0 Cost Estimates

The total estimated cost of the required upgrades for PI-2024-07 to interconnect for Provisional Interconnection Service at the Comanche 345 kV substation is **$6.710 million**. Note that cost estimates for system Network Upgrades on Affected Systems would not be provided by PSCo.

- **Cost of Transmission Provider's Interconnection Facilities (TPIF) is $4.064 million** (Table 16)
- **Cost of Station Network Upgrades is $2.646 million** (Table 17)
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the Provisional Interconnection of PI-2024-07 are given in Table 16 and Table 17.

Table 16 – Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Million)
PSCo's Comanche 345 kV substation	Interconnection of 5RSC-2024-12 (PI-2024-07) at the Comanche 345 kV Substation. The new equipment includes: • (2) 345 kV single bay dead end structures • (1) 345 kV 3-phase arrester • (1) 345 kV 3000 A line disconnect switch • (3) 345 kV 1-phase CTs for metering • (3) 345 kV 1-phase CVTs • Yard expansion including grading, ground grid, 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	$3.684
PSCo's Comanche 345 kV substation	Transmission Provider's underground to aboveground transition structure at the Point of Change of Ownership (PCO) outside the substation fence line and transmission line into new switching station from the PCO. Transition structure, single span, 3 conductors, insulators, hardware, jumpers and labor.	$0.380
Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities		**$4.064**

Table 17 – Station Network Upgrades

Element	Description	Cost Est. (Million)
PSCo's Comanche 345 kV substation	Interconnection of 5RSC-2024-12 (PI-2024-07) at the Comanche 345 kV substation. The new equipment includes: • (1) 345 kV 3000 A SF6 circuit breaker • (2) 345 kV 3000 A disconnect switches • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$2.334
PSCo's Comanche 345 kV substation	Install required communication in the EEE at the Comanche 345 kV substation	$0.262
PSCo's Comanche 345 kV substation	Siting and Land Rights permitting	$0.050
Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities		**$2.646**

PSCo has developed cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of PI-2024-07 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) 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 most current version of the *Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW*, as amended from time to time, and available at: Interconnection | Transmission | Corporate | Xcel Energy

6.1 Schedule

This section provides proposed milestones for the interconnection of PI-2024-07 to the Transmission Provider's Transmission System. The customer requested a back-feed (In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection) for the Provisional Interconnection of December 1, 2026. 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 18.

Table 18 – Proposed Milestones for PI-2024-07

Milestone	Responsible Party	Estimated Completion Date
LGIA Execution	Interconnection Customer and Transmission Provider	December 2024
In-Service Date for Transmission Provider Interconnection Facilities and Station Network Upgrades required for interconnection	Transmission Provider	December 1, 2026
In-Service Date & Energization of Interconnection Customer's Interconnection Facilities	Interconnection Customer	December 1, 2026
Initial Synchronization Date	Interconnection Customer	February 1, 2027
Begin trial operation & testing	Interconnection Customer and Transmission Provider	March 1, 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 LGIA 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-2024-07 to qualify for Provisional Interconnection Service is $6.710 million.

The initial maximum permissible output of PI-2024-07 Generating Facility is 200 MW in discharging and 200 MW grid charging. The maximum permissible output of the Generating Facility in the PLGIA will 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-2024-12 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-2024-12 Large Generation Interconnection Procedure (LGIP) in the 5RSC cluster is $5 million.

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

8.0 Contingent Facilities

The Contingent Facilities identified for PI-2024-07 include the TPIF and Station Network Upgrades identified in Table 16 and Table 17, respectively.

9.0 Preliminary One-Line Diagram and General Arrangement for PI-2024-07

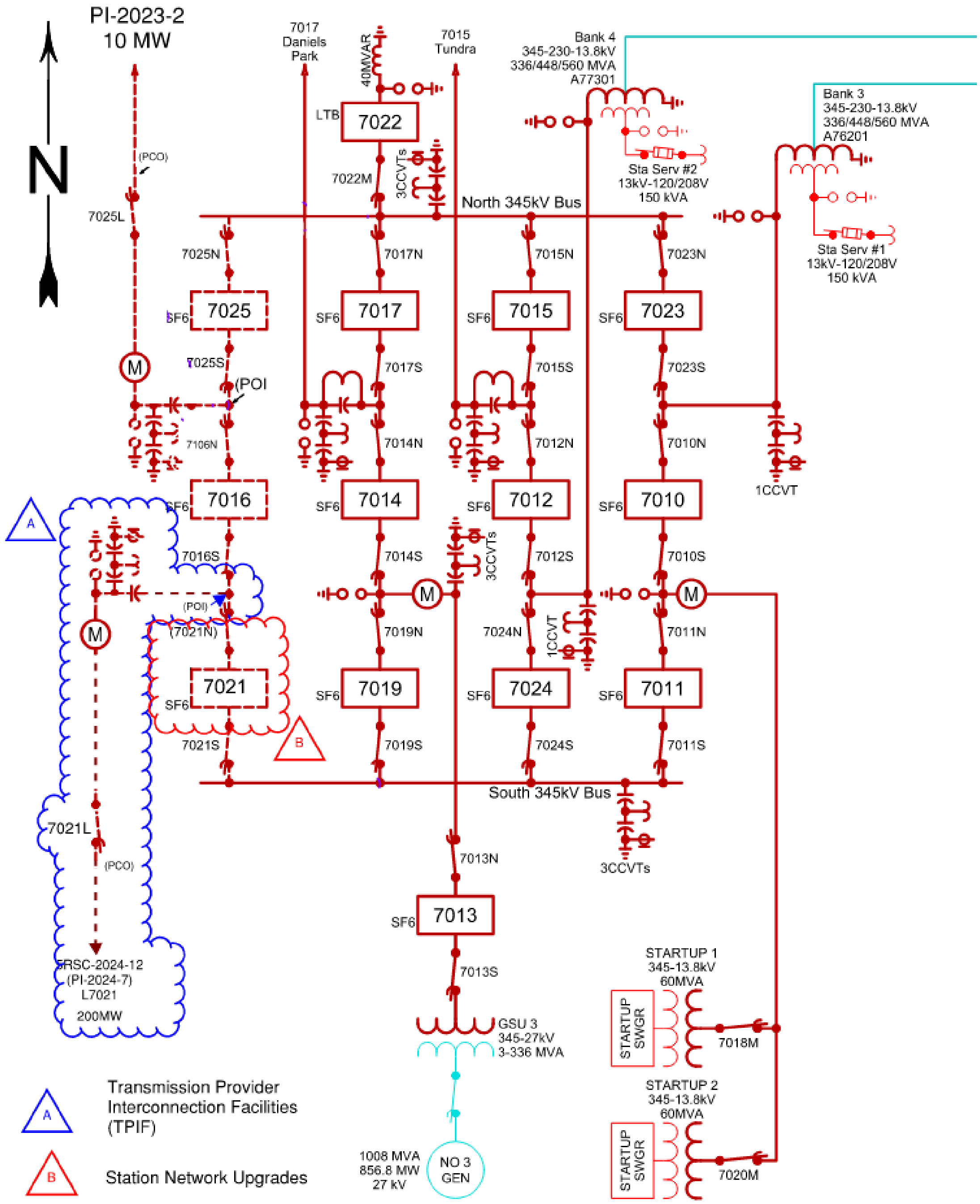


Figure 2: Preliminary One-Line of PI-2024-07 at the Comanche 345 kV substation

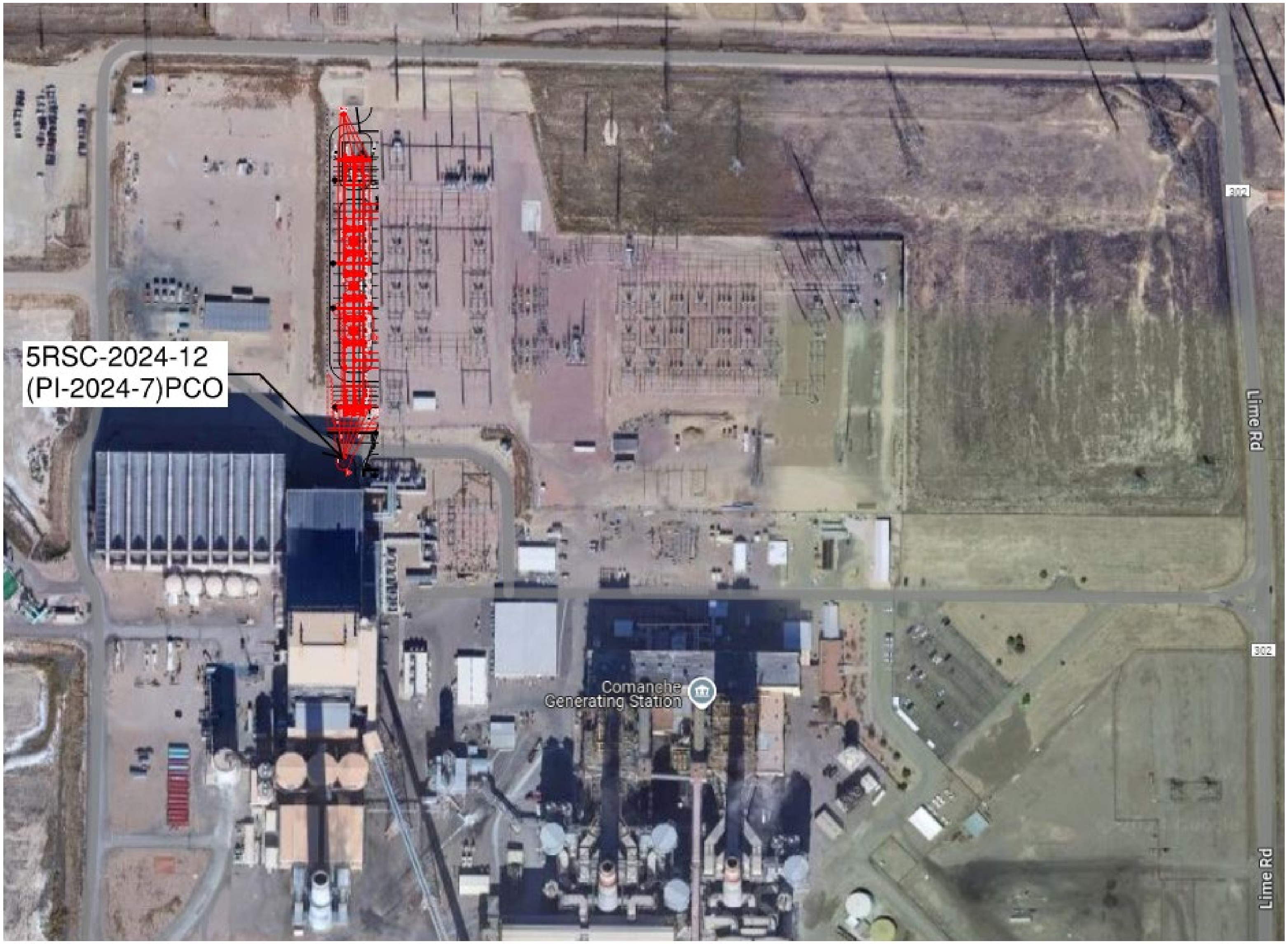


Figure 3: General Arrangement Location Map for PI-2024-07 at the Comanche 345 kV substation

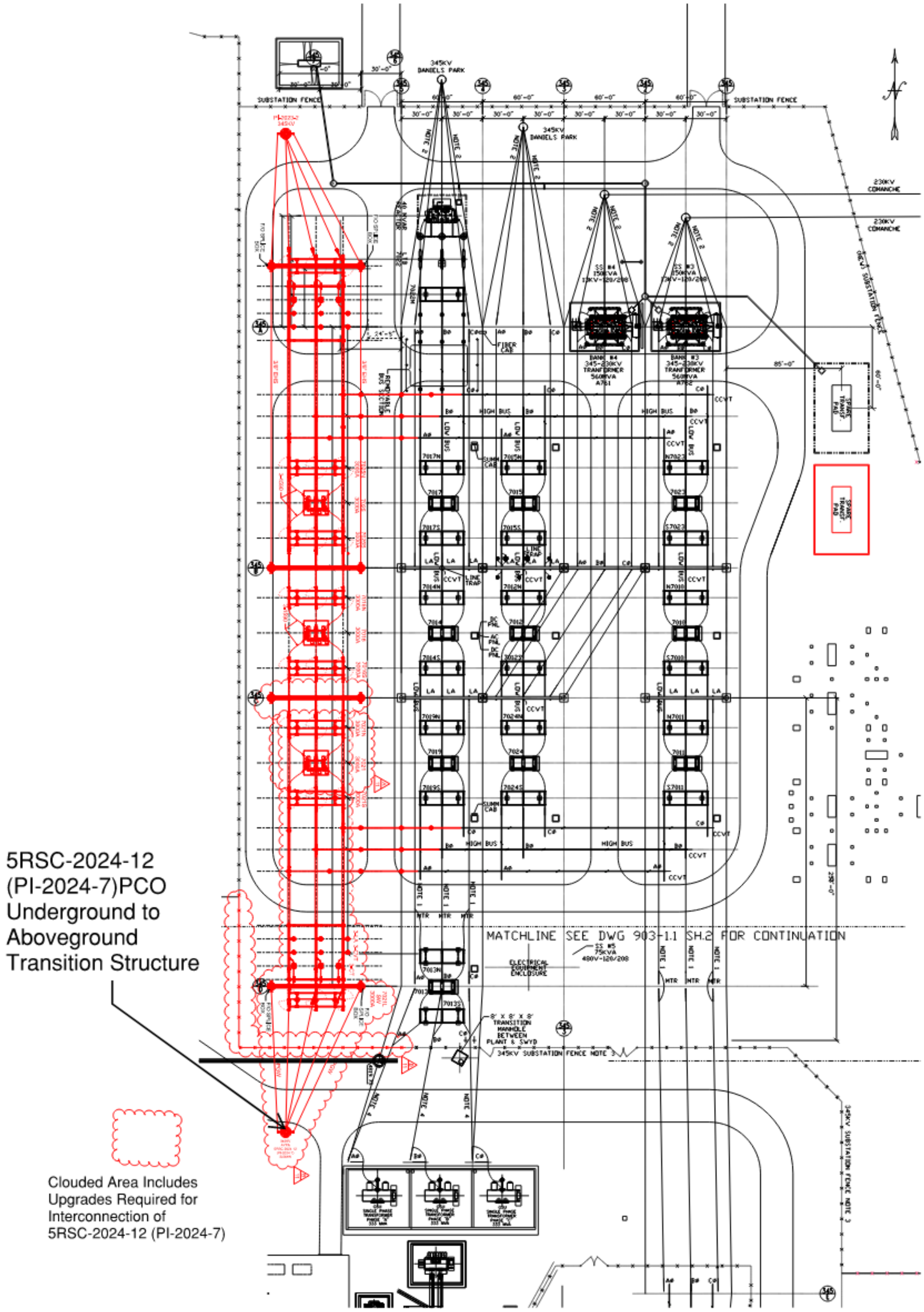
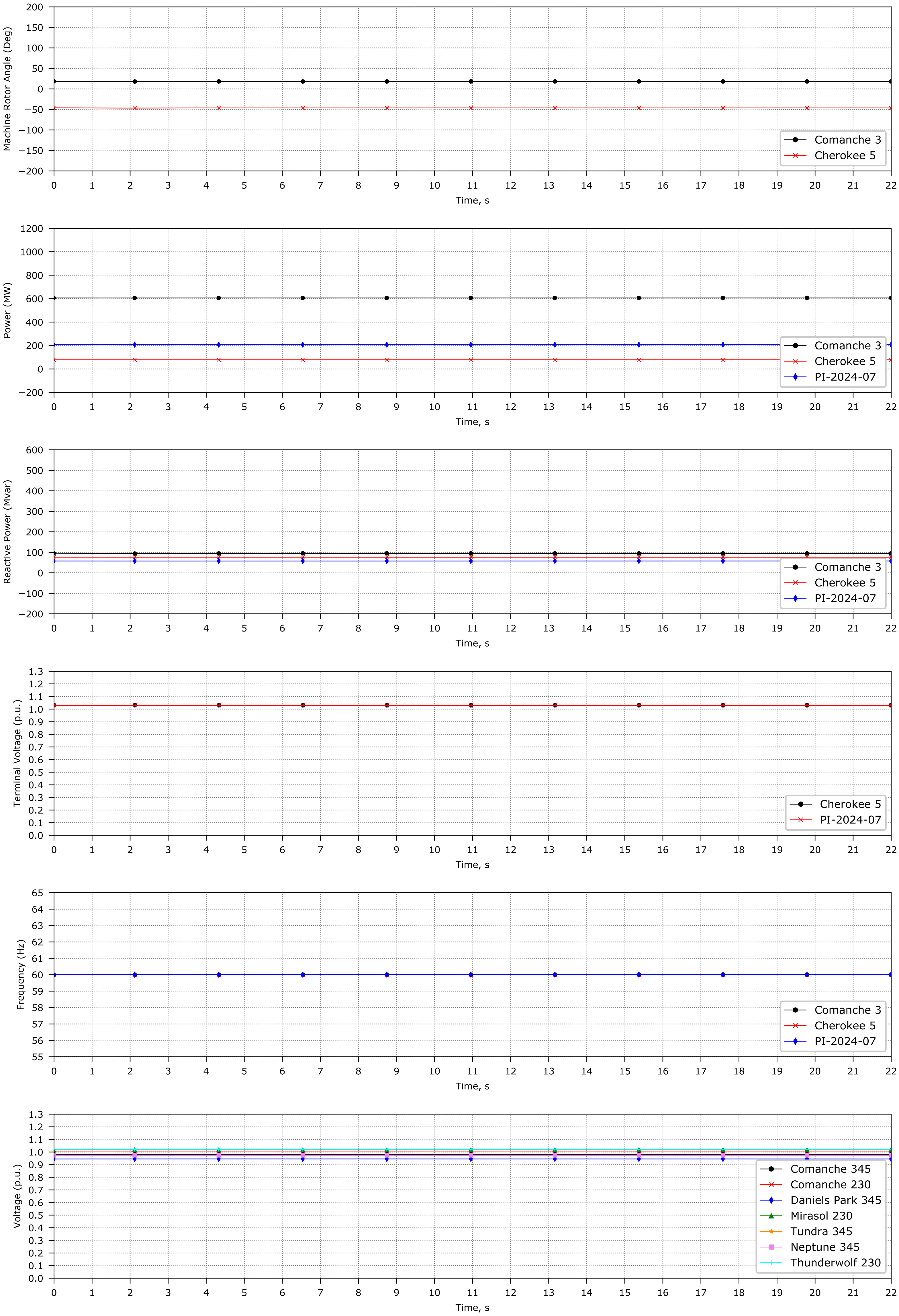


Figure 4: Preliminary General Arrangement for PI-2024-07 at the Comanche 345 kV substation

10.0 Appendices

Appendix A: Transient Stability Plots for Discharging Scenario	PI-2024-07 Discharging - Transi
Appendix B: Transient Stability Plots for Grid Charging Scenario	PI-2024-07 Grid Charging - Transien

Flatrun


Machine Rotor Angle (Deg)
Time, s
Comanche 3
Cherokee 5
Power (MW)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Reactive Power (Mvar)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Terminal Voltage (p.u.)
Time, s
Cherokee 5
PI-2024-07
Frequency (Hz)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Voltage (p.u.)
Time, s
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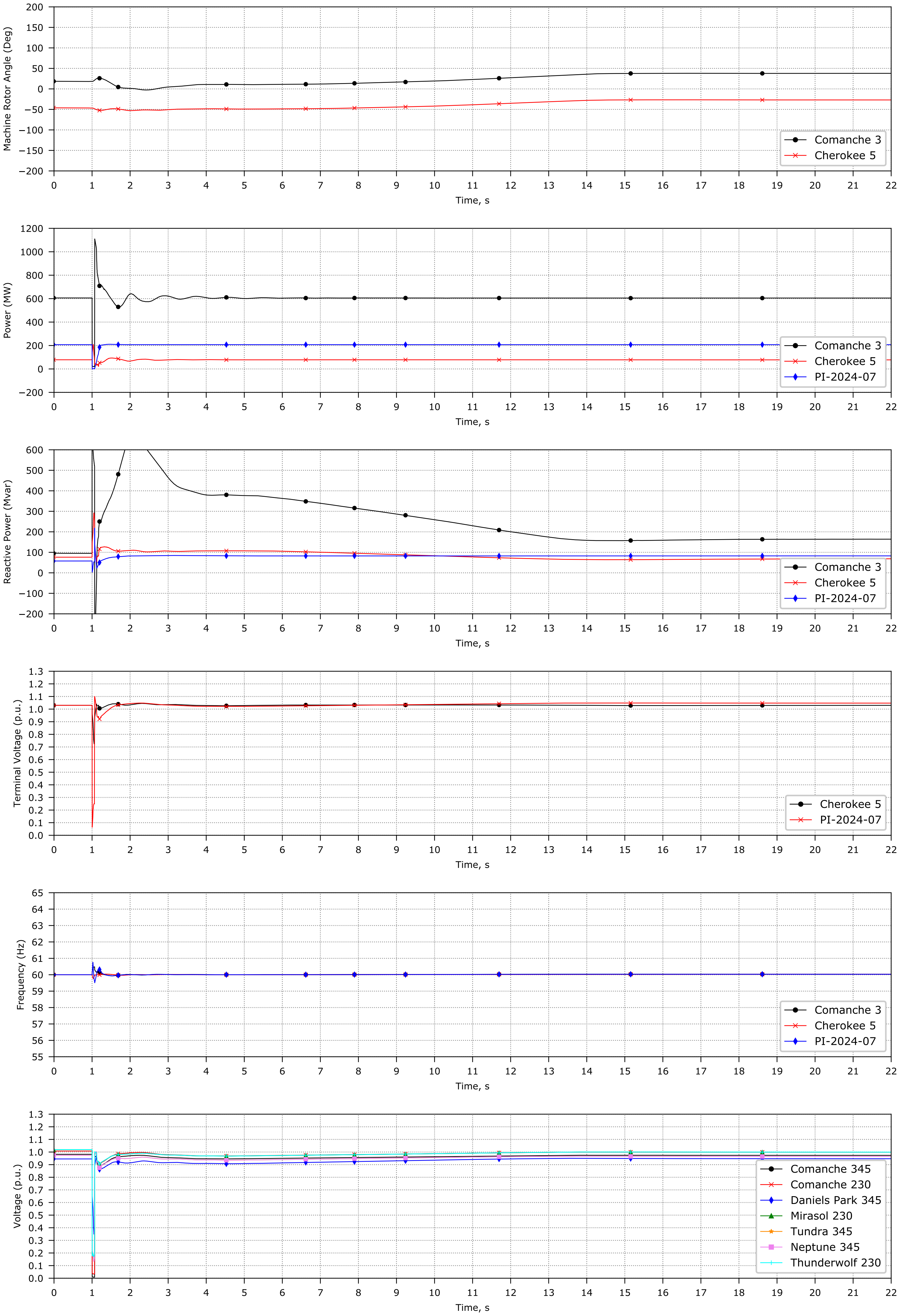
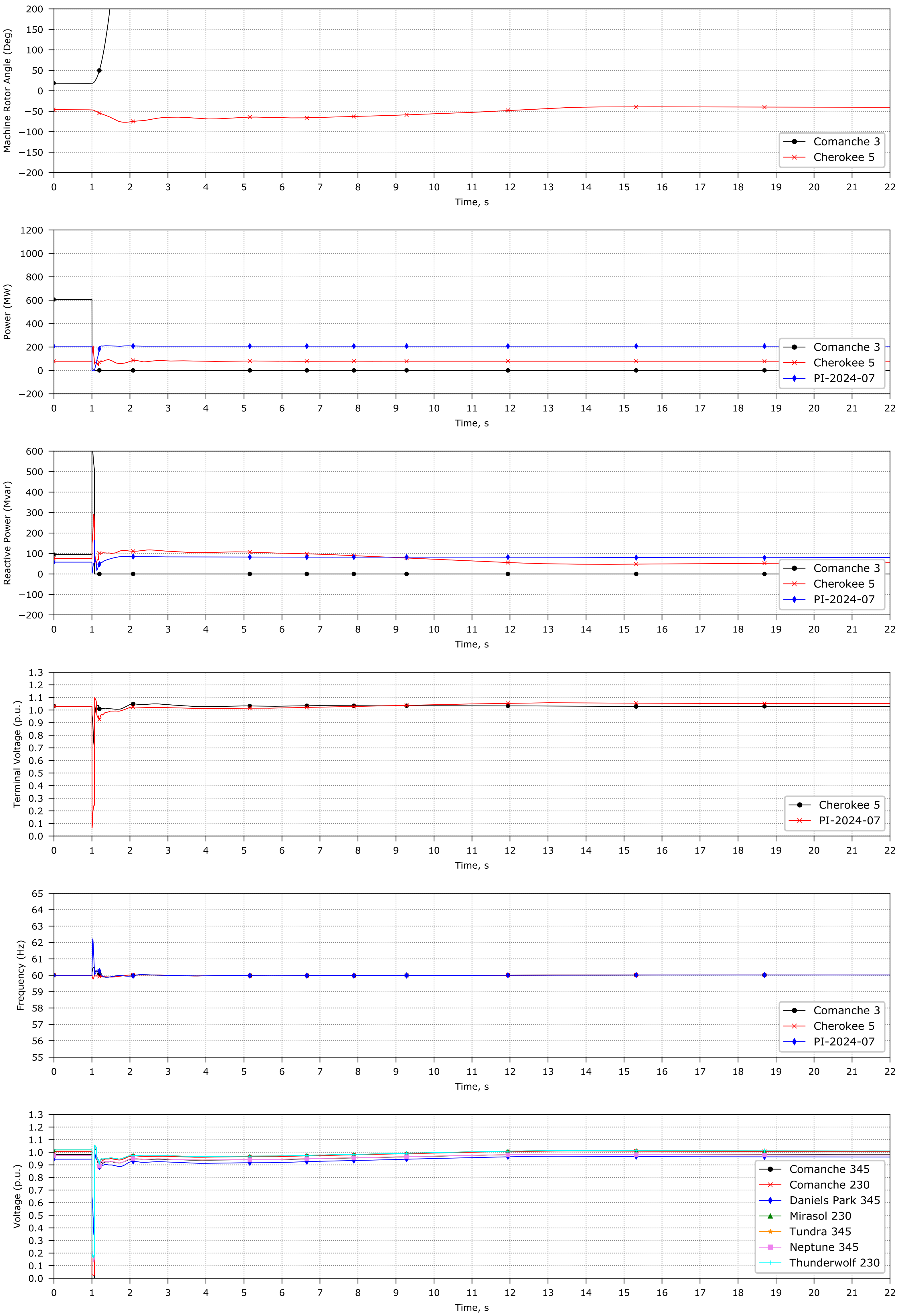
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230

Comanche-Tundra_345kV



Comanche G3


Machine Rotor Angle (Deg)
Comanche 3
Cherokee 5
Time, s
Power (MW)
PI-2024-07
Reactive Power (Mvar)
Terminal Voltage (p.u.)
Frequency (Hz)
Voltage (p.u.)
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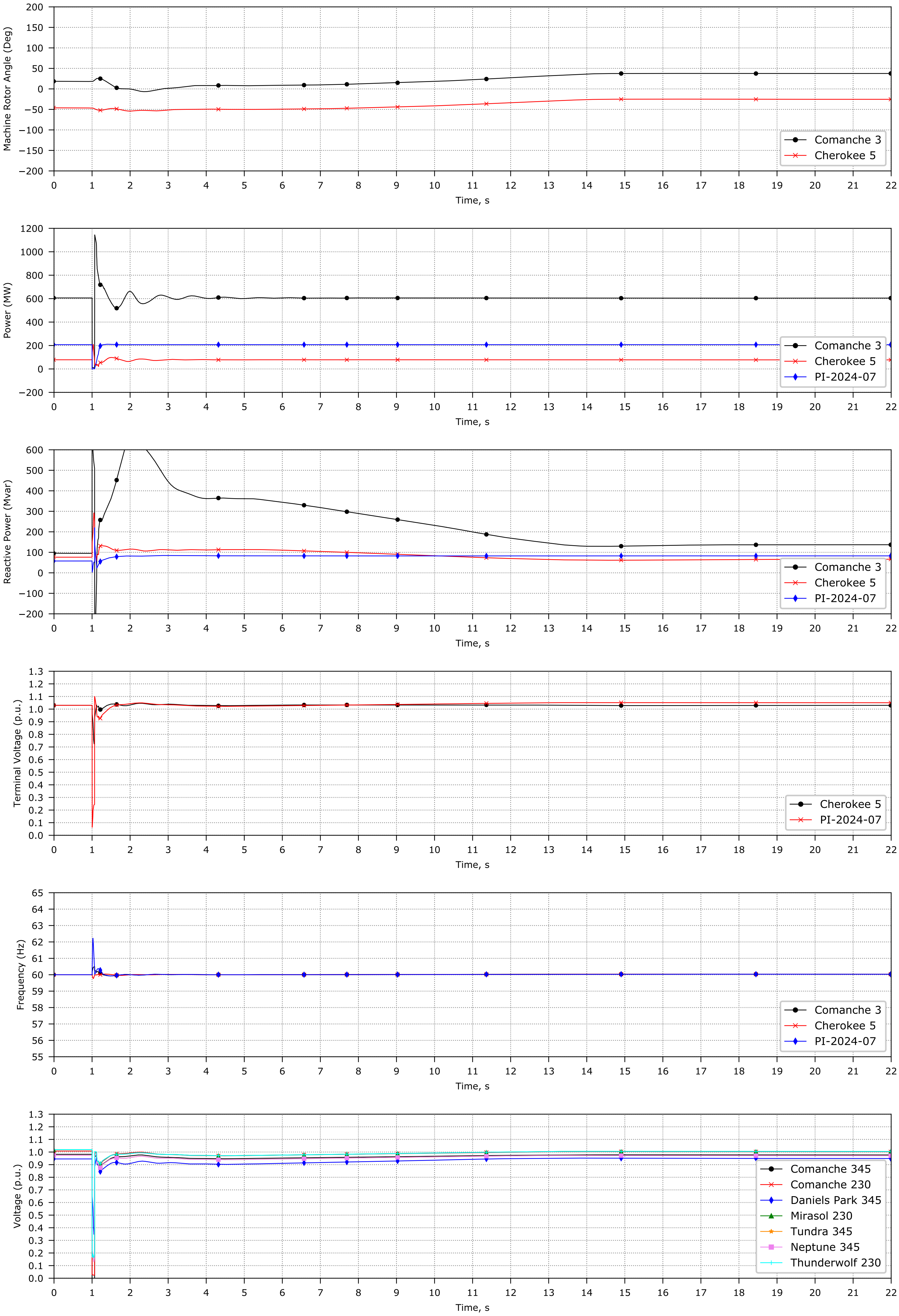
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230

Comanche T3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Cherokee 5
Time, s
Power (MW)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Reactive Power (Mvar)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Terminal Voltage (p.u.)
Cherokee 5
PI-2024-07
Time, s
Frequency (Hz)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Voltage (p.u.)
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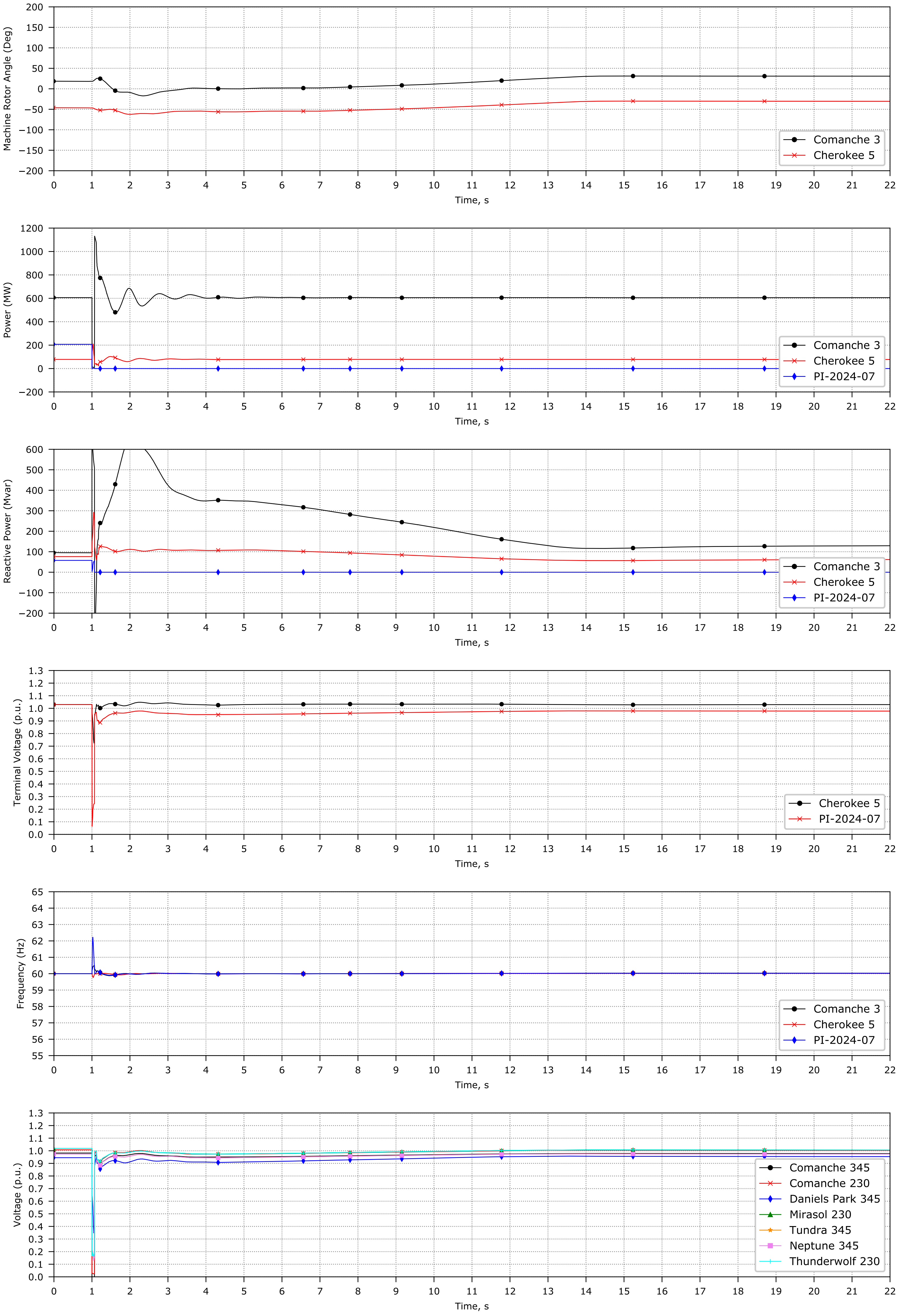
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230
Time, s

PI-2024-7_Gen


Machine Rotor Angle (Deg)
Comanche 3
Cherokee 5
Time, s
Power (MW)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Reactive Power (Mvar)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Terminal Voltage (p.u.)
Cherokee 5
PI-2024-07
Time, s
Frequency (Hz)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Voltage (p.u.)
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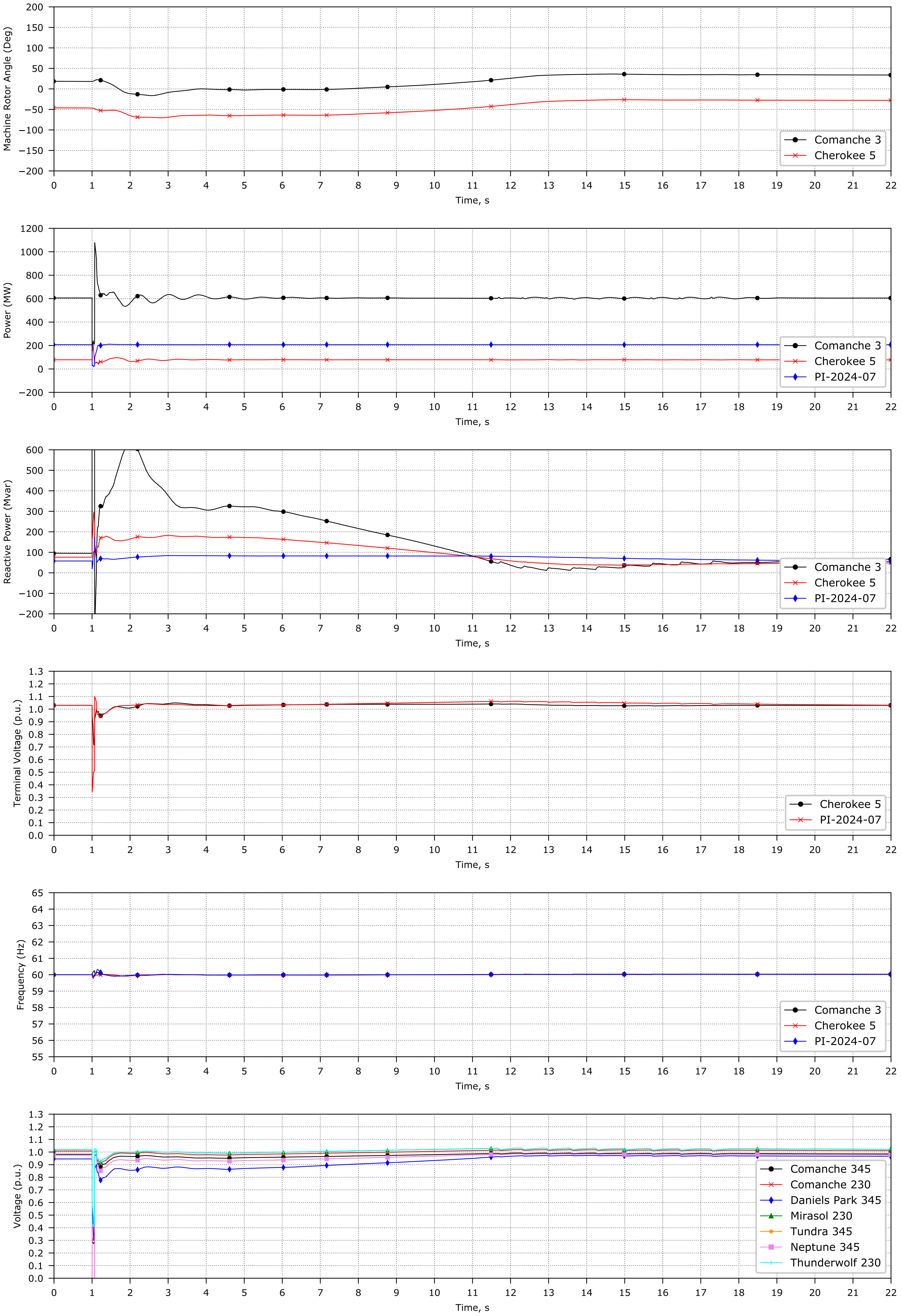
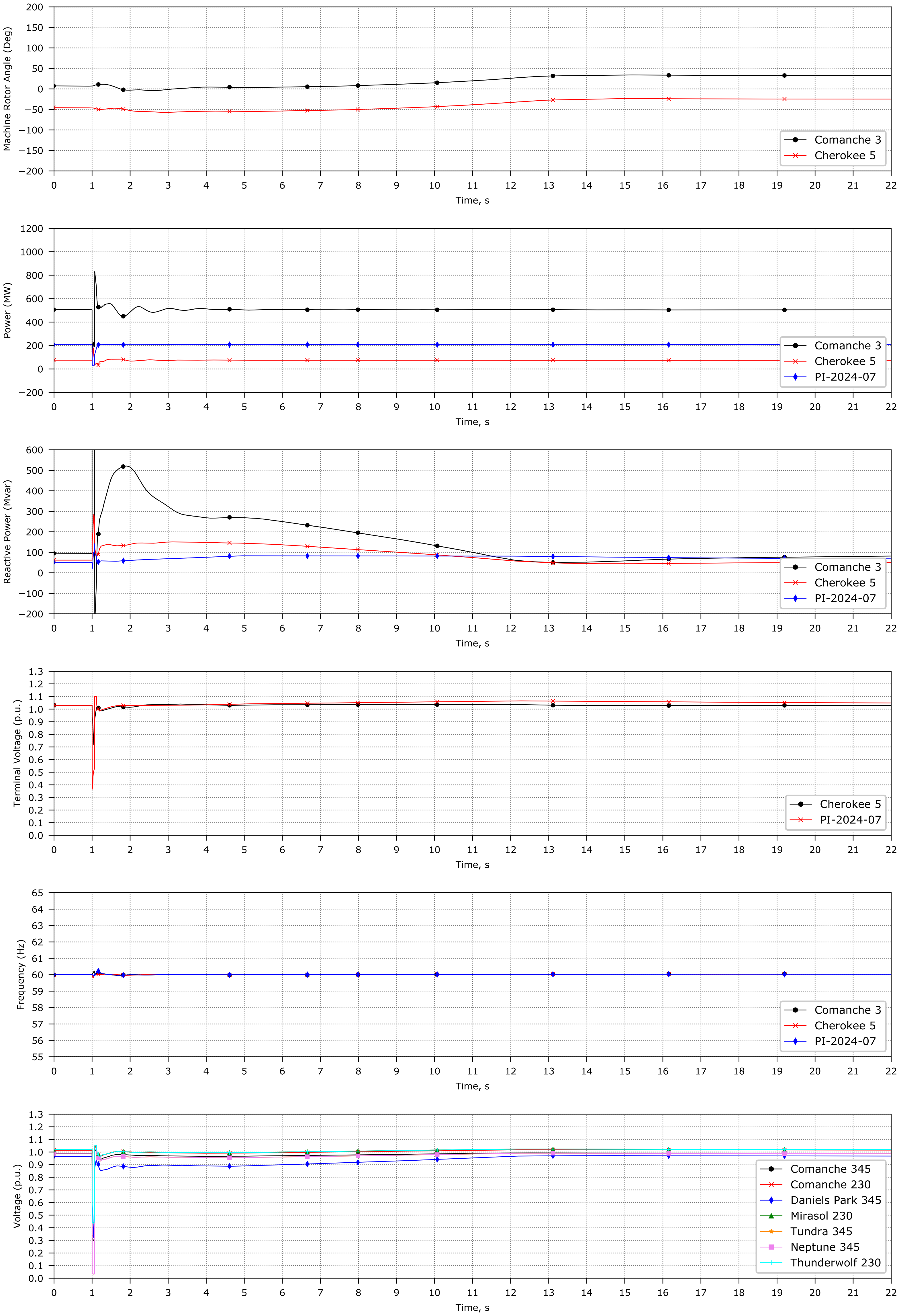
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230
Time, s

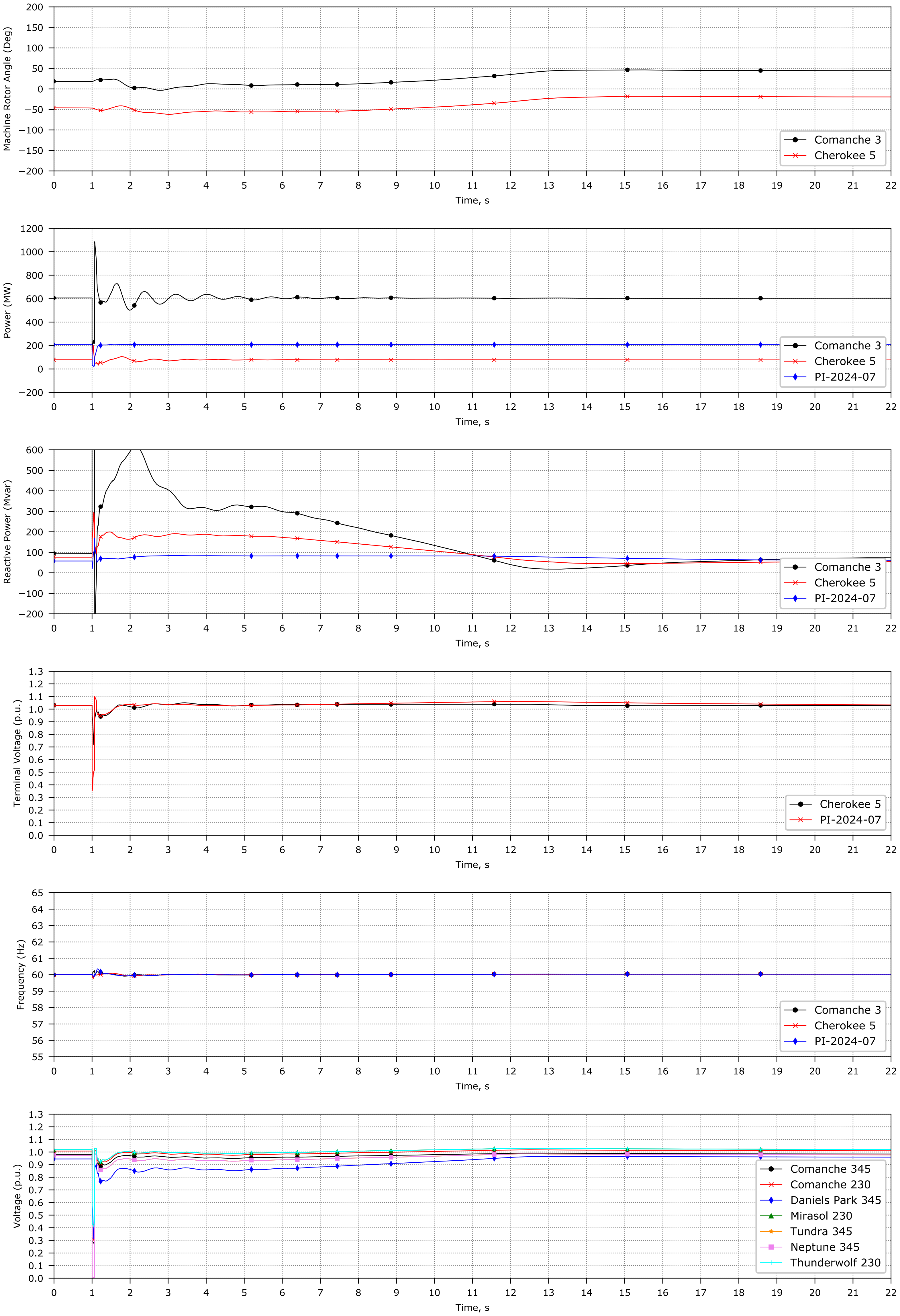
Neptune_Gen


Machine Rotor Angle (Deg)
Time, s
Comanche 3
Cherokee 5
Power (MW)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Reactive Power (Mvar)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Terminal Voltage (p.u.)
Time, s
Cherokee 5
PI-2024-07
Frequency (Hz)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Voltage (p.u.)
Time, s
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230

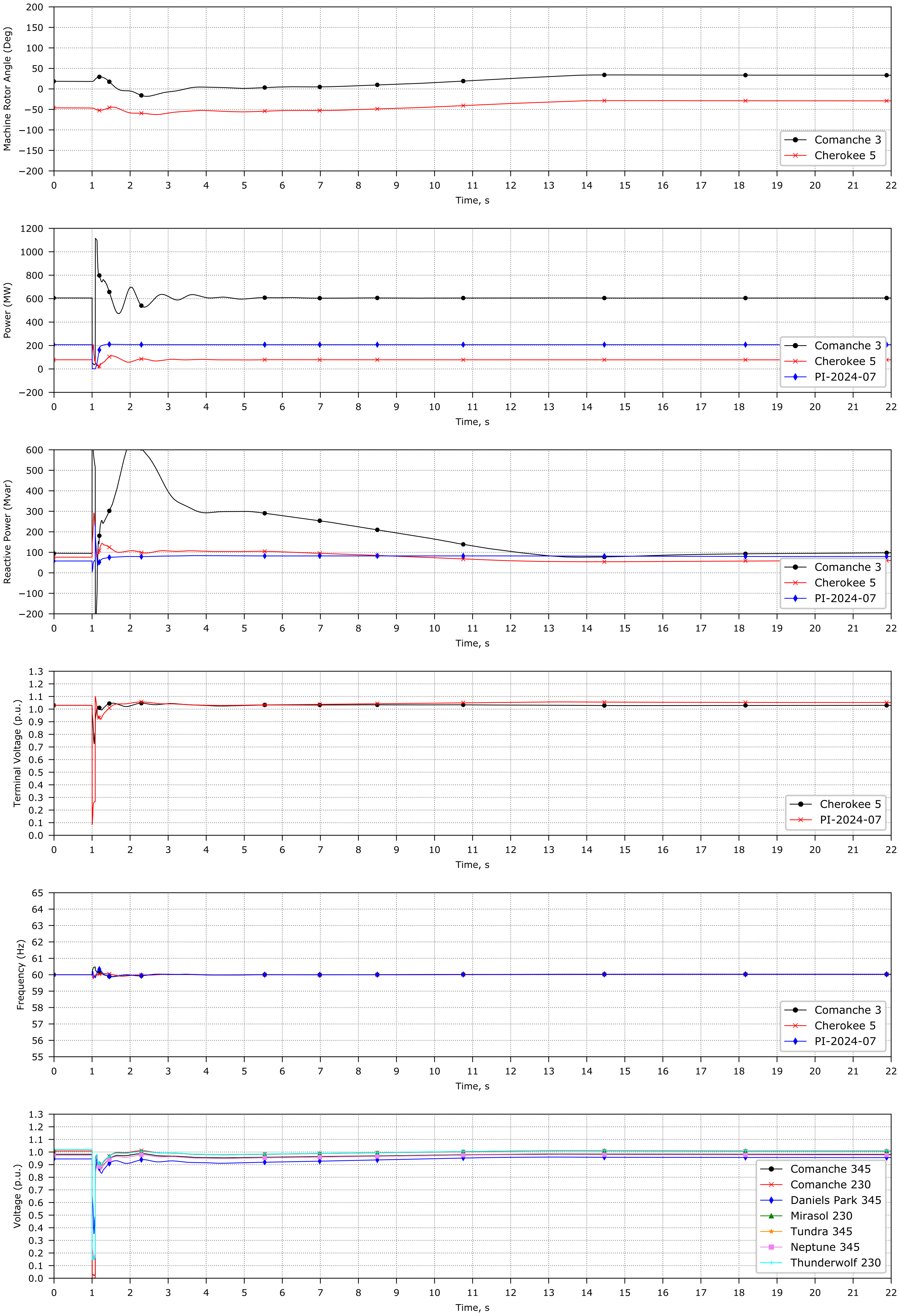
Tundra-DanielsPark_345kV



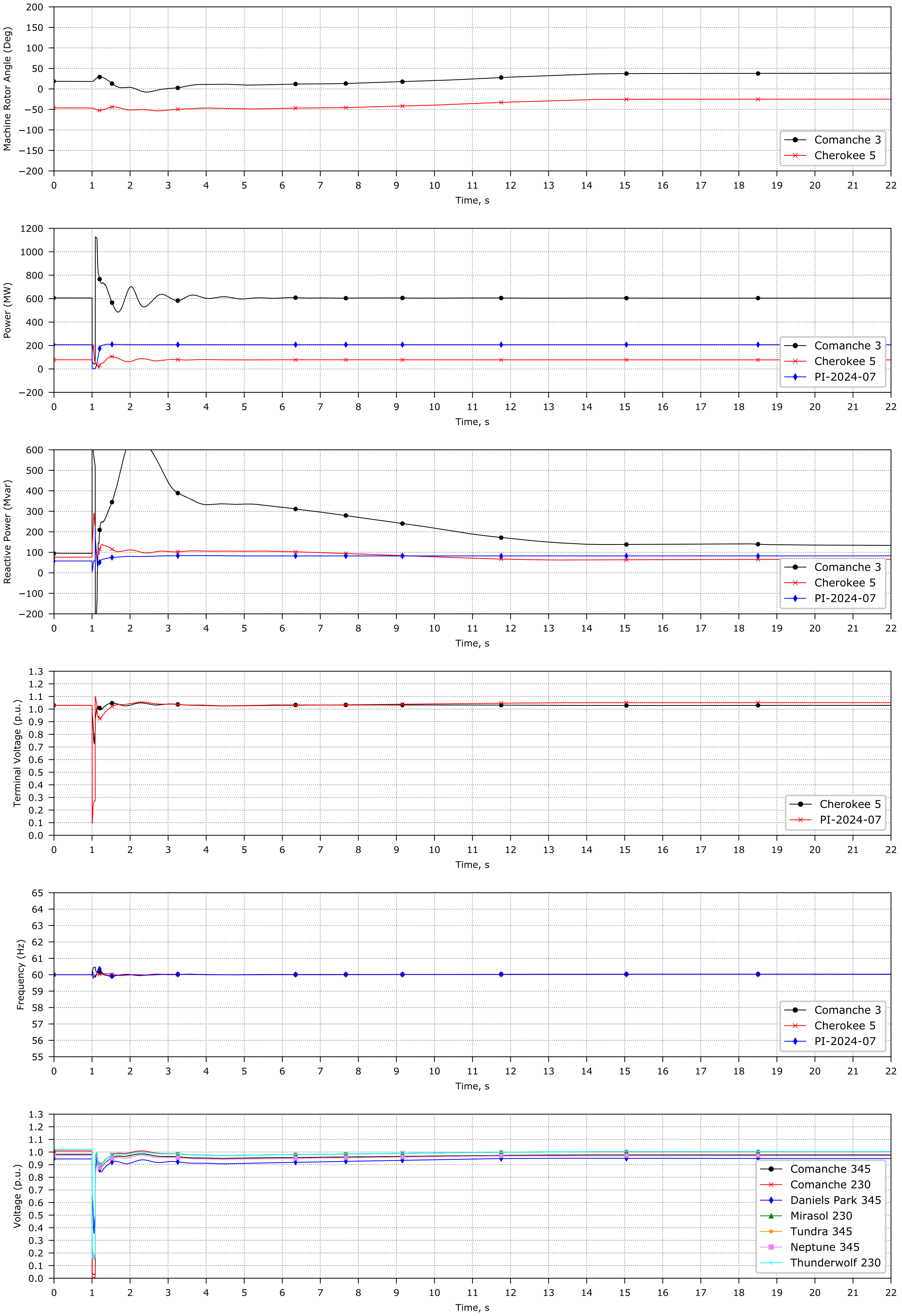
Tundra-Sandstone_345kV



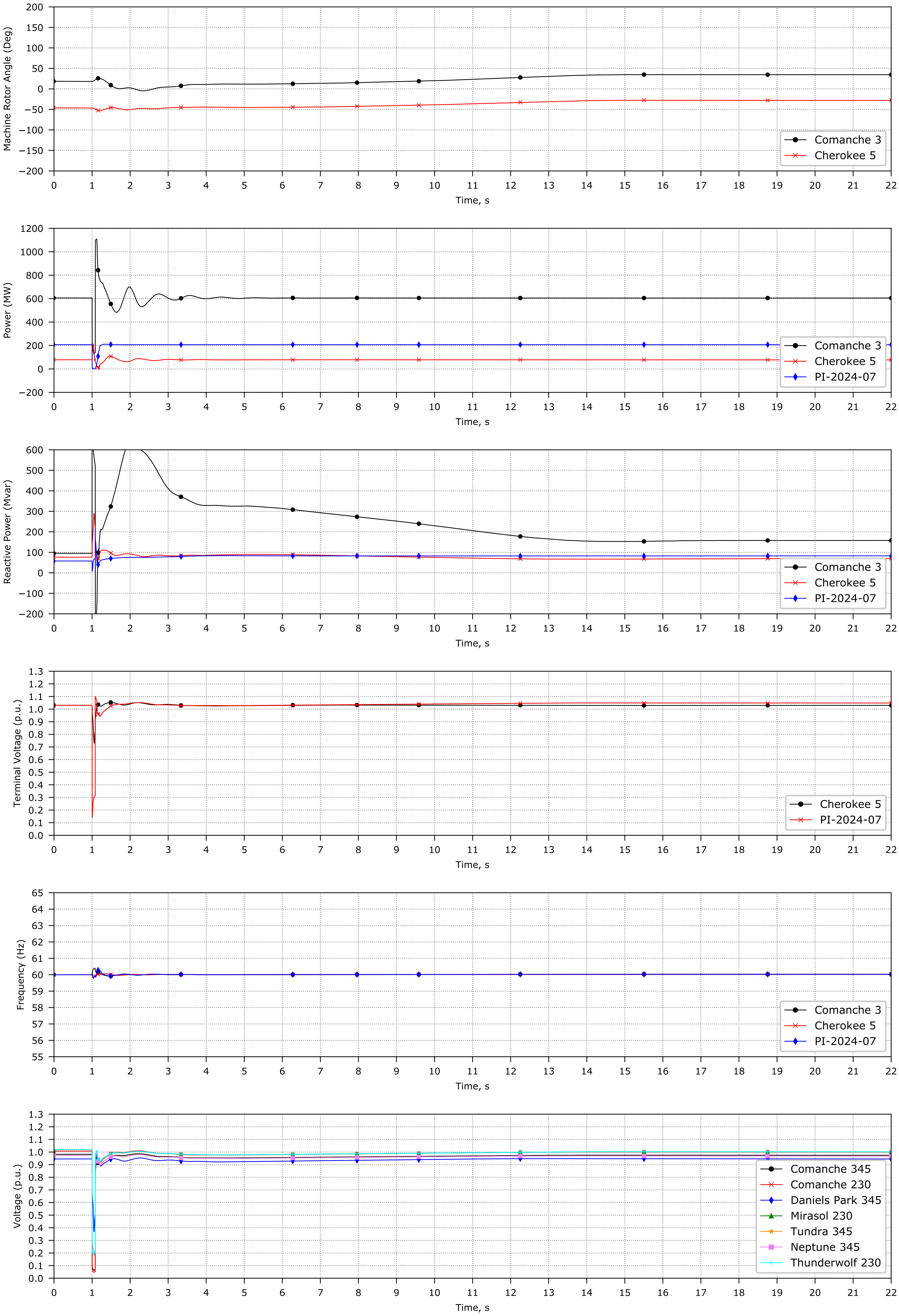
Comanche-Bighorn_230kV



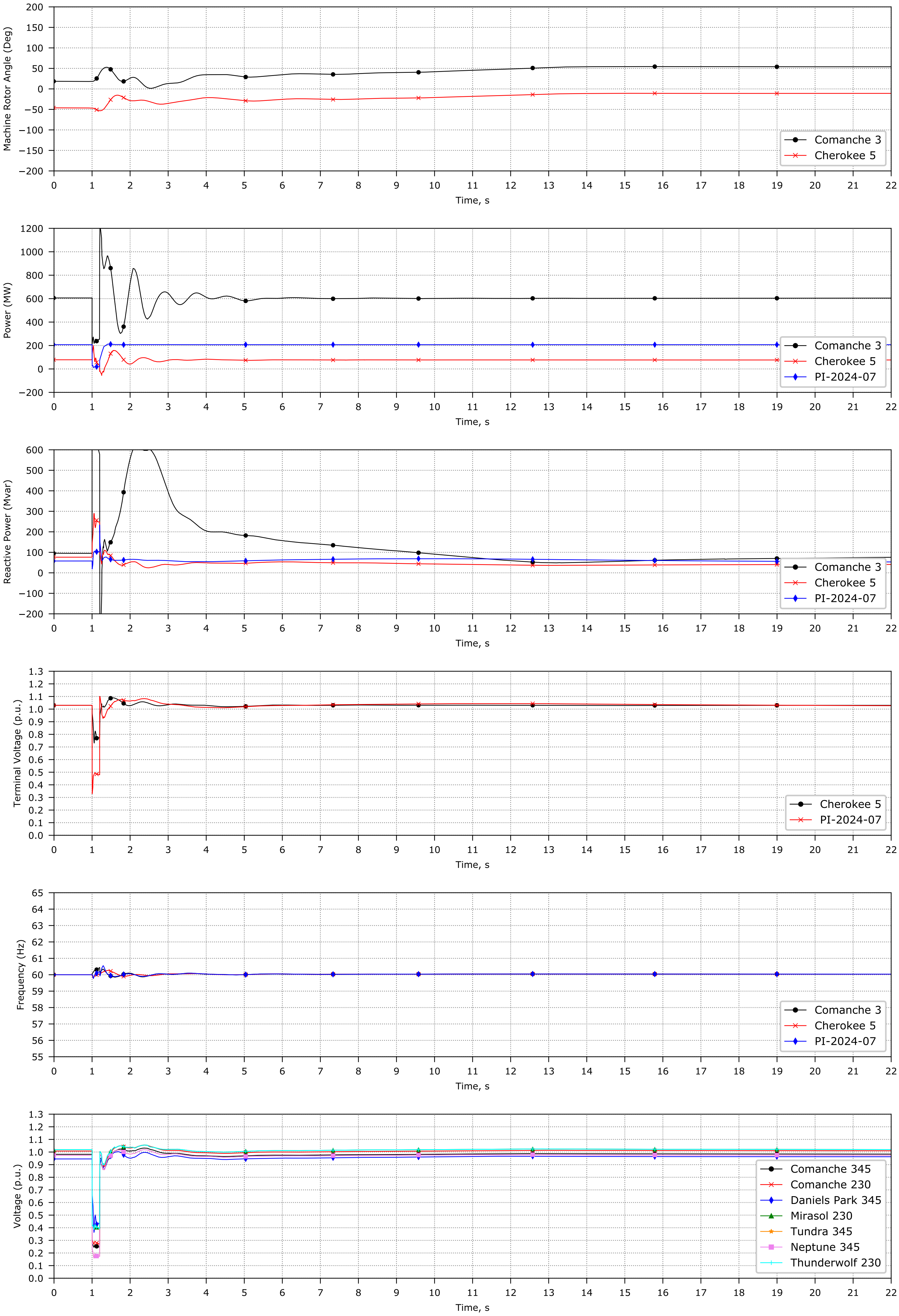
Comanche-Huckleberry_230kV



Coman-Boone_230kV

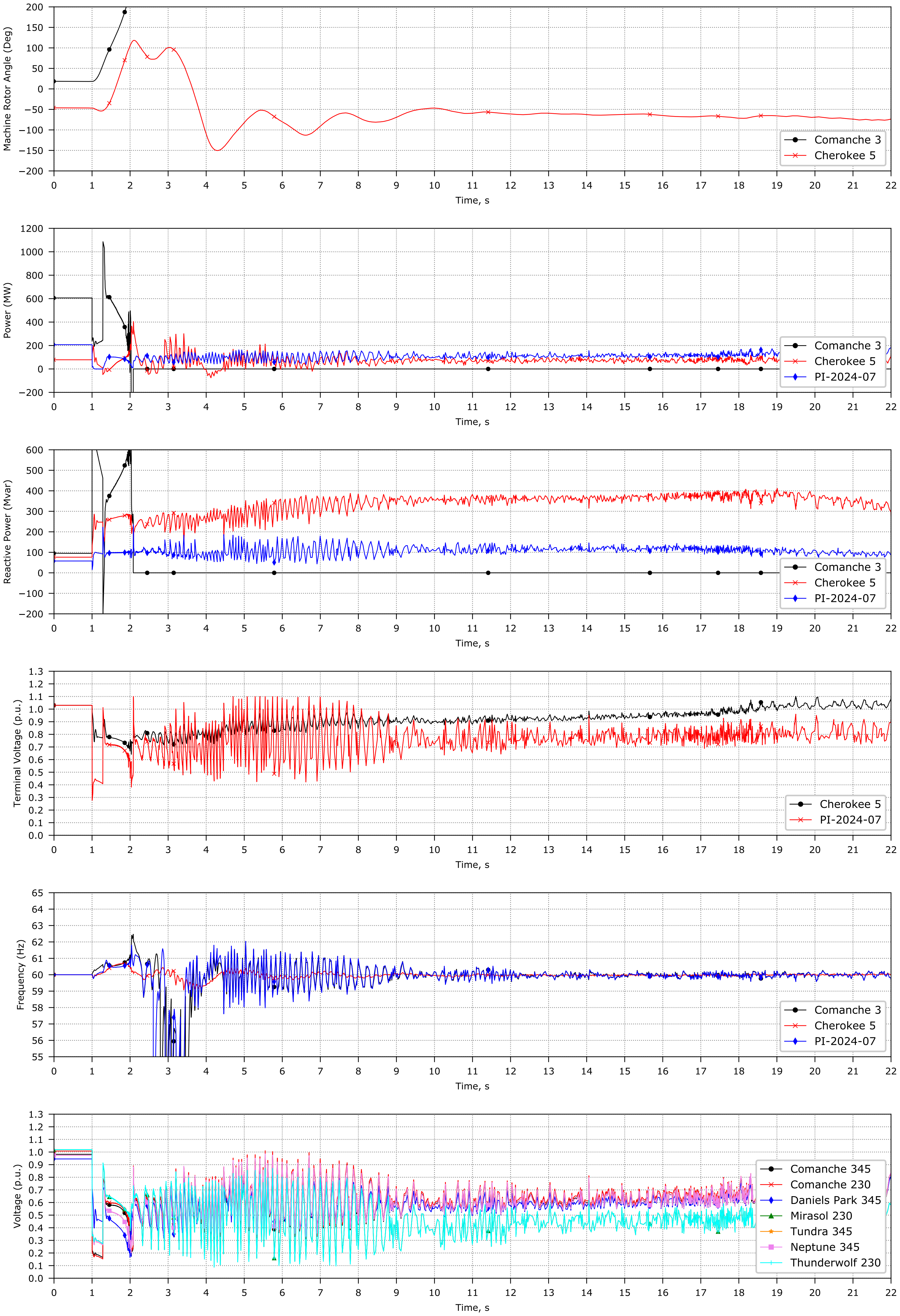


line_128

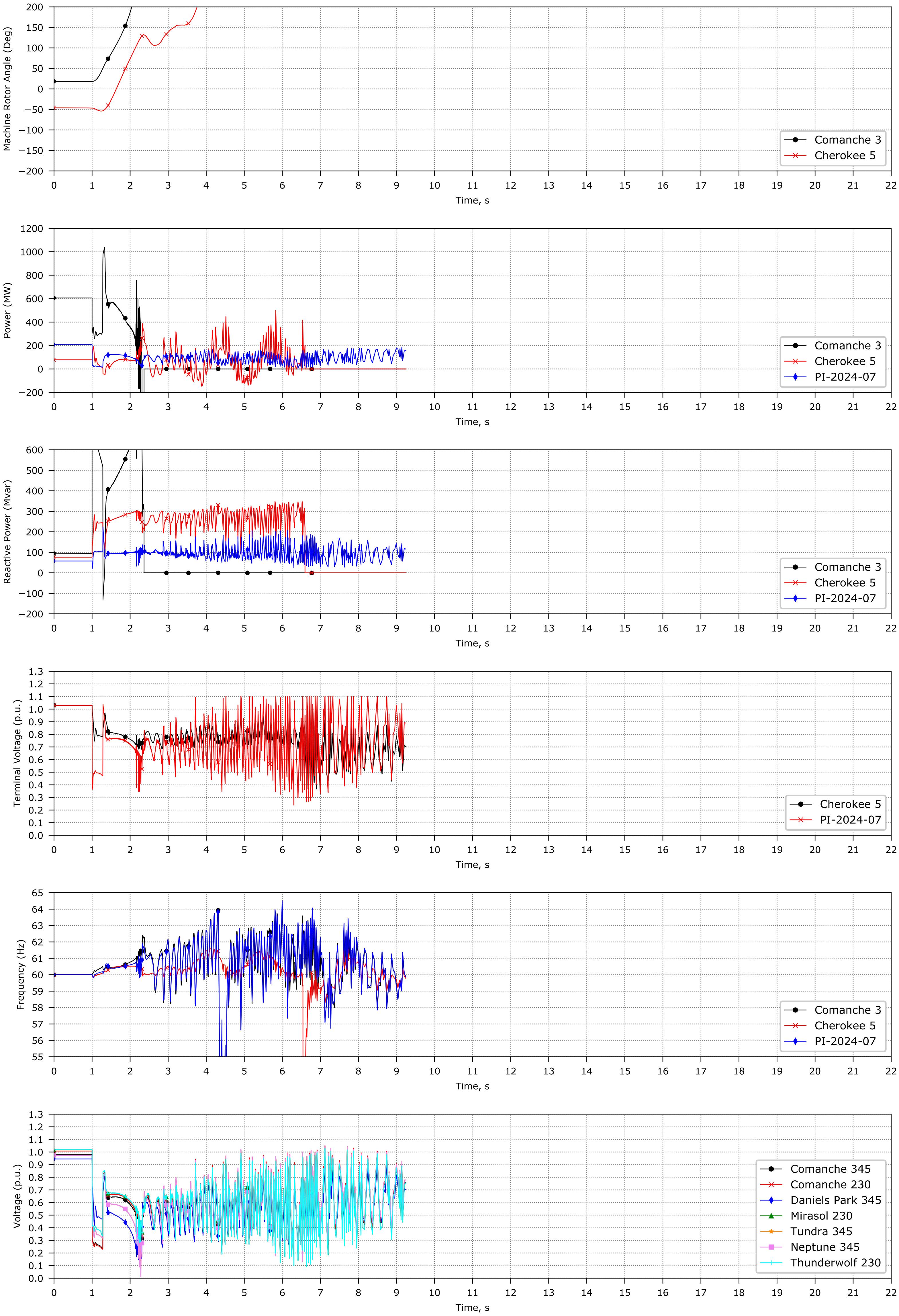


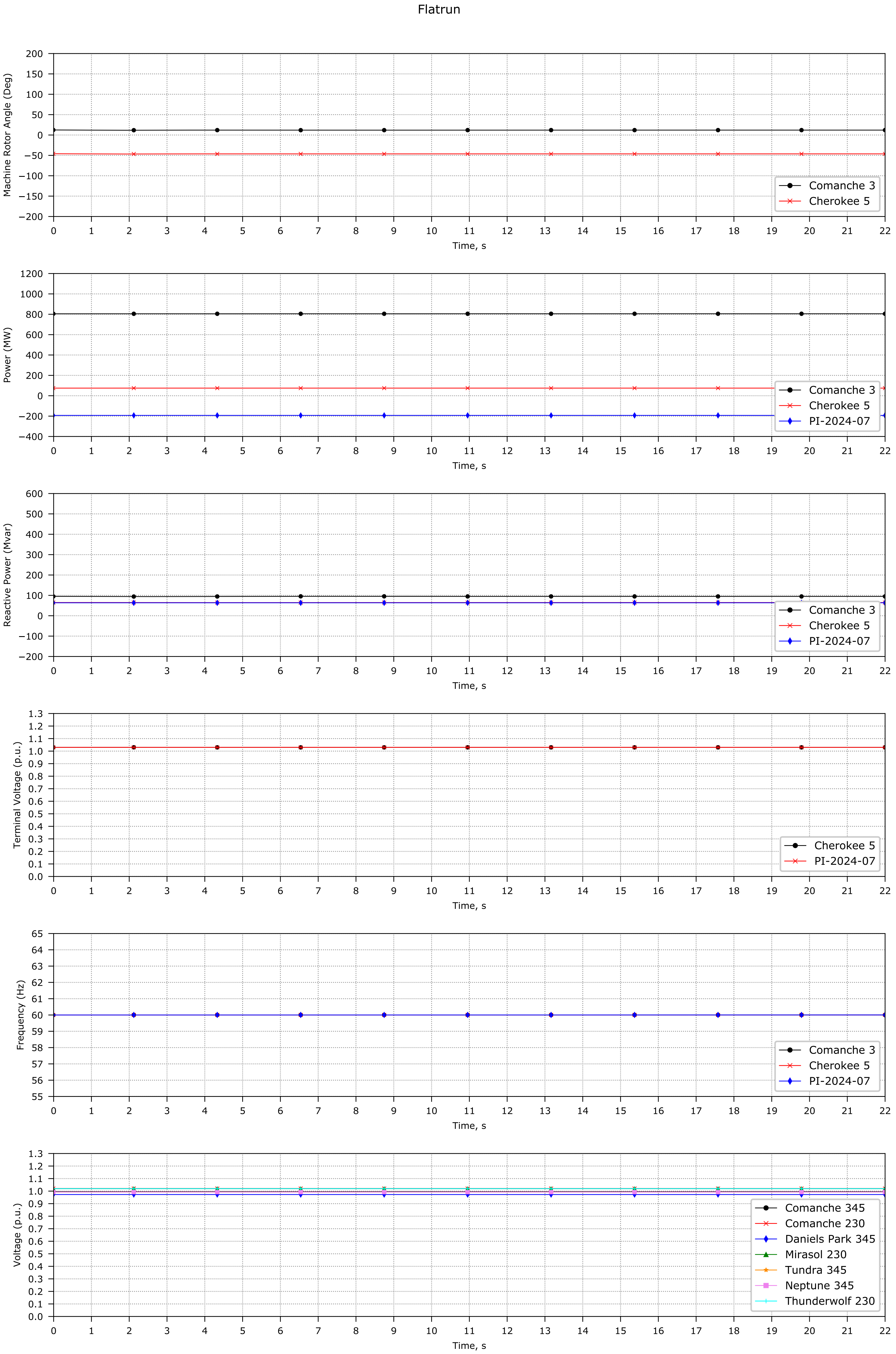
Machine Rotor Angle (Deg)
Time, s
Comanche 3
Cherokee 5
Power (MW)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Reactive Power (Mvar)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Terminal Voltage (p.u.)
Time, s
Cherokee 5
PI-2024-07
Frequency (Hz)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Voltage (p.u.)
Time, s
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230

line_134


Machine Rotor Angle (Deg)
Comanche 3
Cherokee 5
Time, s
Power (MW)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Reactive Power (Mvar)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Terminal Voltage (p.u.)
Cherokee 5
PI-2024-07
Time, s
Frequency (Hz)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Voltage (p.u.)
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230
Time, s

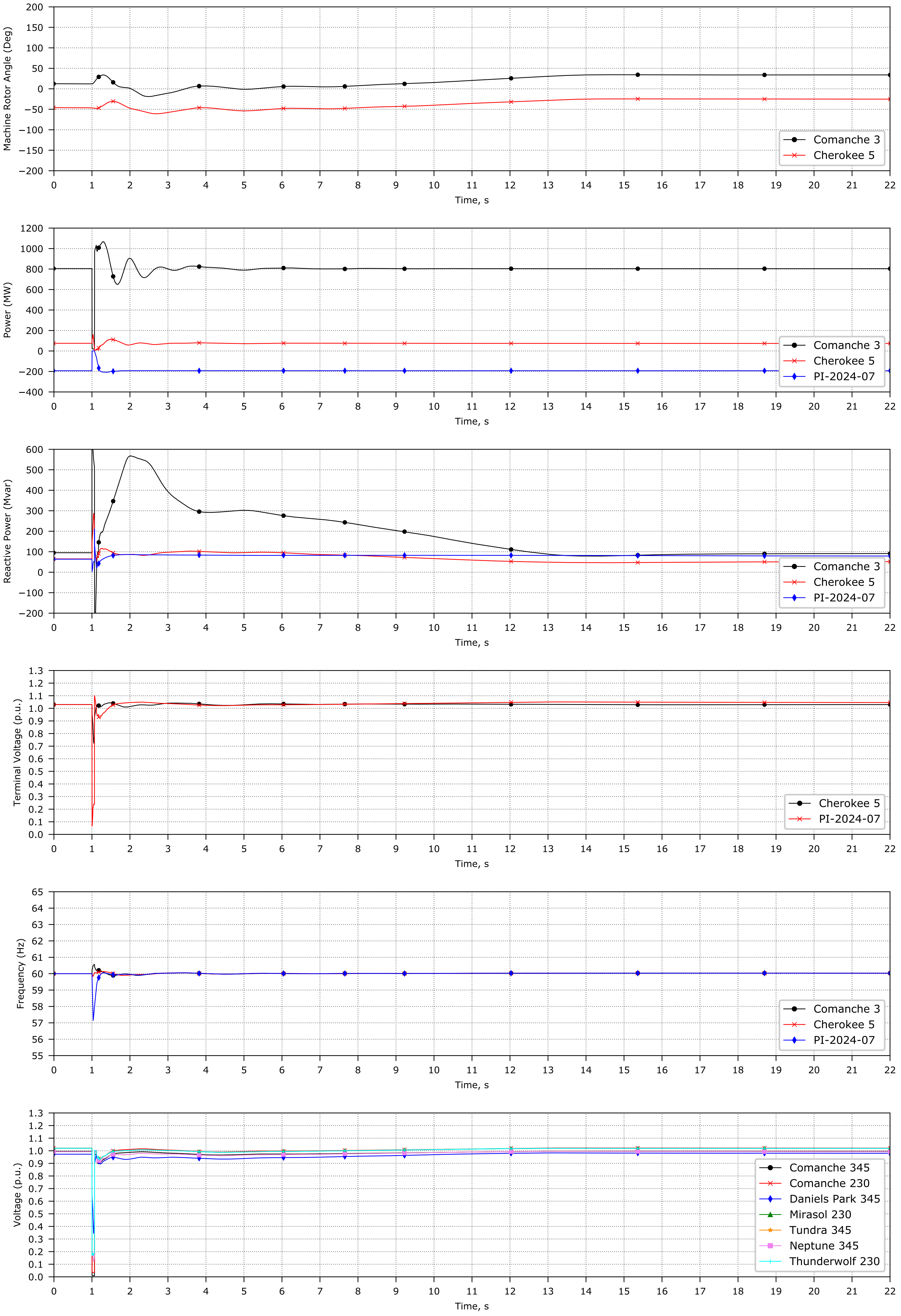
line_135


Machine Rotor Angle (Deg)
Time, s
Comanche 3
Cherokee 5
Power (MW)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Reactive Power (Mvar)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Terminal Voltage (p.u.)
Time, s
Cherokee 5
PI-2024-07
Frequency (Hz)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Voltage (p.u.)
Time, s
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230

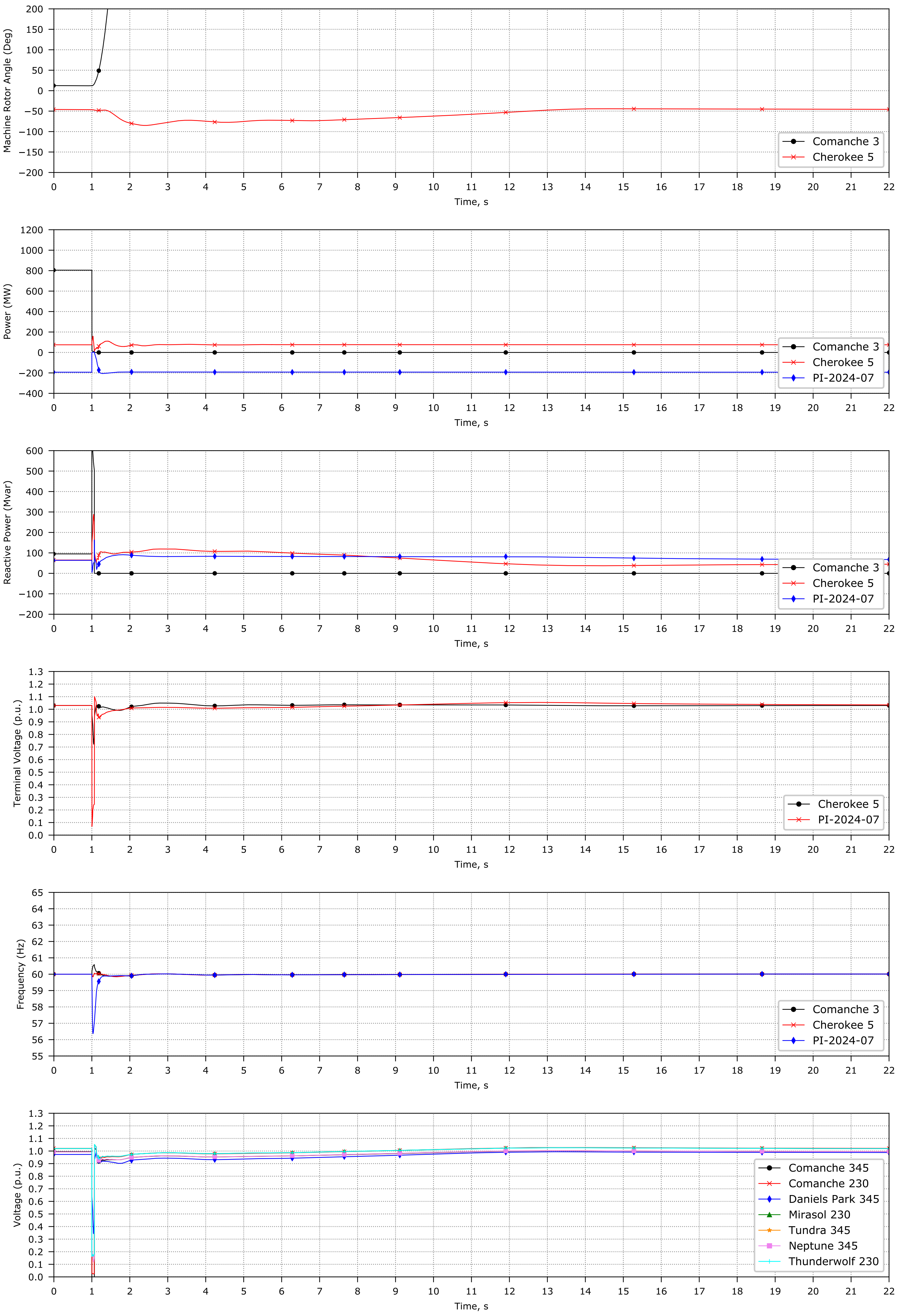


Flatrun
Machine Rotor Angle (Deg)
Comanche 3
Cherokee 5
Time, s
Power (MW)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Reactive Power (Mvar)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Terminal Voltage (p.u.)
Cherokee 5
PI-2024-07
Time, s
Frequency (Hz)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Voltage (p.u.)
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230
Time, s

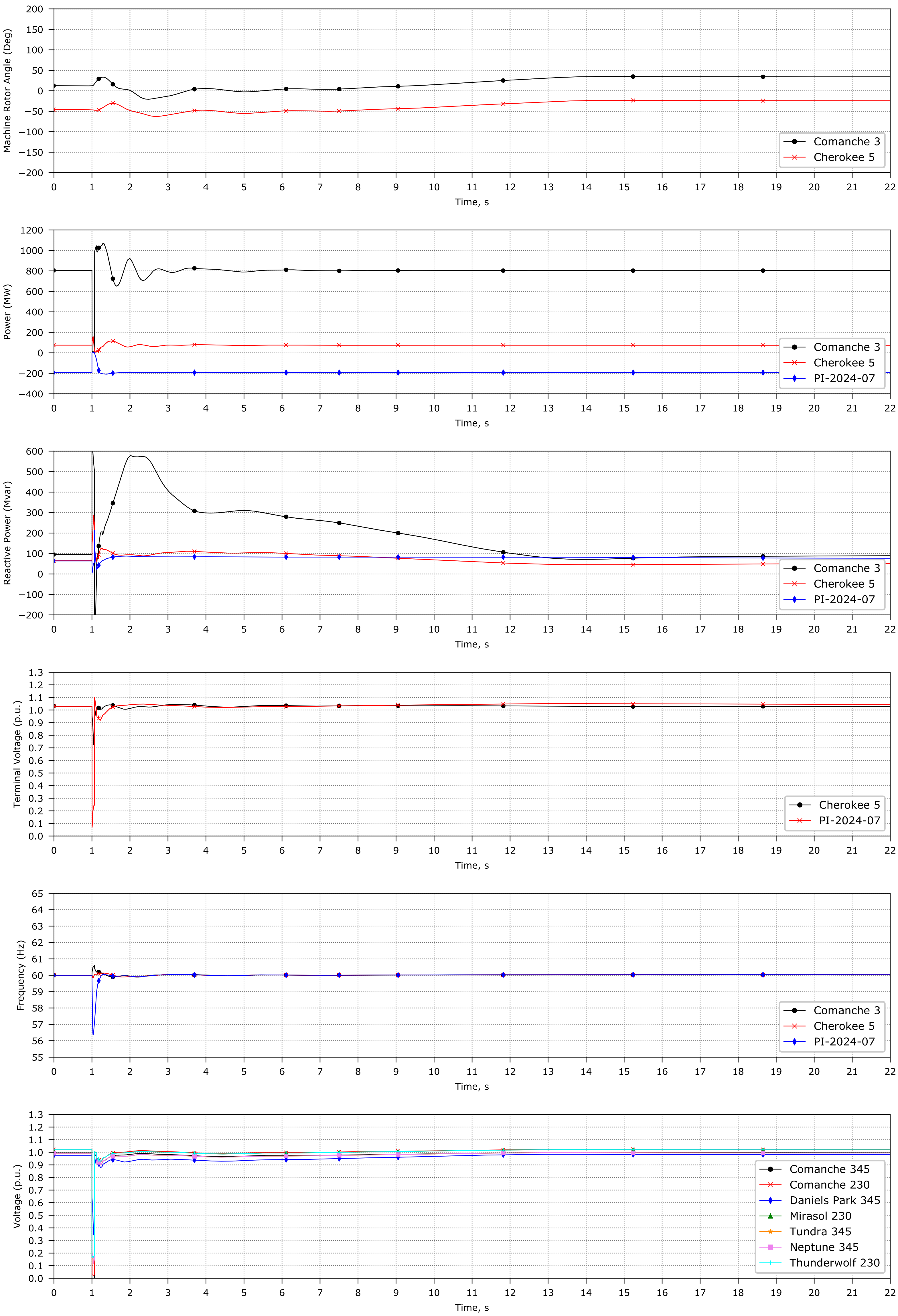
Comanche-Tundra_345kV



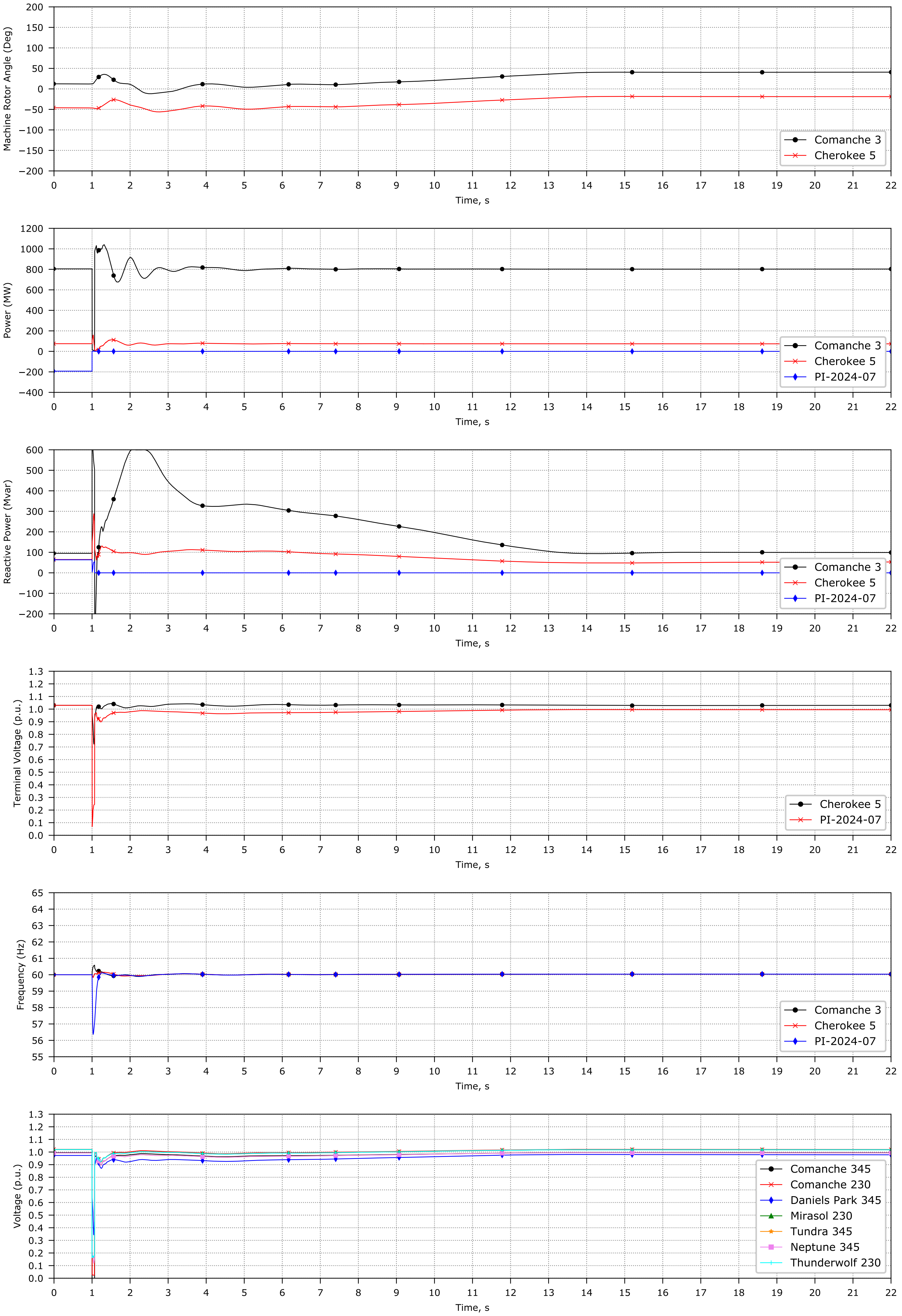
Comanche G3


Machine Rotor Angle (Deg)
Comanche 3
Cherokee 5
Time, s
Power (MW)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Reactive Power (Mvar)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Terminal Voltage (p.u.)
Cherokee 5
PI-2024-07
Time, s
Frequency (Hz)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Voltage (p.u.)
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230
Time, s

Comanche T3

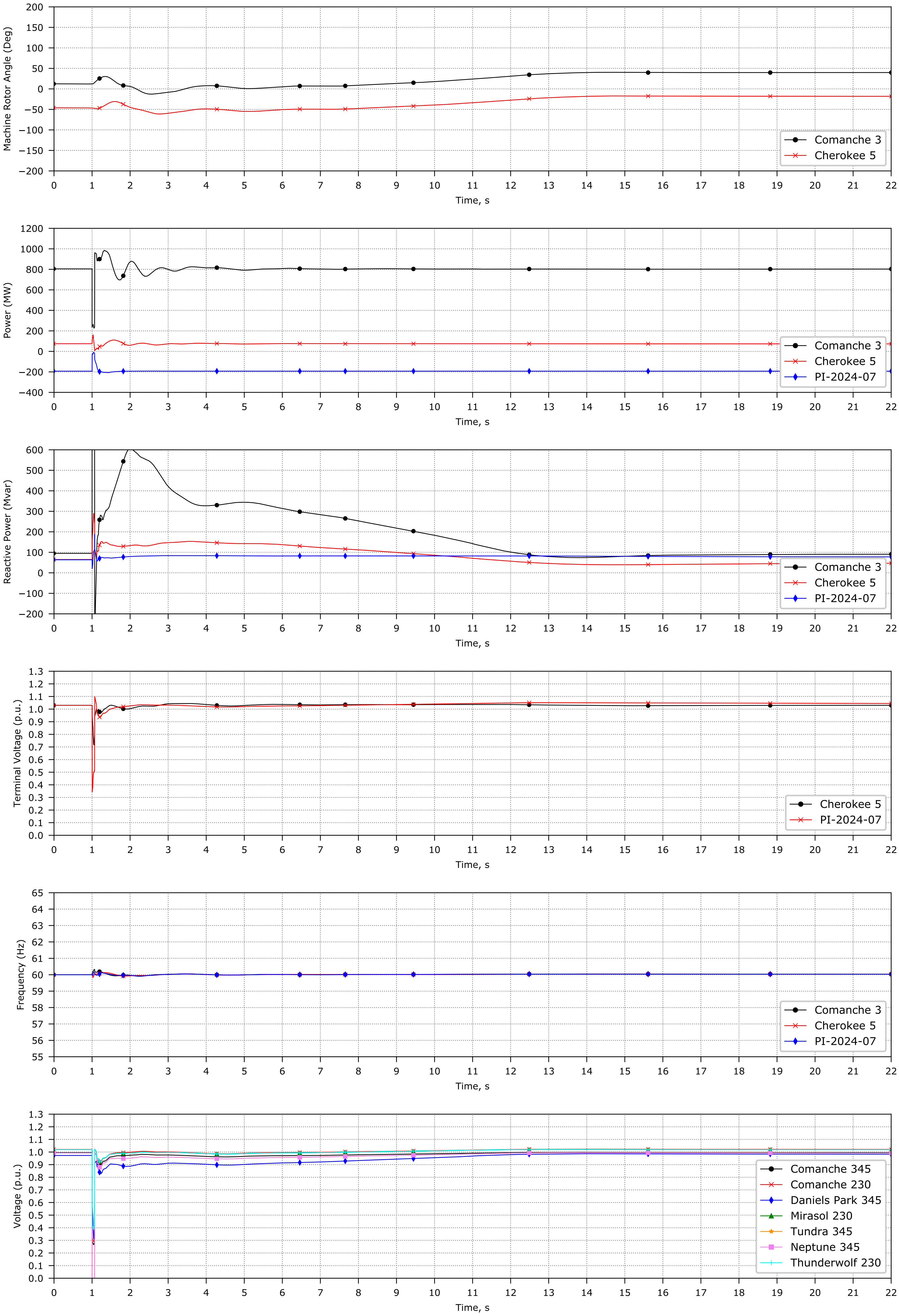

Machine Rotor Angle (Deg)
Time, s
Comanche 3
Cherokee 5
Power (MW)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Reactive Power (Mvar)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Terminal Voltage (p.u.)
Time, s
Cherokee 5
PI-2024-07
Frequency (Hz)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Voltage (p.u.)
Time, s
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230

PI-2024-7_Gen

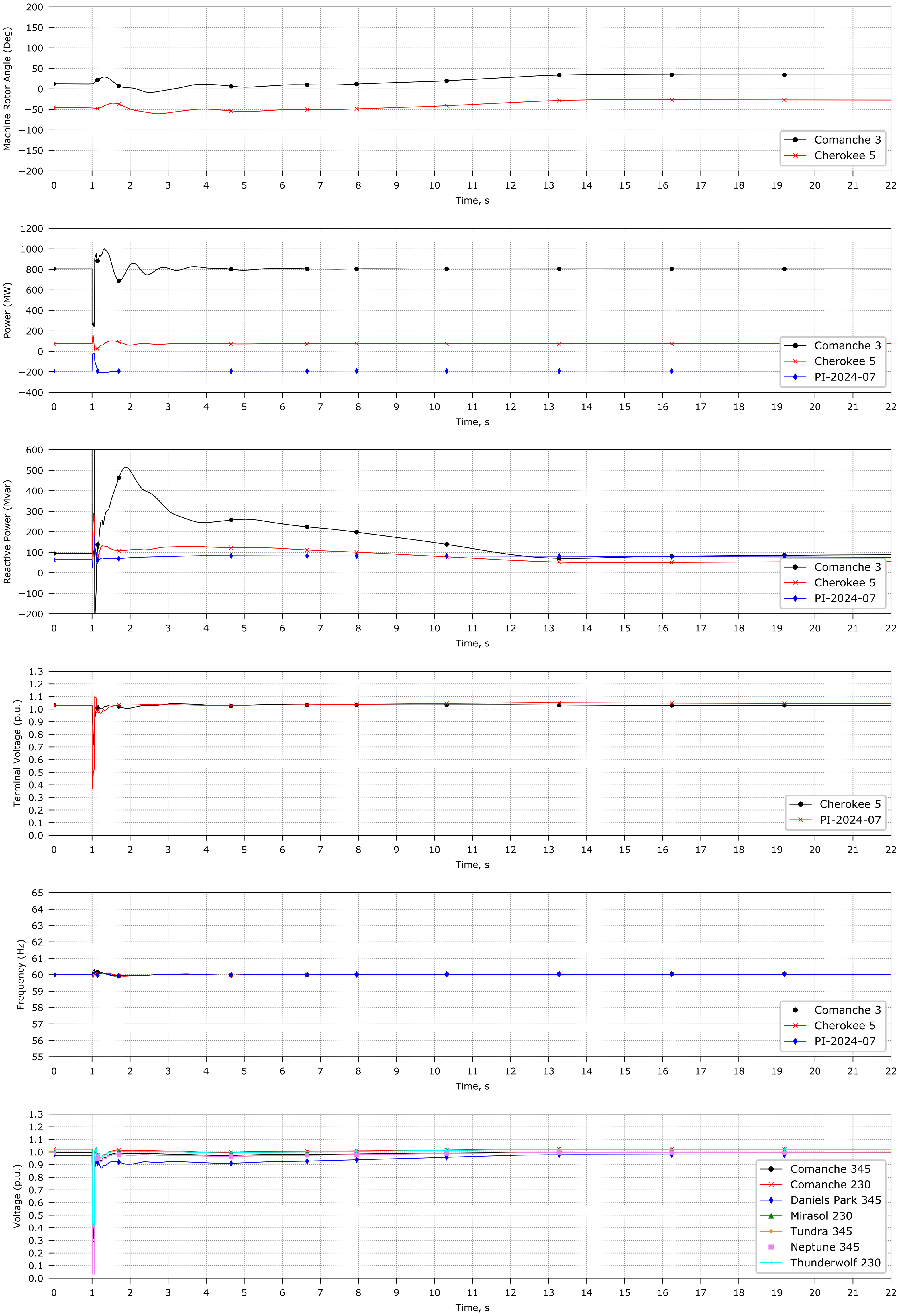


Machine Rotor Angle (Deg)
Comanche 3
Cherokee 5
Time, s
Power (MW)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Reactive Power (Mvar)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Terminal Voltage (p.u.)
Cherokee 5
PI-2024-07
Time, s
Frequency (Hz)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Voltage (p.u.)
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230
Time, s

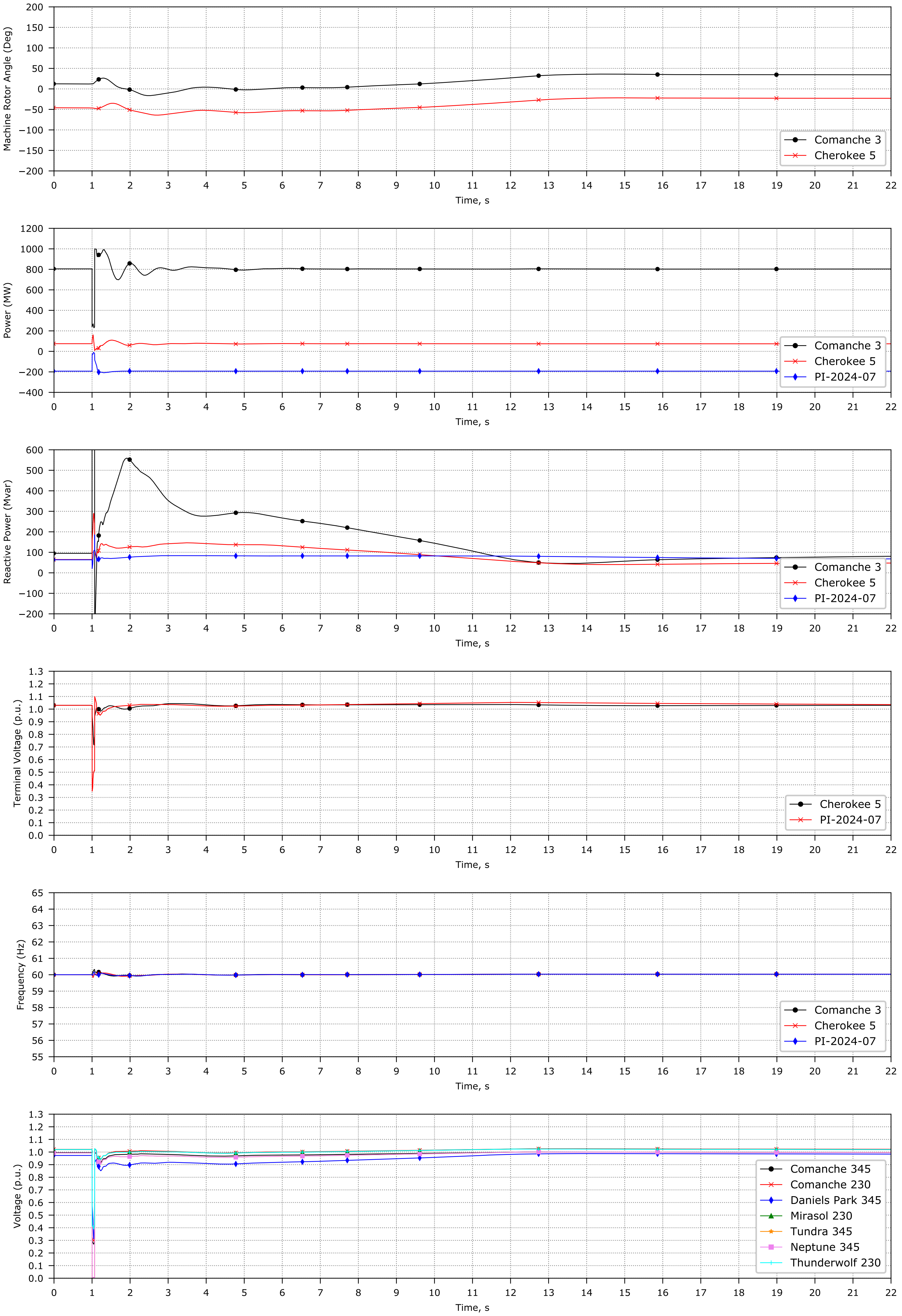
Neptune_Gen


Machine Rotor Angle (Deg)
Time, s
Comanche 3
Cherokee 5
Power (MW)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Reactive Power (Mvar)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Terminal Voltage (p.u.)
Time, s
Cherokee 5
PI-2024-07
Frequency (Hz)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Voltage (p.u.)
Time, s
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230

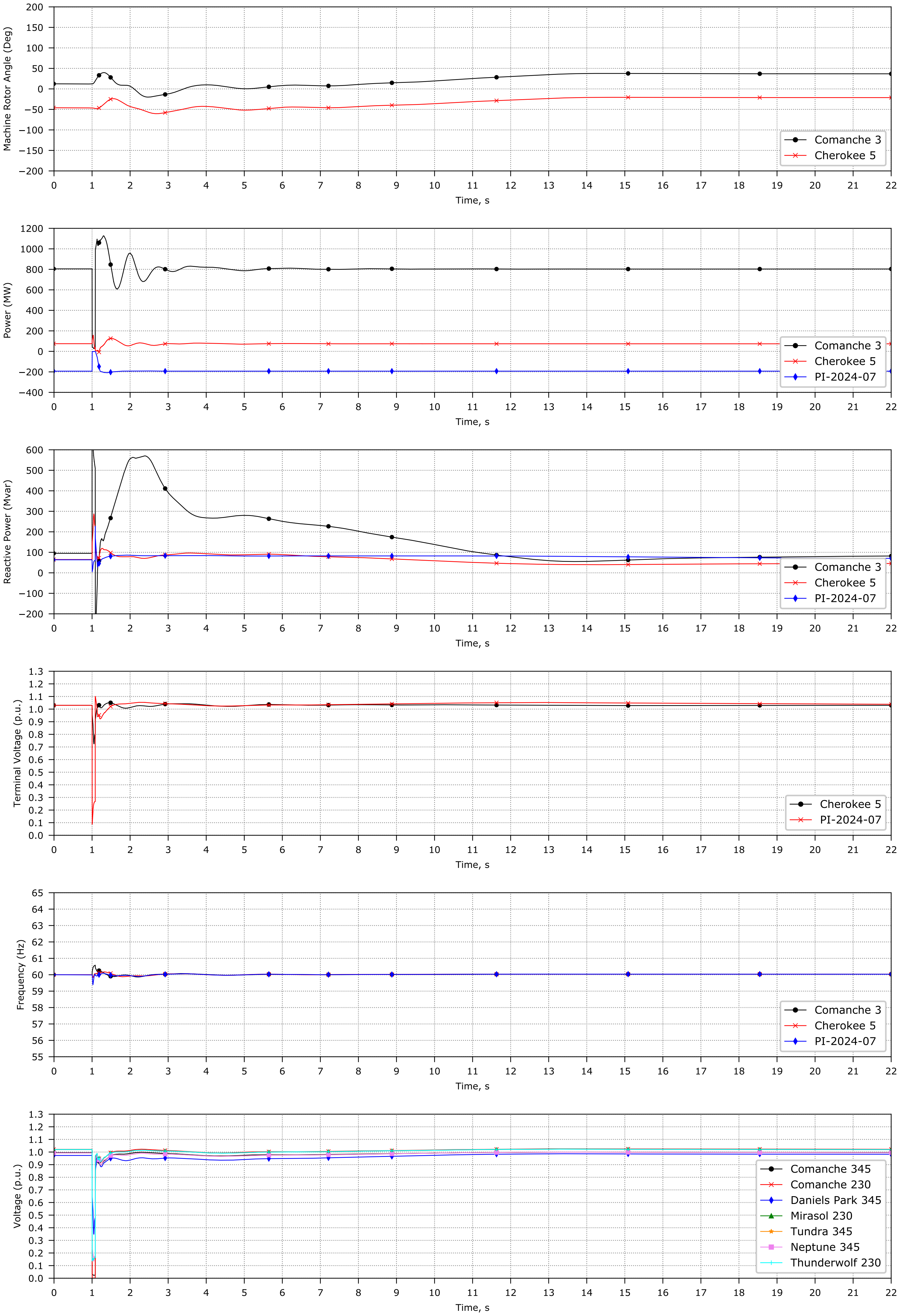
Tundra-DanielsPark_345kV



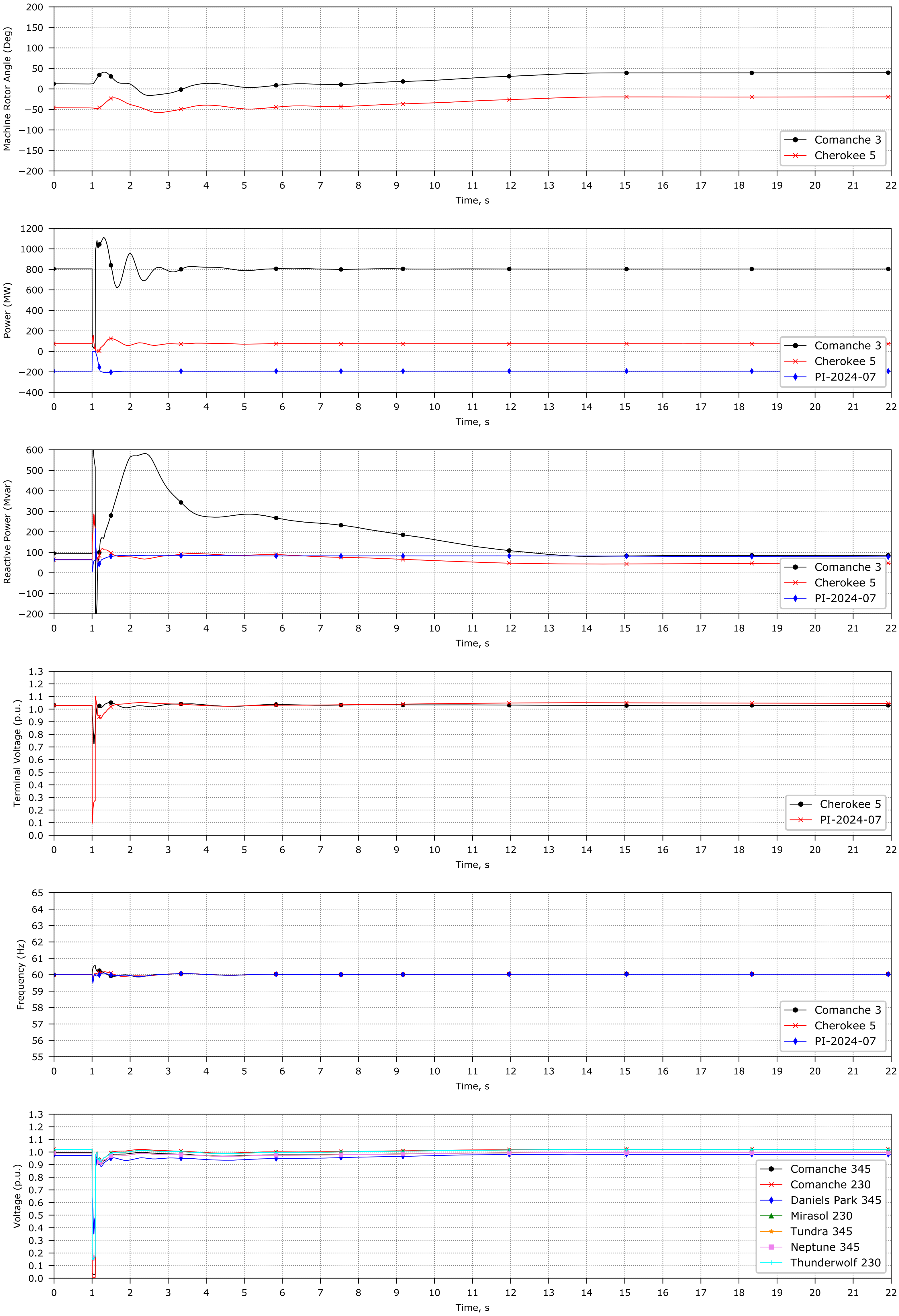
Tundra-Sandstone_345kV



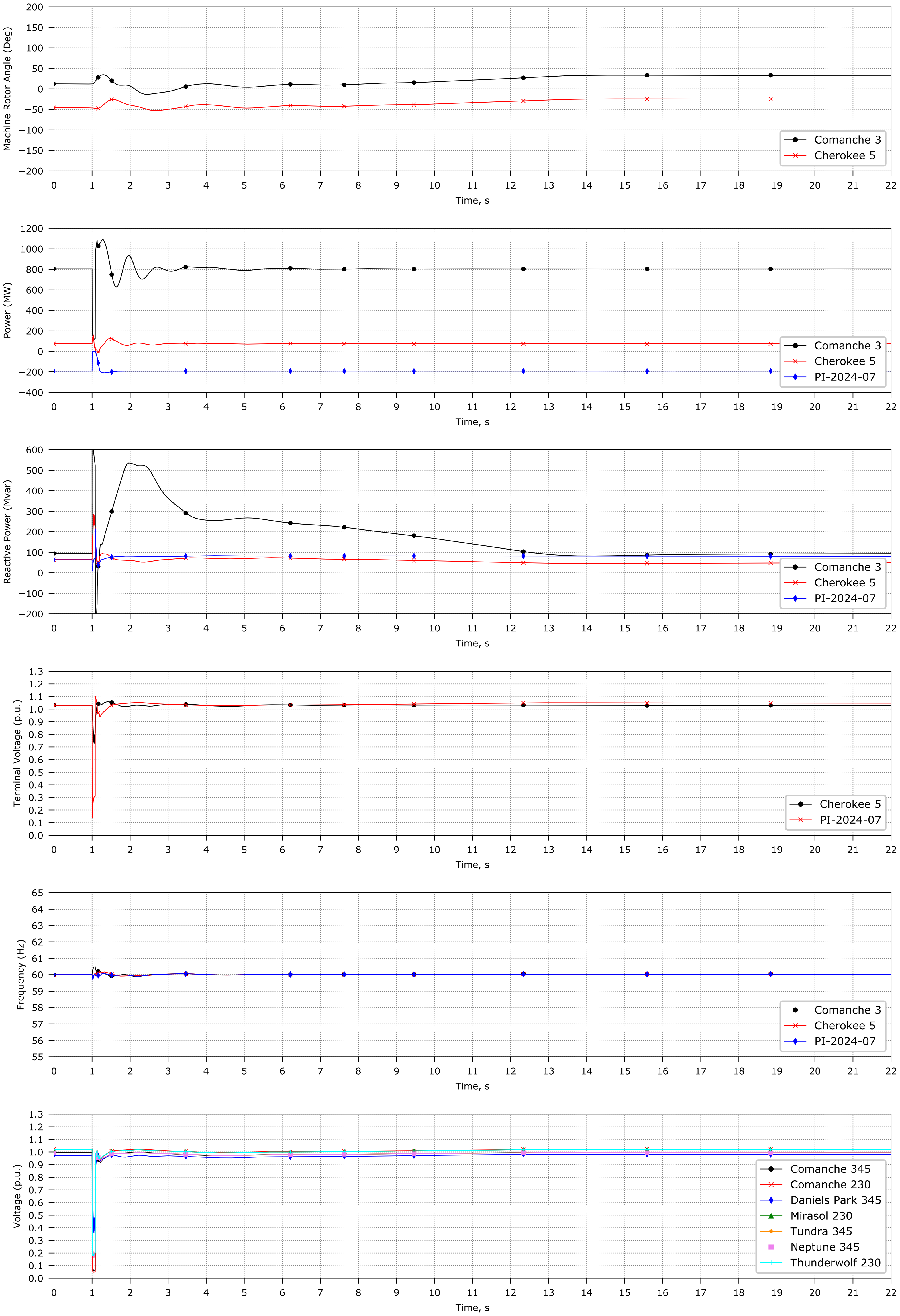
Comanche-Bighorn_230kV



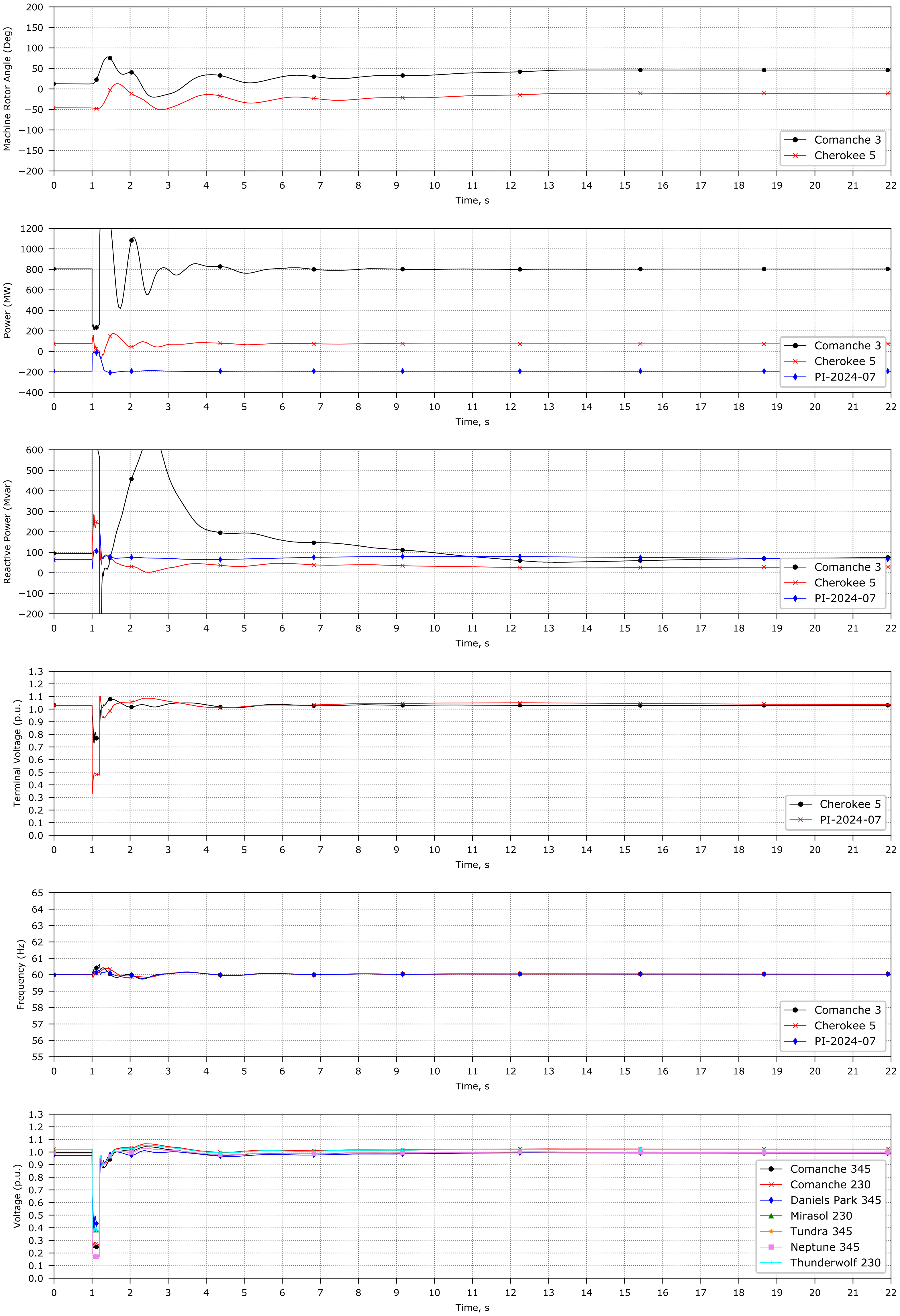
Comanche-Huckleberry_230kV



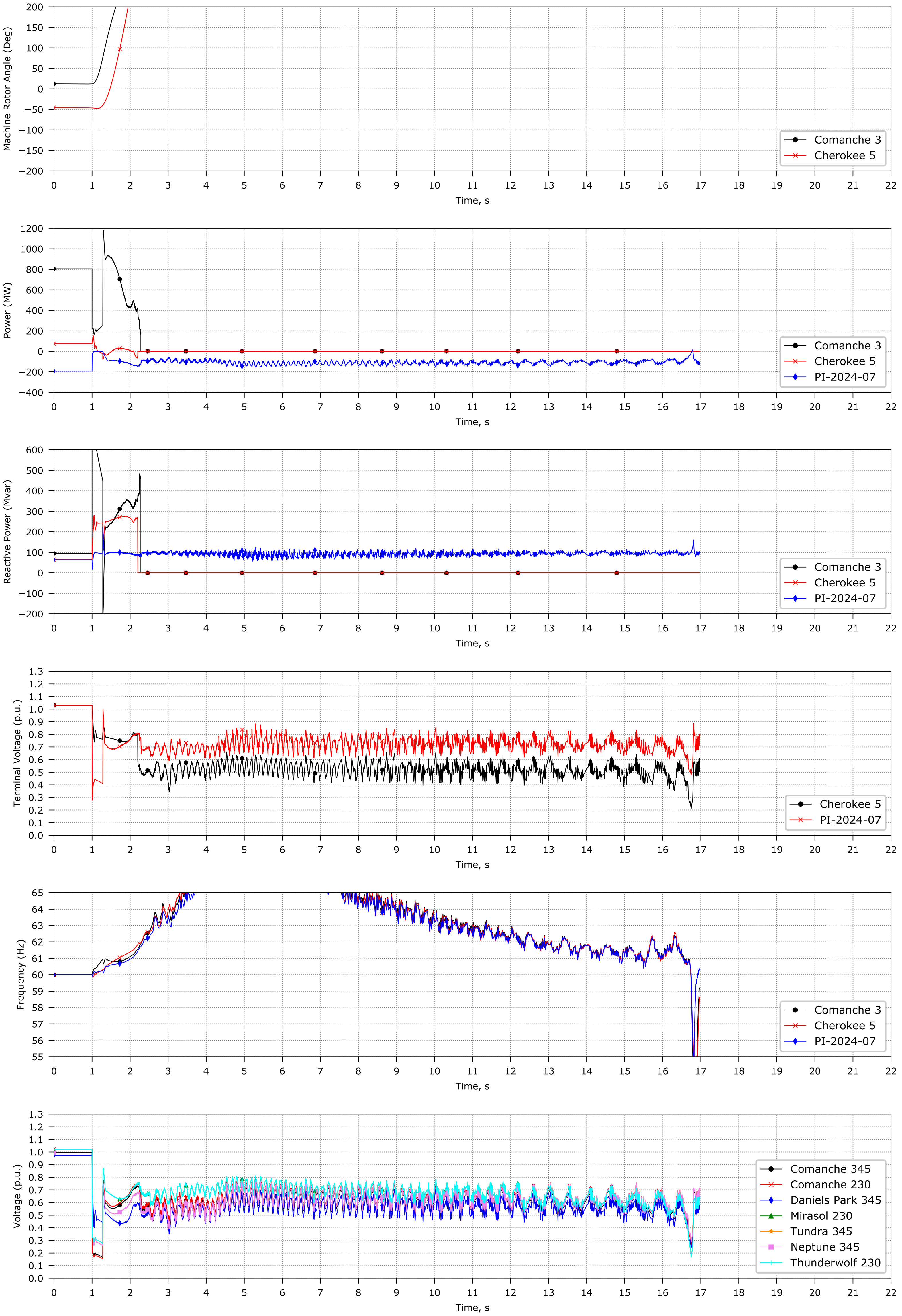
Coman-Boone_230kV



line_128

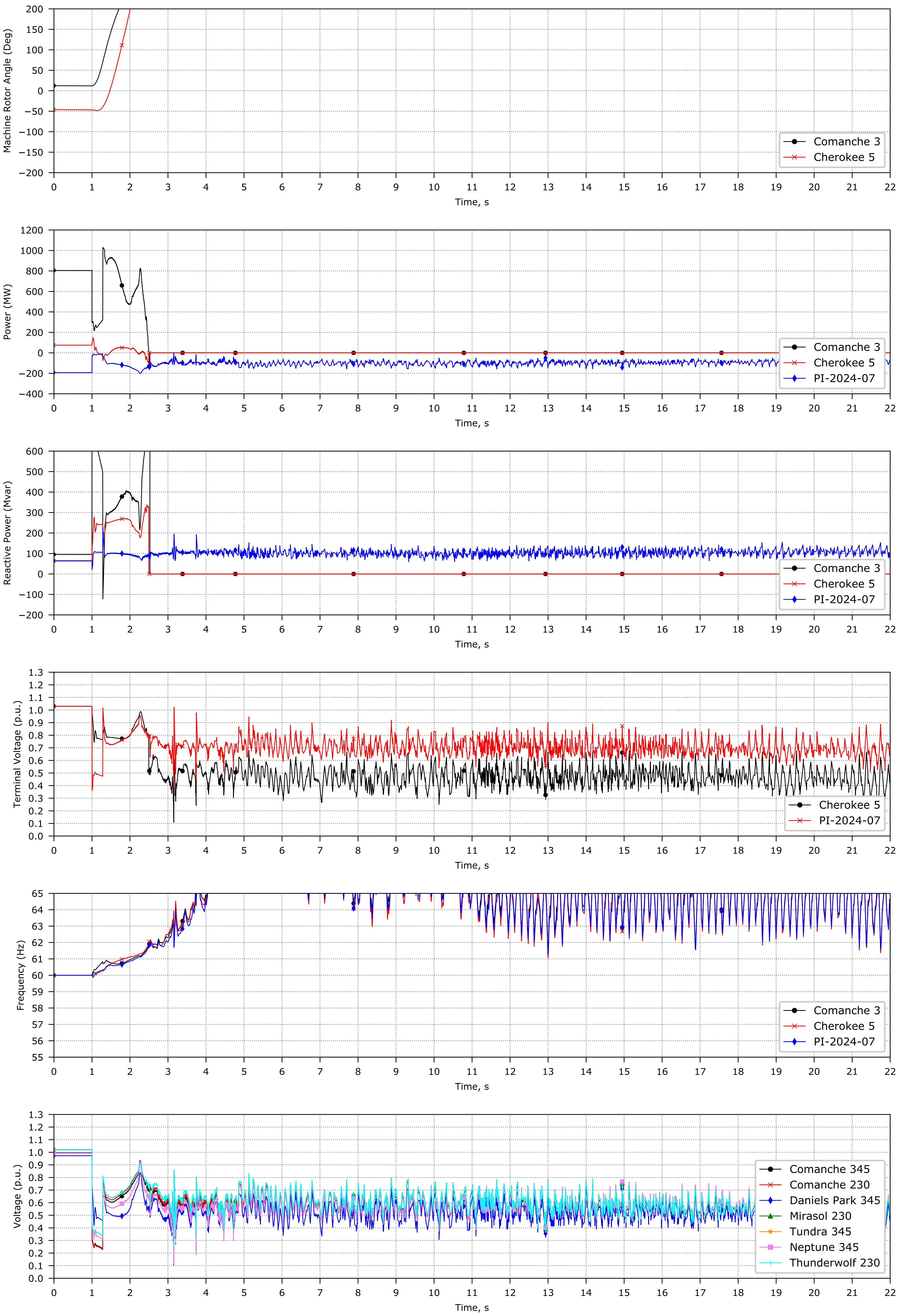

Machine Rotor Angle (Deg)
Time, s
Comanche 3
Cherokee 5
Power (MW)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Reactive Power (Mvar)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Terminal Voltage (p.u.)
Time, s
Cherokee 5
PI-2024-07
Frequency (Hz)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Voltage (p.u.)
Time, s
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230

line_134



Machine Rotor Angle (Deg)
Comanche 3
Cherokee 5
Time, s
Power (MW)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Reactive Power (Mvar)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Terminal Voltage (p.u.)
Cherokee 5
PI-2024-07
Time, s
Frequency (Hz)
Comanche 3
Cherokee 5
PI-2024-07
Time, s
Voltage (p.u.)
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230
Time, s

line_135



Machine Rotor Angle (Deg)
Time, s
Comanche 3
Cherokee 5
Power (MW)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Reactive Power (Mvar)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Terminal Voltage (p.u.)
Time, s
Cherokee 5
PI-2024-07
Frequency (Hz)
Time, s
Comanche 3
Cherokee 5
PI-2024-07
Voltage (p.u.)
Time, s
Comanche 345
Comanche 230
Daniels Park 345
Mirasol 230
Tundra 345
Neptune 345
Thunderwolf 230