3RSC – 2023

Phase 2 Study Report

05/22/2025

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1.0 Executive Summary

Phase 2 of the 3RSC-2023 Resource Solicitation Cluster (RSC) includes Transient Stability, Short-Circuit and Contingent Facilities analyses, as well as cost estimates, for three (3) Generator Interconnection Requests (GIRs):

3RSC-2023-1 is a 200 MW net rated Solar Photovoltaic (PV) Generating Facility requesting Network Resource Interconnection Service (NRIS). The requested Point of Interconnection (POI) is at the Mirasol 230 kV switching station, sharing the common gen-tie with 3RSC-2023-2.

3RSC-2023-2 is a 100 MW net rated Battery Energy Storage System (BESS) Generating Facility requesting NRIS. The requested POI is the Mirasol 230 kV switching station, sharing the common gen-tie with 3RSC-2023-1.

3RSC-2023-3 is a 200 MW net rated Wind Generating Facility requesting NRIS. The requested POI is the May Valley 345 kV switching station.

All generators in this cluster were studied as part of the South study pocket as defined in the Business Practice Manual.

The Transient Stability analysis results indicate that the transmission system will be stable for the addition of the three generator models.

The Short-circuit study results indicate that there will be four overstressed breakers due to the addition of the cluster; however, there are end-of-life replacement projects underway for these breakers. These breakers are added to the list of Contingent Facilities in the report.

The Contingent Facilities analysis confirms a list of unbuilt Interconnection Facilities and Network Upgrades upon which the costs, timing, and study findings of the 3RSC–2023 are dependent, and if delayed or not built, could cause a need for re-studies of the Interconnection Service or a reassessment of the Interconnection Facilities and/or Network Upgrades and/or costs and timing.

The Interconnection Service determined for GIRs in this report in and of itself does not convey any transmission service.

1.1 3RSC-2023-1 Results

The total cost of the upgrades required to interconnect 3RSC-2023-1 at the Mirasol 230 kV switching station for NRIS is $2.5425 million (Table 15, Table 16, Table 19, and Table 20).

NRIS of 3RSC-2023-1 is 200 MW.

1.2 3RSC-2023-2 Results

The total estimated cost of the Network Upgrades required to interconnect 3RSC-2023-2 at the Mirasol 230 kV switching station for NRIS is $2.5425 million (Table 15, Table 16, Table 19, and Table 20).

The Grid Charging study for the 100 MW BESS Generating Facility did not identify any impacts. There are no additional costs identified in the Grid Charging study.

NRIS of 3RSC-2023-2 is 100 MW.

1.3 3RSC-2023-3 Results

The total estimated cost of the Network Upgrades required to interconnect 3RSC-2023-3 at the May Valley 345 kV switching station for NRIS is $5.352 million (Table 17 and Table 21).

NRIS of 3RSC-2023-3 is 200 MW.

2.0 Introduction

Phase 1 of the 3RSC-2023 Cluster was completed, and the study report was published by Public Service Company of Colorado (PSCo) on 12/13/2024. A link to the report is found below:

https://www.rmao.com/public/wtpp/Final_Studies/3RSC-2023%20Phase%201%20Report.pdf

Phase 2 of the 3RSC–2023 Cluster consists of three (3) GIRs, shown in Table 1. The total Interconnection Service requested in the 3RSC-2023 is 500 MW.

All three GIRs requested Network Resource Interconnection Service (NRIS)[1]. A summary and description of the requests is shown in Table 1.

Table 1 – Summary of GIRs in 3RSC-2023 Cluster

GI#	Resource Type	Interconnection Service (MW)	COD	POI	Location	Service Type
3RSC-2023-1	PV	200	12/31/2025	Mirasol 230 kV	Pueblo County, CO	NRIS
3RSC-2023-2	BESS	100	12/31/2025	Mirasol 230 kV	Pueblo County, CO	NRIS
3RSC-2023-3	Wind	200	12/31/2025	May Valley 345 kV	Kiowa County, CO	NRIS
Total		500				

The approximate geographical locations of the POIs within the Transmission System are shown in Figure 1.

[1] Network Resource Interconnection Service shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission system (1) in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an RTO or ISO with market-based congestion management, in the same manner as all other Network Resources. Network Resource Interconnection Service in and of itself does not convey transmission service.

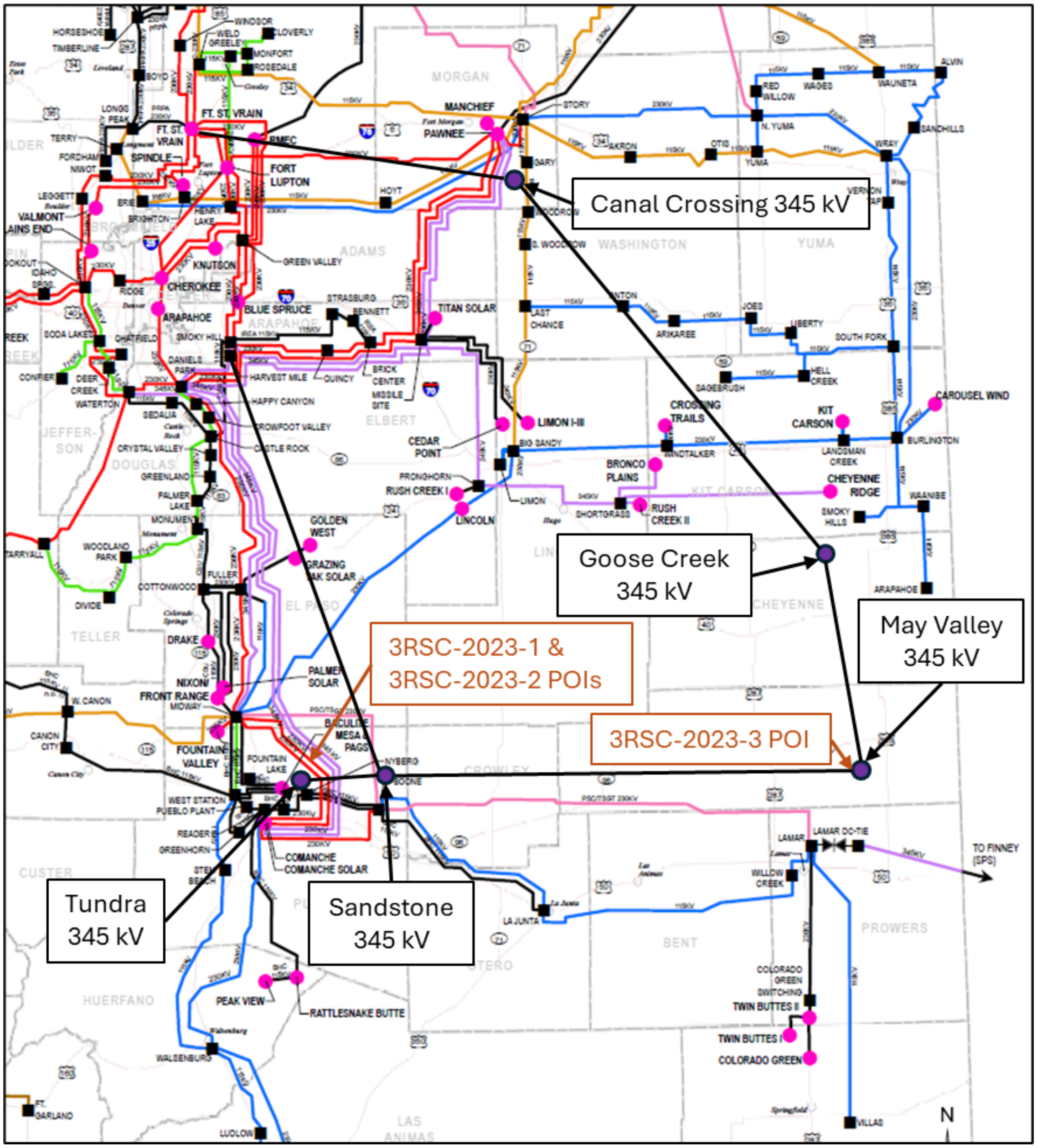


Figure 1 – Approximate Locations of 3RSC-2023 Generator Interconnection POIs

3.0 Description of the GIRs

3.1 3RSC-2023-1

3RSC-2023-1 is a 200 MW net rated Solar Photovoltaic Generating Facility located in Pueblo County, Colorado. The project assumes the following:

- The use of fifty-six (56) Power Electronics FreeSun FS4200M inverters, each rated at 4.2 MVA at 45 degrees C operating at +/-0.87 power factor.
- Each of the 4.2 MVA inverters is connected to a collector transformer, 0.66/34.5 kV, rated at 4.2 MVA.
- Two 230/34.5/13.8 kV main GSU transformers rated at 99/132/165 MVA step the voltage up from the collector transformer voltage to the POI voltage.
- An approximately 1.27-mile generation tie line connecting the project to the Mirasol 230 kV switching station. This is the common generation tie line shared with 3RSC-2023-2.
- The proposed Commercial Operation Date (COD) is December 31, 2025. The back-feed date is assumed to be June 30, 2025, approximately six (6) months before the COD.

3.2 3RSC-2023-2

3RSC-2023-2 is a 100 MW net rated Battery Energy Storage System Generating Facility located in Pueblo County, Colorado. This project assumes the following:

- The use of twenty-eight (28) Power Electronics FreeSun FS4200M inverters, each rated at 4.2 MVA at 45 degrees C operating at +/-0.87 power factor.
- Each of the 4.2 MVA inverters is connected to a collector transformer, 0.66/34.5 kV, rated at 4.2 MVA.
- A 230/34.5/13.8 kV main GSU transformer rated at 99/132/165 MVA steps the voltage up from the collector transformer voltage to the POI voltage.
- An approximately 1.27-mile generation tie line connecting the project to Mirasol 230 kV switching station. This is the common generation tie line shared with 3RSC-2023-1.
- The BESS facility has a maximum state of charge of 100% and minimum state of charge of 0%.
- The proposed COD is December 31, 2025. The back-feed date is assumed to be June 30, 2025, approximately six (6) months before the COD.

3.3 3RSC-2023-3

3RSC-2023-3 is a 200 MW net rated Wind Generating Facility located in Kiowa County, Colorado. This project assumes the following:

- The use of sixty-one (61) GE 3.4-140 wind turbine generators (WTGs), each rated at 3.778 MVA at 45 degrees C operating at +/-0.90 power factor.
- Each of the WTGs is connected to a collector transformer, 0.69/34.5 kV, rated at 3.811 MVA.
- Two 345/34.5/13.8 kV main GSU transformers rated at 73.8/98/123 MVA step the voltage up from the collector transformer voltage to the POI voltage.
- An approximately 8-mile generation tie line connecting the project to the May Valley 345 kV switching station.
- The proposed COD of 3RSC-2023-3 is December 31, 2025. The back-feed date is assumed to be June 30, 2025, approximately six (6) months before the COD.

4.0 Study Scope

The purpose of the Phase 2 study is to determine the system impact of interconnecting three (3) GIRs for the 3RSC-2023 cluster for Interconnection Service. Each GIR will be studied for impacts on the specific study pocket to determine the full impact of the proposed generation.

The scope of the study includes Transient Stability, Short-Circuit and Contingent Facility analyses, as well as cost estimates. The non-binding cost estimates provide total costs and each GIR's cost responsibility for Transmission Provider Interconnection Facilities (TPIF), Station Network Upgrades, and System Network Upgrades.

Additionally, GIRs that include BESS and specified grid charging were studied at their respective charging rate in a Grid Charging Study Case.

4.1 Study Pockets

Based on the POI location of each GIR, they were all grouped within the South Colorado study pocket. The South 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. Below is the current generation in the Southern Colorado study area:

- Comanche: Golden West Wind at Fuller, Fountain Valley Gas at Midway, Comanche Coal and (Solar—replacement generator), Community Solar at Comanche, Mirasol, Tundra.
- Lamar: Colorado Green Wind, Twin Buttes Wind, DC Tie.

4.2 Study Criteria

The following criteria are used for the reliability analysis of the PSCo system and Affected Systems. The transient voltage stability criteria are as follows:

a. Following fault clearing, 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.
d. Please note, generator bus frequency plots are included, however, PSCo does not have criteria for frequency events.

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.

The breaker duty analysis criterion is fault current after GIR(s) addition should not exceed 100% of the breaker duty rating.

4.3 Study Methodology

4.3.1 Transient Stability Study Methodology

All generators in the study pocket should meet the transient stability criteria. If any violations are found, the contributing GIR(s) will be identified for performance violations and mitigations will be attributed to the contributing generator(s). The stability analysis is performed by running selected single and multiple contingencies in the study pocket.

4.3.2 Short-Circuit and Breaker Duty Study Methodology

Generator tie lines and customer main power transformers connected at the voltage of the POI were modeled in CAPE based on impedance and configuration information provided by the customer. Conventional generators were modeled on a per-machine basis, using impedance information provided by the customer. All inverter-based generation, including generator step-up transformers, were modeled on an aggregate basis using appropriately scaled generic models at the low side of the main power transformer(s).

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, regardless of any limitations to the output that would be imposed otherwise.

All studies included in-service equipment, plus any additional network upgrades identified by Transmission Planning. A base case study was performed, without any of the interconnections or network upgrades from the cluster included, to identify prior fault current levels.

Short circuit current and equivalent system impedances were obtained from CAPE for three-phase and single-line-to-ground faults at each POI used by any customer in the cluster. The fault currents and system impedances were calculated for the base case scenario without any of the cluster elements and for the entire cluster, including identified network upgrades.

Breaker duty studies were performed for the base case scenario and for the entire cluster, including network upgrades. Transmission circuit breakers that were identified as overstressed (0% margin) in the base case study are not included in the list.

Breaker duty studies are conducted using a sub-transient fault analysis. Single and three phase faults are placed at each substation in the system. Fault current supplied by the generation interconnect is variable and dependent upon the location of the fault in the system. Each breaker is modeled by the manufacturer and model number with the catalog characteristics for that breaker and its application, i.e., the relevant standard applying to that breaker's date of manufacture, kA interrupting rating, voltage rating, relay operate time, breaker interrupting time, proximity to generation, etc. The reclosing scheme is not considered in the analysis. The aforementioned factors are used to calculate an XR factor according to ANSI C37.010-1999, ANSI C37.5-1979, or C37.6-1971. For evaluation of breaker opening by C37.010-1999, applicable to all breakers identified in this study, and with no reclosing and no additional de-rating, the equivalent current that the breaker is required to interrupt is simply the fault current multiplied by the XR factor ($I_{breaking}$). This is compared against that breaker's rated interrupting capacity to determine whether the breaker is overstressed. If it is greater than the breaker's interrupting capacity, it is considered to be overstressed (0% margin).

4.3.3 Contingent Facilities Study Methodology

This analysis assesses unbuilt Interconnection Facilities and Network Upgrades that may be necessary to accommodate the Interconnection Customer's requested interconnection. Any unbuilt facility included in the study model that is necessary as determined by this technical study to accommodate the Interconnection Request will be identified as a Contingent Facility.

The unbuilt facilities listed in Table 2 were studied individually, and each one of them was considered a potential contingent facility. The study involves reverting the unbuilt facility and a power flow impact analysis to assess the impact of not building those facilities. If reverting the unbuilt facility causes or increases an overload in more than 1% of the monitored facility rating, with more than 3% study generator DFAX, the unbuilt facility will be identified as a contingent facility for that study generator.

Table 2 – Tested Potential Contingent Facilities

Ref. No.	Unbuilt Facility
1	Daniels Park - Jackson Fuller L5119 uprate to 637 MVA
2	Midway - Jackson Fuller L5129 uprate to 637 MVA
3	New Fort St. Vrain 230/345 kV 560 MVA Transformer T9
4	Gray Street - Lakewood L9000 uprate to 128 MVA
5	Gray Street - Lakewood L9005 uprate to 128 MVA
6	Palmer Lake - Fox Run L9605 uprate to 239 MVA
7	May Valley 345 kV Synchronous Condensers
8	Goose Creek 345 kV STATCOM
9	New Smoky Hill 230/345 kV 560 MVA Transformer T7
10	Double Circuit Cherokee-Sandown-Chambers-Harvest Mile

5.0 Base Case Modeling Assumptions

The 2029HS2 WECC case released on May 8, 2023, was selected as the Starting Case. The 2030HS Base Case was created from the Starting Case by including the following modeling changes:

- Godfrey – Gilcrest – Anadarko line uprate to 239 MVA
- Greenwood bus tie uprate to 956 MVA
- Daniels Park – Prairie – Greenwood L5707 uprate to 916 MVA
- Leetsdale – Monroe L5283 uprate to 796 MVA
- Cherokee – Federal Heights – Broomfield line uprate to 398 MVA
- Daniels Park – Prairie – Greenwood L5111 uprate to 916 MVA
- Arapahoe – Greenwood L5709 uprate to 956 MVA
- Arapahoe – South – Bancroft L9335 uprate to 239 MVA
- Arapahoe – ARLQ – South – Gray L9332 uprate to 159 MVA
- Updating Greenwood – Monaco series reactor to X = 0.0145
- New Fort Lupton 230/115 kV transformer #4
- New Arapahoe 230/115 kV transformer #6
- Monroe – Elati – Denver Terminal line uprate to 796 MVA
- Leetsdale – Harrison L9955 uprate tot 378 MVA
- Cherokee – Mapleton 115 kV line uprate to 318 MVA
- Daniels Park – Santa Fe 230 kV line uprate to 637 MVA
- New South 230 kV bus
- New Smoky Hill 345/230 kV transformer #6
- Cherokee – Federal Heights – Semper L9055 uprate to 398 MVA
- Daniels Park 345/230 kV 560 MVA transformer #4
- Gray Street rebuild (GRAY – FEDC, GRAY – DTER)
- Buckley – Tollgate L5285 uprate to 796 MVA
- Jewell – Tollgate L5285 uprate to 796 MVA
- Jewell – Leetsdale L5285 uprate to 796 MVA
- Buckley – Smoky Hill L5167 uprate to 796 MVA
- Spruce – High Point 230 kV line uprate to 741.4 MVA
- Daniels Park – Fuller FAC-8 uprate to 637 MVA
- Gray Street – Lakewood 1 FAC-8 uprate to 128 MVA
- Gray Street – Lakewood 2 FAC-8 uprate to 128 MVA
- Midway PS – Fuller FAC-8 uprate to 637 MVA
- Poncha W – Smelter rate correction to 119.5 MVA.
- New Fort St. Vrain 345/230 kV 560 MVA transformer #9
- New Smoky Hill 345/230 kV 560 MVA transformer #7
- Double circuit PRJ topology – ISD TBD.
- Addition of New Harvest Mile 345/230 kV 560 MVA transformer #3
- Palmer – Fox Run uprate to 239 MVA

- New Harvest Mile – New Chambers double circuit uprate to 1195 MVA

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.
- Segment #4: May Valley – Sandstone – Tundra 345 kV Double Circuit.
- Segment #5: Sandstone – Harvest Mile 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.

PSCo used this 2030HS base case to reflect the major system upgrades expected after the latest requested COD (YE 2025) in the RSC Cluster and associated transmission system use by native load (PSCo's reservation for native load priority).

5.1 South Colorado Benchmark Case Modeling

The Benchmark Case was created from the Base Case (2030HS) by changing the study pocket generation dispatch to reflect heavy generation in the Southern Colorado study pocket. This was accomplished by adopting the generation dispatch in Table 3. Additionally, 4050 MW of Native Load Priority (NLP) was modeled, as shown in Table 4.

Table 3 – Generation Dispatch Used to Create the Southern Colorado Benchmark Case (MW is Gross Capacity)

Bus Number	Bus Name	Voltage (kV)	ID	Status	Pgen (MW)	Pmax (MW)
70878	BIGHORN_S	0.63	S1	1	210.4	247.5
70708	CO_GRN_E	0.58	W1	1	64.8	81.0
70256	CO_GRN_W	0.58	W2	1	64.8	81.0
70120	COMAN_2	24.00	C2	1	365.0	365.0
70777	COMAN_3	27.00	C3	1	804.9	804.9
70934	COMAN_S1	0.42	S1	1	102.0	120.0
70577	FTNVL1&2	13.8	G1	1	35.4	40.0
70577	FTNVL1&2	13.8	G2	1	35.4	40.0

Bus Number	Bus Name	Voltage (kV)	ID	Status	Pgen (MW)	Pmax (MW)
70578	FTNVL3&4	13.8	G4	1	35.4	40.0
70578	FTNVL3&4	13.8	G3	1	35.4	40.0
70579	FTNVL5&6	13.8	G5	1	35.4	40.0
70579	FTNVL5&6	13.8	G6	1	35.4	40.0
70663	GLDNWST_W1	0.69	W1	1	199.5	249.4
70756	NEPTUNE_B1	0.48	B1	1	106.3	125.0
70758	NEPTUNE_S1	0.66	S1	1	212.9	250.5
70859	SUN_MTN_S1	0.66	S1	1	172.3	202.7
70704	TBI_GEN	0.58	W1	1	60.0	75.0
70010	TBII_GEN	0.69	W	1	62.4	78.0
70761	THNDWLF_B1	0.48	B1	1	85.0	100.0
70763	THNDWLF_S1	0.66	S1	1	170.0	200.0
700119	21_1_S1	0.66	S1	1	75.0	121.2
700120	21_1_S2	0.66	S2	1	75.0	121.2
700121	21_1_S3	0.66	S3	1	75.0	121.2
700122	21_1_B1	0.69	B1	1	33.3	76.6
700123	21_1_B2	0.69	B2	1	33.3	76.6
700124	21_1_B3	0.69	B3	1	33.3	76.6
Total (MW)					**3217.6**	

Table 4 – NLP Generation Included

Generator Bus Number	Name	ID	Status	Pgen (MW)
700043	24_14_B	B	1	192.3
700057	24_13_W2	W2	1	143.3
700060	24_13_W3	W3	1	143.3
700063	24_13_W4	W4	1	122.9
700067	24_13_W1	W1	1	143.3
700076	24_12_W1	W1	1	109.2
700077	24_12_W2	W2	1	122.9
700078	24_12_W3	W3	1	109.2
700079	24_9_W1	W1	1	116.0
700082	24_9_W2	W2	1	122.9
700085	24_9_W3	W3	1	102.4
700088	24_9_W4	W4	1	116.0
700095	24_18_W	W	1	235.8
700182	24_28_W	W	1	389.2
700196	24_19_W1	W1	1	419.8

Generator Bus Number	Name	ID	Status	Pgen (MW)
700226	24_6_S	S	1	336.4
700232	24_22_S	S	1	384.9
700235	24_26_S1	S1	1	116.0
700237	24_26_B1	B1	1	76.6
700239	24_26_S2	S2	1	116.0
700241	24_26_B2	B2	1	76.6
700244	24_27_B1	B1	1	82.9
700245	24_27_B2	B2	1	79.3
700246	24_27_S1	S1	1	96.8
700247	24_27_S2	S2	1	96.8
Total (MW)				**4050.8**

5.2 Grid Charging Benchmark Case Modeling

The Grid Charging Benchmark Case was created from the Benchmark Case from the previous section 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 in Table 5.

Table 5 – Generation Dispatch to Create the Southern Colorado Grid Charging Benchmark Case (MW is Gross Capacity)

Bus Number	Bus Name	Voltage (kV)	ID	Status	Pgen (MW)	Pmax (MW)
70878	BIGHORN_S	0.63	S1	1	0.0	247.5
70708	CO_GRN_E	0.58	W1	1	17.0	81.0
70256	CO_GRN_W	0.58	W2	1	17.0	81.0
70120	COMAN_2	24.00	C2	1	365.0	365.0
70777	COMAN_3	27.00	C3	1	804.9	804.9
70934	COMAN_S1	0.42	S1	1	0.0	120.0
70577	FTNVL1&2	13.8	G1	1	35.4	40.0
70577	FTNVL1&2	13.8	G2	1	35.4	40.0
70578	FTNVL3&4	13.8	G4	1	35.4	40.0
70578	FTNVL3&4	13.8	G3	1	35.4	40.0
70579	FTNVL5&6	13.8	G5	1	35.4	40.0
70579	FTNVL5&6	13.8	G6	1	35.4	40.0
70663	GLDNWST_W1	0.69	W1	1	52.4	249.4
70756	NEPTUNE_B1	0.48	B1	1	-112.9	125.0

Bus Number	Bus Name	Voltage (kV)	ID	Status	Pgen (MW)	Pmax (MW)
70758	NEPTUNE_S1	0.66	S1	1	0.0	250.5
70859	SUN_MTN_S1	0.66	S1	1	0.0	202.7
70704	TBI_GEN	0.58	W1	1	15.8	75.0
70010	TBII_GEN	0.69	W	1	16.4	78.0
70761	THNDWLF_B1	0.48	B1	1	-50.0	100.0
70763	THNDWLF_S1	0.66	S1	1	0.0	200.0
700119	21_1_S1	0.66	S1	1	0.0	121.2
700120	21_1_S2	0.66	S2	1	0.0	121.2
700121	21_1_S3	0.66	S3	1	0.0	121.2
700122	21_1_B1	0.69	B1	1	-76.6	76.6
700123	21_1_B2	0.69	B2	1	-76.6	76.6
700124	21_1_B3	0.69	B3	1	-76.6	76.6
Total					1108.2	

5.3 Study Case Modeling

The Southern Colorado pocket NRIS Study Case was developed from the Benchmark Case by modeling 3RSC-2023-1, 3RSC-2023-2, and 3RSC-2023-3 at their respective POIs. The total 500 MW generation from study GIRs was balanced against all PSCo generation connected to the PSCo Transmission System outside the study pocket on a pro-rata basis.

The Southern Colorado pocket Grid Charging Study Case was developed from the Grid Charging Benchmark Case by modeling 3RSC-2023-2 as a load at its respective POI. The 100 MW consumption from the study GIR was balanced against all PSCo generation connected to the PSCo Transmission System outside the study pocket on a pro-rata basis.

6.0 Steady State Analysis

This section summarizes the Steady-State Analysis results obtained in the Phase 1 of the 3RSC–2023 study. As stated in the Phase 1 report, the multiple contingency analysis was done for informational purposes only and, per TPL-001-5, overloads resulting from multiple contingencies were mitigated using system adjustments including generation redispatch and/or operator actions. Thus, the Phase 2 study report will only include a summary of the system intact and single contingency analyses.

6.1 NRIS Study Case Results

Contingency analysis was performed on the Southern Colorado pocket NRIS Study Case. The results are summarized below:

- System-Intact analysis: No voltage violations attributable to 3RSC-2023-01, 3RSC-2023-02 and 3RSC-2023-03 were identified. Table 6 lists the overloads attributed to 3RSC-2023-01 and 3RSC-2023-02 GIRs. No thermal overload is attributed to 3RSC-2023-03 GIR. Thermal overloads occur on Affected Systems' facilities and, therefore, they will not be mitigated as part of this analysis. The Affected System in Table 6 is CSU and the customer is responsible for working with the Affected System to identify any needed mitigation.
- Single Contingency analysis: No voltage violations attributable to 3RSC-2023-01, 3RSC-2023-02 and 3RSC-2023-03 were identified. Table 7 lists the overloads attributed to 3RSC-2023 GIRs. Thermal overloads Ref. Nos. 1, 7, 8, 9, 10, 14, 16, 17,19, and 21 are not attributed to 3RSC-2023-03 GIR. Note thermal overloads occur on non-PSCo-owned facilities and, therefore, they will not be mitigated as part of this analysis. The Affected Systems in Table 7 are CSU, TSGT, WAPA and Black Hills, and the customer is responsible for working with the Affected Systems to identify any needed mitigation.

Table 6 – System Intact Thermal Overloads for NRIS Study Case

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	Base Case	115	73	CSU	142	100.73	111.59	10.86
2	Flyhorse S (73576) - Kettleck N (73711) 115 kV CKT 1	Base Case	115	73	CSU	162	100.74	110.28	9.54
3	Cttnwd N (73391) - Kettleck S (73410) 115 kV CKT 1	Base Case	115	73	CSU	162	100.53	107.64	7.11

Table 7 – Single Contingency Thermal Overloads for NRIS Study Case

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Normal Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
1	Cttnwd N (73391) - Kettleck S (73410) 115 kV CKT 1	Briargate S (73389) - Briargate N (73710) 115 kV CKT 1	115	73	CSU	162	165.66	175.98	10.32
2	Foxrun (73414) - Flyhorse N2 (73738) 115 kV CKT 1	Vollmert (72413) - Fuller (73481) 115 kV CKT 1	115	73	CSU	142	154.33	168.20	13.87
3	W. Canon (70550) - Hogback115 (71025) 115 kV CKT 1	Midway BR (73413) - Hambone Tap (73638) 230 kV CKT 1	115	70	Black Hills	120	152.78	164.49	11.71
4	Smelter (70394) - W.Canon (70550) 115 kV CKT 1	W Canon (73551) - Poncha BR (79054) 230 kV CKT 1	115	70	Black Hills	73	148.87	161.82	12.95
5	Flyhorse S (73576) - Kettleck N (73711) 115 kV CKT 1	Vollmert (72413) - Fuller (73481) 115 kV CKT 1	115	73	CSU	162	147.72	159.95	12.23
6	Ftn Vly (70193) - Midway BR (73412) 115 kV CKT 1	Midway PS (70286) - Midway BR (73413) 230 kV CKT 1	115	70/73	Black Hills	179	119.12	131.47	12.35
7	Briargate N (73710) - Kettleck N (73711) 115 kV CKT 1	Cttnwd N (73391) - Kettleck S (73410) 115 kV CKT 1	115	73	CSU	186	116.07	123.94	7.87

Ref. No.	Monitored Facility	Contingency Name	kV	Areas	Owner	Normal Rating (MVA)	Benchmark Case Loading (%)	Study Case Loading (%)	Loading Difference (%)
8	Kelker E (73408) - Templton (73422) 115 kV CKT 1	Kelker E (73408) - Rockisld (73420) 115 kV CKT 1	115	73	CSU	131	113.96	118.77	4.81
9	Kelker E (73408) - Rockisld (73420) 115 kV CKT 1	Kelker E (73408) - Templton (73422) 115 kV CKT 1	115	73	CSU	162	109.50	113.60	4.10
10	Vollmert (72413) - Fuller (73481) 115 kV CKT 1	Flyhorse S (73576) - Kettleck N (73711) 115 kV CKT 1	115	73	Tri-State G&T	173	106.63	114.18	7.55
11	Portland (70330) - Skala (70390) 115 kV CKT 1	N Penrose (71024) - Trk Crk Poi (71032) 115 kV CKT 1	115	70	Black Hills	110	104.75	110.95	6.20
12	Desrtcov (70449) - W.Staton (70456) 115 kV CKT 1	Midway PS (70286) - Midway BR (73413) 230 kV CKT 1	115	70	Black Hills	221	104.56	114.63	10.07
13	Puebplnt (70339) - Reader (70352) 115 kV CKT 1	Greenhrn (70004) - Reader (70352) 115 kV CKT 1	115	70	Black Hills	160	104.02	111.11	7.09
14	Vollmert (72413) - Blk Sqmv (73460) 115 kV CKT 1	Flyhorse S (73576) - Kettleck N (73711) 115 kV CKT 1	115	73	Tri-State G&T	173	101.48	108.92	7.44
15	Midway PS (70286) - Midway BR (73413) 230 kV CKT 1	Midway PS (70286) - Fuller (73477) 230 kV CKT 1	230	70/73	PSCo/WAPA	637	99.88	112.44	12.56
16	Briargate S (73389) - Cttnwd S (73393) 115 kV CKT 1	Cttnwd N (73391) - Kettleck S (73410) 115 kV CKT 1	115	73	CSU	150	99.02	108.13	9.11
17	Midway BR (73412) - Rancho (73416) 115 kV CKT 1	LoTC_28: Midway PS - Fuller 230 kV CKT 1	115	73	Tri-State G&T	119	97.26	103.04	5.78
18	Ftn Vly (70193) - Desrtcov (70449) 115 kV CKT 1	Midway PS (70286) - Midway BR (73413) 230 kV CKT 1	115	70	Black Hills	221	97.06	107.07	10.01
19	Drake E (73575) - Fontero E (73706) 115 kV CKT 1	LoTC_28: Midway PS - Fuller 230 kV CKT 1	115	73	CSU	167	96.88	102.13	5.25
20	W.Canon (70550/73551) 115/230 kV transformer T1	Midway BR (73413) - Hambone Tap (73638) 230 kV CKT 1	115/230	70/73	Black Hills	100	96.13	104.42	8.29
21	Kettleck S (73410) - Kettleck N (73711) 115 kV CKT 1	Briargate S (73389) - Briargate N (73710) 115 kV CKT 1	115	73	CSU	239	95.73	102.51	6.78

6.2 Grid Charging Study Case

Contingency analysis was performed on the Southern Colorado pocket Grid Charging Study Case. The results are summarized below:

- System-Intact analysis: No thermal overload or voltage violations attributable to 3RSC-2023-02 were identified.
- Single Contingency analysis: No thermal overload or voltage violations attributable to 3RSC-2023-02 were identified.

7.0 Transient Stability Analysis

The Study and Grid Charging Study Cases presented in the previous section were used as a starting point for the Transient Stability Analysis conducted in this study.

Before conducting the analysis, the following was observed:

- 3RSC Study Units did not have a Reactive Power Droop Control gain, which resulted in high voltages during the simulations mainly observed for 3RSC-2023-2 unit. This has been adjusted as described in Table 8 below.
- It was observed that the dynamic behavior presented by Composite Load Group model, identified as HID-RES, was responsible for cascading generation trips in areas 70 and 73 resulting in voltage collapse and unstable results in Study Case simulations. To overcome this issue, the loads in area 70 that had "HID_RES" as their climate zone, were modified to have no climate zone in effect.

Table 8 – Modified Parameter on Dynamic Database for Models in 3RSC – 2023

Model Name	Parameter Name	Description	Original Value	Modified Value
REPC_A	Kc	Reactive Power Droop Gain, p.u.	0.00	0.05

The results presented in the following sections describe the results obtained with the above modifications already in place.

7.1 South Colorado Transient Stability Results

Table 9 is a summary of the contingencies studied and the corresponding stability results for the Discharging Scenario. Table 10 is a summary of the contingencies studied and the corresponding stability results for the Grid Charging Scenario.

The following results were obtained for the stability analysis on both scenarios:

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

The transient stability plots for both scenarios are shown in Appendices A and B, in Section 12.0 in this report.

7.2 Summary of South Colorado Analysis

The transient stability analysis did not identify any Network Upgrades.

Table 9 – South Colorado Transient Stability Analysis Results for Discharging Scenario

Ref. No.	Contingency Name	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Flat Run	P0	-	-	Stable	Stable
2	Gens 3RSC_23_1	P1	3RSC-23-01 Units S1 and S2	5	Stable	Stable
3	Gens 3RSC_23_2	P1	3RSC-23-02 Unit B	5	Stable	Stable
4	Gens 3RSC_23_3	P1	3RSC-23-03 Units W1 and W3	4	Stable	Stable
5	Comanche - Mirasol 230 kV (LoTC_79)	P1	Comanche - Mirasol 230 kV CKT 1 GI-2020-10 Generators	5	Stable	Stable
6	Midway - Mirasol 230 kV (LoTC_102)	P1	Midway - Mirasol 230 kV CKT 1	5	Stable	Stable
7	Mirasol - Thunderwolf 230 kV (LoTC_103)	P1	Mirasol - Thunderwolf 230 kV CKT 1 Thunderwolf Generators	5	Stable	Stable
8	Midway - Fuller 230 kV (LoTC_28)	P1	Midway - Fuller 230 kV CKT 1	5	Stable	Stable
9	Midway - Boone 230 kV (LoTC_69)	P1	Midway PS - PI 2024 15 230 kV CKT 1 PI 2024 15 - Boone 230 kV CKT 1	5	Stable	Stable
10	Comanche - Huckleberry 230 kV (LoTC_76)	P1	Comanche - Huckleberry 230 kV CKT 1	5	Stable	Stable
11	Comanche - Bighorn 230 kV (LoTC_97)	P1	Comanche - Bighorn 230 kV CKT 1 Bighorn Solar Generators	5	Stable	Stable
12	Comanche - Sun Mountain 230 kV (LoTC_98)	P1	Comanche - Sun Mountain 230 kV CKT 1 Sun Mountain Solar Generators	5	Stable	Stable
13	May Valley - Goose Ck. 345 kV (LoTC_295)	P1	May Valley - Goose Creek 345 kV CKT 1	4	Stable	Stable

Ref. No.	Contingency Name	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
14	May Valley - Sandstone 345 kV CKT 1 (LoTC_316)	P1	May Valley - Crow 345 kV CKT 1 Crow - Sandstone 345 kV CKT 1 PI-2024-06 Generators	4	Stable	Stable
15	May Valley - Sandstone 345 kV CKT 2 (LoTC_318)	P1	May Valley - Kiowa 345 kV CKT 1 Kiowa - Sandstone 345 kV CKT 1 5RSC-2024-22 Generators	4	Stable	Stable
16	Goose Ck. - Canal Crossing 345 kV (LoTC_293)	P1	Goose Creek - Canal Crossing 345 kV CKT 1	4	Stable	Stable
17	Goose Ck. - Shortgrass 345 kV	P1	Goose Creek - Shortgrass 345 kV CKT 1	4	Stable	Stable
18	Mirasol 230 kV BF (BF_096a)	P4	Comanche - Mirasol 230 kV CKT 1 Mirasol - Midway PS 230 kV CKT 1 GI-2020-10 Generators Thunderwolf Generators	17	Stable	Stable
19	Mirasol 230 kV P7 (P7_54)	P7	Comanche - Mirasol 230 kV CKT 1 Comanche - Huckleberry 230 kV CKT 1 Huckleberry - Walsenburg 230 kV CKT 1 GI-2020-10 Generators	5	Stable	Stable
20	May Valley 345 kV BF 1 (BF_156b)	P4	May Valley - Crow 345 kV CKT 1 Crow - Sandstone 345 kV CKT1 Sandstone - New Harvest Mile 345 kV CKT 1 PI-2024-06 Generators	12	Stable	Stable
21	May Valley 345 kV BF 2 (BF_155a)	P4	May Valley - Goose Creek 345 kV CKT 1 Goose Creek - Canal Crossing 345 kV CKT 1	12	Stable	Stable

Ref. No.	Contingency Name	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
22	May Valley 345 kV P7 (P7_163)	P7	May Valley - Crow 345 kV CKT 1 Crow - Sandstone 345 kV CKT 1 May Valley - Kiowa 345 kV CKT 1 Kiowa - Sandstone 345 kV CKT 1 PI-2024-06 Generators 5RSC-2024-22 Generators	4	Stable	Stable

Table 10 – South Colorado Transient Stability Analysis Results for Grid Charging Scenario

Ref. No.	Contingency Name	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Flat Run	P0	-	-	Stable	Stable
2	Gens 3RSC_23_2	P1	3RSC-23-02 Unit B	5	Stable	Stable
3	Comanche - Mirasol 230 kV (LoTC_79)	P1	Comanche - Mirasol 230 kV CKT 1 GI-2020-10 Generators	5	Stable	Stable
4	Midway - Mirasol 230 kV (LoTC_102)	P1	Midway - Mirasol 230 kV CKT 1	5	Stable	Stable
5	Mirasol - Thunderwolf 230 kV (LoTC_103)	P1	Mirasol - Thunderwolf 230 kV CKT 1 Thunderwolf Generators	5	Stable	Stable
6	Midway - Fuller 230 kV (LoTC_28)	P1	Midway - Fuller 230 kV CKT 1	5	Stable	Stable
7	Midway - Boone 230 kV (LoTC_69)	P1	Midway PS - PI 2024 15 230 kV CKT 1 PI 2024 15 - Boone 230 kV CKT 1	5	Stable	Stable

Ref. No.	Contingency Name	Fault Category	Outage(s)	Clearing Time (Cycles)	Post-Fault Voltage Recovery	Angular Stability
8	Comanche - Huckleberry 230 kV (LoTC_76)	P1	Comanche - Huckleberry 230 kV CKT 1	5	Stable	Stable
9	Mirasol 230 kV BF (BF_096a)	P4	Comanche - Mirasol 230 kV CKT 1 Mirasol - Midway PS 230 kV CKT 1 GI-2020-10 Generators Thunderwolf Generators	17	Stable	Stable
10	Mirasol 230 kV P7 (P7_54)	P7	Comanche - Mirasol 230 kV CKT 1 Comanche - Huckleberry 230 kV CKT 1 Huckleberry - Walsenburg 230 kV CKT 1 GI-2020-10 Generators	5	Stable	Stable

8.0 Short-Circuit and Breaker-Duty Analysis

The three GIR projects studied in this analysis (3RSC-2023-1, 3RSC-2023-2, and 3RSC-2023-3) accurately represent the 3RSC-2023 Cluster with no other higher-queued projects.

8.1 Short-Circuit Analysis Results

Positive, negative, and zero sequence impedances from the fault studies are given in Table 11, Table 12, and Table 13, below. Fault currents at the respective POIs are also given.

Table 11 – Short-Circuit Parameters at 3RSC-2023-1 POI

	Before the Cluster addition	After the Cluster addition
Three Phase		
Three Phase Current	11040A	10650A
Positive Sequence Impedance	1.31602 + j12.3921 ohms	1.31712 + j12.3966 ohms
Negative Sequence Impedance	1.33478 + j12.3973 ohms	1.33585 + j12.4018 ohms
Zero Sequence Impedance	2.83233 + j15.4930 ohms	1.24316 + j9.70432 ohms
Phase-to-Ground		
Single Line to Ground Current	9980A	12630A
Positive Sequence Impedance	1.48382 + j12.2594 ohms	1.48498 + j12.2638 ohms
Negative Sequence Impedance	1.50216 + j12.2631 ohms	1.50330 + j12.2675 ohms
Zero Sequence Impedance	2.83233 + j15.4930 ohms	1.24316 + j9.70432 ohms

Table 12 – Short-Circuit Parameters at 3RSC-2023-2 POI

	Before the Cluster addition	After the Cluster addition
Three Phase		
Three Phase Current	11040A	10650A
Positive Sequence Impedance	1.31602 + j12.3921 ohms	1.31712 + j12.3966 ohms
Negative Sequence Impedance	1.33478 + j12.3973 ohms	1.33585 + j12.4018 ohms
Zero Sequence Impedance	2.83233 + j15.4930 ohms	1.24316 + j9.70432 ohms
Phase-to-Ground		
Single Line to Ground Current	9980A	12630A
Positive Sequence Impedance	1.48382 + j12.2594 ohms	1.48498 + j12.2638 ohms
Negative Sequence Impedance	1.50216 + j12.2631 ohms	1.50330 + j12.2675 ohms
Zero Sequence Impedance	2.83233 + j15.4930 ohms	1.24316 + j9.70432 ohms

Table 13 – Short-Circuit Parameters at 3RSC-2023-3 POI

	Before the Cluster addition	After the Cluster addition
Three Phase		
Three Phase Current	4810	5220A
Positive Sequence Impedance	3.45836 + j41.1754 ohms	3.47684 + j41.2844 ohms
Negative Sequence Impedance	3.48943 + j41.1679 ohms	3.50807 + j41.2769 ohms
Zero Sequence Impedance	26.4233 + j110.716 ohms	8.48255 + j58.5911 ohms
Phase-to-Ground		
Single Line to Ground Current	3050A	4580A
Positive Sequence Impedance	3.45836 + j41.1754 ohms	3.47684 + j41.2844 ohms
Negative Sequence Impedance	3.48943 + j41.1679 ohms	3.50807 + j41.2769 ohms
Zero Sequence Impedance	26.4233 + j110.716 ohms	8.48255 + j58.5911 ohms

8.2 Breaker-Duty Analysis Results

Breakers that are overstressed with the addition of the cluster are shown below in Table 14. They are not additional network upgrades because these breakers have projects underway for their replacement. However, note that the in-service date for the new breakers is after the scheduled in-service date for all GIRs in this report.

Table 14 – Overstressed Breakers Due to Cluster Addition

SUBSTATION	BASE KV	BREAKER NAME	Scheduled ISD
DANIELS PARK (PSCO)	230	5085	5/2028
DANIELS PARK (PSCO)	230	5102	5/2028
DANIELS PARK (PSCO)	230	5106	12/2025
DANIELS PARK (PSCO)	230	5119	5/2028

8.3 Summary of South Colorado Pocket Results

The fault currents at each POI for three-phase and phase-to-ground faults can be found in Table 11, Table 12, and Table 13, along with the Thévenin impedance at each POI. Both the base case and the case with the cluster added are shown.

Breakers that are overstressed with the addition of the cluster are shown in Table 14, but they are not additional network upgrades because these breakers have projects underway for their replacement.

FERC has directed transmission providers to include in the interconnection study report the method for identifying contingent facilities with sufficient base case data, including all assumptions and contingency lists. Please refer to Table 11, Table 12, and Table 13 for fault currents.

9.0 Cost Estimates and Assumptions

There are three types of costs identified in the study:

- Transmission Provider's Interconnection Facilities (TPIF) which are directly assigned to each GIR.
- Station equipment Network Upgrades, which are allocated each GIR connecting to that station on a per-capita basis per Section 4.2.4(a) of the LGIP.
- All System Network Upgrades, which are allocated by the proportional impact per Section 4.2.4(b) of the LGIP.

9.1 Transmission Provider's Interconnection Facilities

9.1.1 3RSC-2023-1 and 3RSC-2023-2

Table 15 – 3RSC-2023-1 and 3RSC-2023-2 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (million)
PSCo's Mirasol 230 kV switching station	Interconnection of 3RSC-2023-1 and 3RSC-2023-2 at the Mirasol 230 kV switching station sharing an interconnection position. The new equipment includes: • (1) 230 kV dead end bay • (1) 230 kV 3-phase arrester • (1) 230 kV 3000 A line disconnect switch • (1) 230 kV 3-phase CT for metering • (1) 230 kV 3-phase 3-winding CCVT • Dual fiber communication equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing	$2.380
PSCo's Mirasol 230 kV switching station	Transmission Provider's dead-end structure at the Point of Change of Ownership (PCO) outside the switching station fence line and transmission line into new switching station from the PCO. Single span, dead end structure, 3 conductors, insulators, hardware, jumpers and labor.	$0.200
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$2.580**

The total cost of Transmission Provider Interconnection Facilities for each GIR is given in Table 16.

Table 16 – Allocation of Transmission Provider Interconnection Facilities Costs by GIR at Mirasol 230 kV Switching Station

GIR	% Share	Total Cost (million)
3RSC-2023-1	50.0%	$1.290
3RSC-2023-2	50.0%	$1.290

9.1.2 3RSC-2023-3

Table 17 – 3RSC-2023-3 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (million)
PSCo's May Valley 345 kV switching station	Interconnection of 3RSC-2023-3 at the May Valley 345 kV switching station. The new equipment includes: • (1) 345 kV dead end structure • (1) 345 kV 3-phase arrester • (1) 345 kV 3000A line disconnect switch • (1) 345 kV 3-phase CT for metering • (1) 345 kV 3-phase 3-winding CCVT • Dual fiber communication equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing	$3.395
PSCo's May Valley 345 kV switching station	Transmission Provider's dead-end structure at the Point of Change of Ownership (PCO) outside the switching station fence line and transmission line into new switching station from the PCO. Single span, dead end structure, 3 conductors, insulators, hardware, jumpers and labor.	$0.250
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$3.645**

9.2 Station Network Upgrades

The total cost of Station Network Upgrades for each GIR is given in Table 18.

Table 18 – Total Cost of Station Network Upgrades by GIR

GIR	POI	Total Cost (million)
3RSC-2023-1	Mirasol 230 kV switching station	**$2.505**
3RSC-2023-2		
3RSC-2023-3	May Valley 345 kV switching station	**$1.707**

9.2.1 Mirasol 230 kV switching station

The details of the Station Network Upgrades required at the Mirasol 230 kV switching station are shown in Table 19. These Station Network Upgrade costs are shared according to Table 20.

Table 19 – Station Network Upgrades – Mirasol 230 kV switching station

Element	Description	Cost Est. (million)
PSCo's Mirasol 230 kV switching substation	Interconnection of 3RSC-2023-1 and 3RSC-2023-2 at Mirasol 230 kV switching station on the existing ring bus. The new equipment includes: • (1) 230 kV dead end structure • (1) 230 kV 3000 A SF6 circuit breaker • (3) 230 kV 3000 A double end break disconnect switches • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$2.422
PSCo's Mirasol 230 kV switching substation	Install communication equipment in the Mirasol 230 kV EEE to accommodate 3RSC-2023-1 and 3RSC-2023-2	$0.083
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$2.505**

Table 20 – Allocation of Mirasol 230 kV Switching Station Upgrade Cost by GIR

GIR	% Share per Section 4.2.4(a) of Attachment N	Costs Allocated to GIR (million)
3RSC-2023-1	50.0%	$1.2525
3RSC-2023-2	50.0%	$1.2525

9.2.2 May Valley 345 kV switching station

The details of the Station Network Upgrades required at the May Valley 345 kV switching station are shown in Table 21. These Station Network Upgrade costs are 100% assigned to 3RSC-2023-3.

Table 21 – Station Network Upgrades – May Valley 345 kV switching station

Element	Description	Cost Est. (million)
PSCo's May Valley 345 kV switching station	Interconnection of 3RSC-2023-3 at May Valley 345 kV switching station on an existing breaker-and-a-half bay. The new equipment includes: • (1) 345 kV dead end structure • (1) 345 kV 3000 A SF6 circuit breaker • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$1.707
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$1.707**

9.3 Summary of Costs per Generator Interconnection Request

9.3.1 3RSC-2023-1

The total estimated cost of the required Network Upgrades for 3RSC-2023-1 to interconnect at the Mirasol 230 kV switching station is $2.5425 million.

- **The cost of Transmission Provider's Interconnection Facilities is $1.290 million (**Table 15 and Table 16**)**
- **The cost of Station Network Upgrades is $1.2525 million (**Table 19 and Table 20**)**
- **The cost of System Network Upgrades is $0 million**

Figure 2 is a conceptual one-line of the Mirasol 230 kV switching station required for the interconnection for 3RSC-2023-1.

The list of improvements required to accommodate the interconnection of 3RSC-2023-1 is given in Table 15 and Table 19. System improvements are subject to revision as a more detailed and refined design is produced.

9.3.2 3RSC-2023-2

The total estimated cost of the required Network Upgrades to allow 3RSC-2023-2 to interconnect at Mirasol 230 kV Switching Station is $2.5425 million.

- **The cost of Transmission Provider's Interconnection Facilities is $1.290 million (**Table 15 and Table 16**)**
- **The cost of Station Network Upgrades is $1.2525 million (**Table 19 and Table 20**)**
- **The cost of System Network Upgrades is $0 million**

Figure 2 is a conceptual one-line of the Mirasol 230 kV switching station for the interconnection of 3RSC-2023-2.

The list of improvements required to accommodate the interconnection of 3RSC-2023-2 is given in Table 15 and Table 19. System improvements are subject to revision as a more detailed and refined design is produced.

9.3.3 3RSC-2023-3

The total estimated cost of the required Network Upgrades to allow 3RSC-2023-3 to interconnect at May Valley 345 kV switching station is $5.352 million.

- **The cost of Transmission Provider's Interconnection Facilities is $3.645 million (**Table 17**)**
- **The cost of Station Network Upgrades is $1.707 million (**Table 21**)**
- **The cost of System Network Upgrades is $0 million**

Figure 3 is a conceptual one-line of the May Valley 345 kV switching station for the interconnection of 3RSC-2023-3.

The list of improvements required to accommodate the interconnection of 3RSC-2023-3 at the May Valley 345 kV switching station is given in Table 17 and Table 21. System improvements are subject to revision as a more detailed and refined design is produced.

9.4 Cost Estimate Assumptions

PSCo has developed cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the GIRs in the 3RSC-2023 cluster for 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 Remote Terminal Unit (RTU) at their customer’s substation. PSCo will be provided with indications, readings, and data from the 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

10.0 Contingent Facilities

The following is the list of the unbuilt Interconnection Facilities and Network Upgrades upon which the costs, timing, and study findings of the 3RSC–2023 are dependent, and if delayed or not built, could cause a need for re-studies of the Interconnection Service or a reassessment of the Interconnection Facilities and/or Network Upgrades and/or costs and timing. The individual GIR's maximum allowable output may be decreased if these Contingent Facilities are not in-service.

Each unbuilt facility was studied as a potential contingent facility independently. The unbuilt facilities in each study pocket were reverted to pre-project topology, and the resultant worst-case overloads were reported in Appendix C. The study generators' DFAX were calculated for the worst-case overloads. If reverting the unbuilt facility causes or increases an overload in more than 1% of the monitored facility rating, with >3% study generator DFAX, the unbuilt facility will be identified as a contingent facility for that study generator.

10.1 3RSC-2023-1

The Contingent Facilities identified for this GIR are:

- The following unbuilt transmission projects, which are modeled in the Study Case, are considered Contingent Facilities:
    1) Daniels Park – Jackson Fuller L5119 uprate to 637 MVA – ISD 5/1/2028.
    2) Midway – Jackson Fuller L5129 uprate to 637 MVA – ISD 12/31/2029.
    3) New Fort St. Vrain 230/345 kV 560 MVA transformer T9 – ISD 12/31/2029.
    4) Palmer Lake – Fox Run L9605 uprate to 239 MVA – ISD 12/31/2029.
    5) Double circuit for Cherokee – Sandown – Chambers – Harvest Mile upgraded substations – ISD 9/13/2029.
- Additional Contingent Facilities identified for 3RSC-2023-1 include the Interconnection Facilities and Station Network Upgrades identified in Table 15 and Table 19, respectively

Tables C-1 through C-5, included in Appendix C, summarize the worst-case branch overloads when an unbuilt facility is included from the Study Case.

10.2 3RSC-2023-2

The Contingent Facilities identified for this GIR are:

- The following unbuilt transmission projects, which are modeled in the Study Case, are considered Contingent Facilities:
  1) Daniels Park – Jackson Fuller L5119 uprate to 637 MVA – ISD 5/1/2028.
  2) Midway – Jackson Fuller L5129 uprate to 637 MVA – ISD 12/31/2029.
  3) New Fort St. Vrain 230/345 kV 560 MVA transformer T9 – ISD 12/31/2029.
  4) Palmer Lake – Fox Run L9605 uprate to 239 MVA – ISD 12/31/2029.
  5) Double circuit for Cherokee – Sandown – Chambers – Harvest Mile upgraded substations – ISD 9/13/2029.
- Additional Contingent Facilities identified for 3RSC-2023-2 include the Interconnection Facilities and Station Network Upgrades identified in Table 15 and Table 19, respectively.

Tables C-1 through C-5, included in Appendix C, summarize the worst-case branch overloads when an unbuilt facility is included from the Study Case.

10.3 3RSC-2023-3

The Contingent Facilities identified for this GIR are:

- The following unbuilt transmission projects, which are modeled in the Study Case, are considered Contingent Facilities:
  1) Midway – Jackson Fuller L5129 uprate to 637 MVA – ISD 12/31/2029.
  2) New Fort St. Vrain 230/345 kV 560 MVA transformer T9 – ISD 12/31/2029.
  3) Double circuit for Cherokee – Sandown – Chambers – Harvest Mile upgraded substations – ISD 9/13/2029.
- Additional Contingent Facilities identified for 3RSC-2023-3 include the Interconnection Facilities and Station Network Upgrades identified in Table 17 and Table 21, respectively.

Tables C-2, C-3, and C-5, included in Appendix C, summarize the worst-case branch overloads when an unbuilt facility is included from the Study Case.

10.4 Short-Circuit Contingent Breakers

During short-circuit and breaker-duty analysis, four (4) 230 kV breakers at Daniels Park were identified as becoming overstressed because of the addition of the cluster; however, there are end-of-life replacement projects underway for these breakers. Those existing breaker replacement projects are not network upgrades. It should be noted that the in-service date (ISD) for three of the breakers is after the ISD of the GIRs in this study. Section 4.7 of the Business Practice Manual states that "All future breaker replacements which have a short-circuit current contribution from the GIR are Contingent Facilities".

11.0 Summary of Generation Interconnection Service

The Interconnection Customer is required to design and build the Generating Facility to mitigate any potential inverter interactions with the neighboring inverter based Generating Facility(ies) and/or the inverters of the hybrid Generating Facility. This report only evaluated Interconnection Service of GIRs in 3RSC-2023 and Interconnection Service in and itself does not convey transmission service.

11.1 3RSC-2023-1

The total estimated cost of the upgrades required to interconnect 3RSC-2023-1 at the Mirasol 230 kV switching station for NRIS is $2.5425 million (Table 15, Table 16, Table 19, and Table 20).

The maximum allowable output of 3RSC-2023-1 without requiring additional Network Upgrades is 200 MW. NRIS of 3RSC-2023-1 is 200 MW.

11.2 3RSC-2023-2

The total estimated cost of the upgrades required to interconnect 3RSC-2023-2 at the Mirasol 230 kV switching station for NRIS is $2.5425 million (Table 15, Table 16, Table 19, and Table 20).

The Grid Charging study for the 100 MW BESS Generating Facility did not identify any impact. There are no additional costs identified in the Grid Charging study.

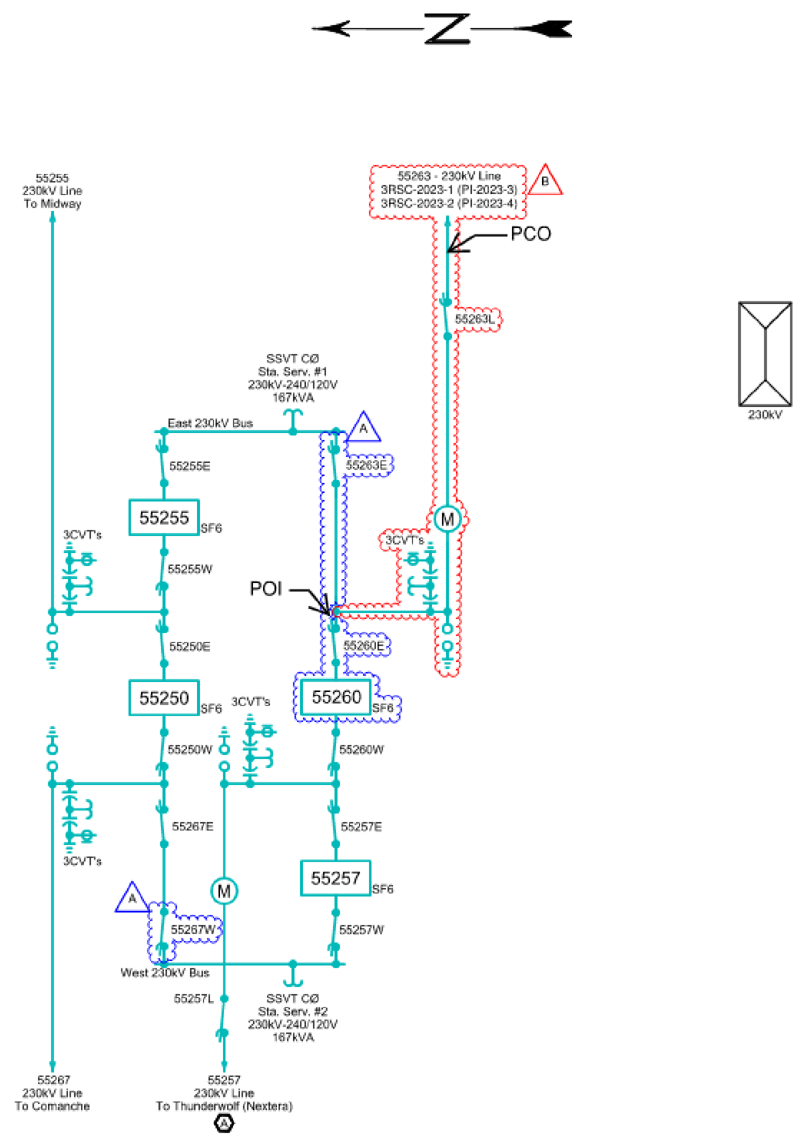
The maximum allowable output of 3RSC-2023-2 without requiring additional Network Upgrades is 100 MW. NRIS of 3RSC-2023-2 is 100 MW.

11.3 3RSC-2023-3

The total estimated cost of the upgrades required to interconnect 3RSC-2023-3 at the May Valley 345 kV switching station for NRIS is $5.352 million (Table 17 and Table 21).

The maximum allowable output of 3RSC-2023-3 without requiring additional Network Upgrades is 200 MW. NRIS of 3RSC-2023-3 is 200 MW.

12.0 Single-Line Diagrams for Each Generator Interconnection Substation



Notes:

A — Station Network Upgrades for 3RSC-2023-1 (PI-2023-3) and 3RSC-2023-2 (PI-2023-4)

B — TPIF for 3RSC-2023-1 (PI-2023-3) and 3RSC-2023-2 (PI-2023-4)

Figure 2 – Preliminary One-line of the 3RSC-2023-1 and 3RSC-2023-2 POI – Mirasol 230 kV

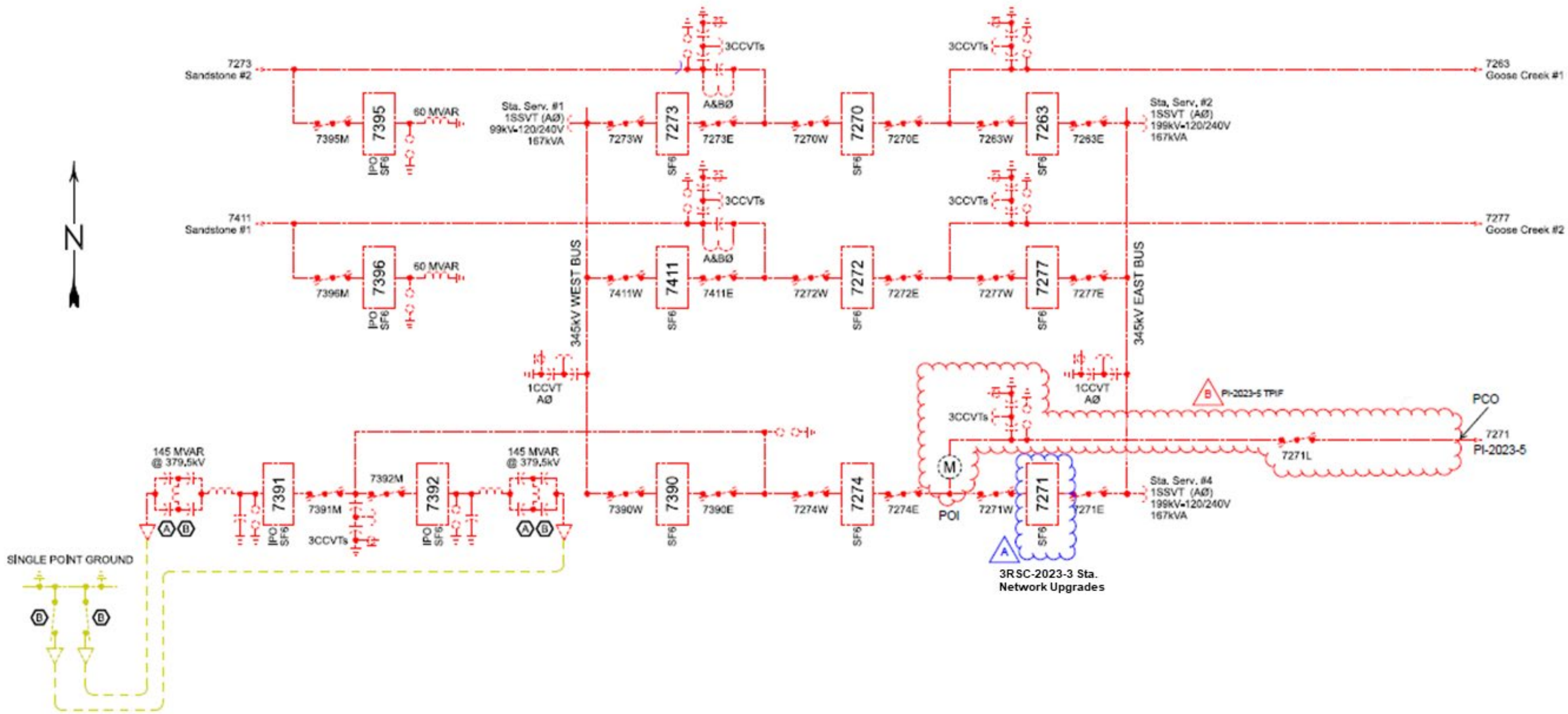
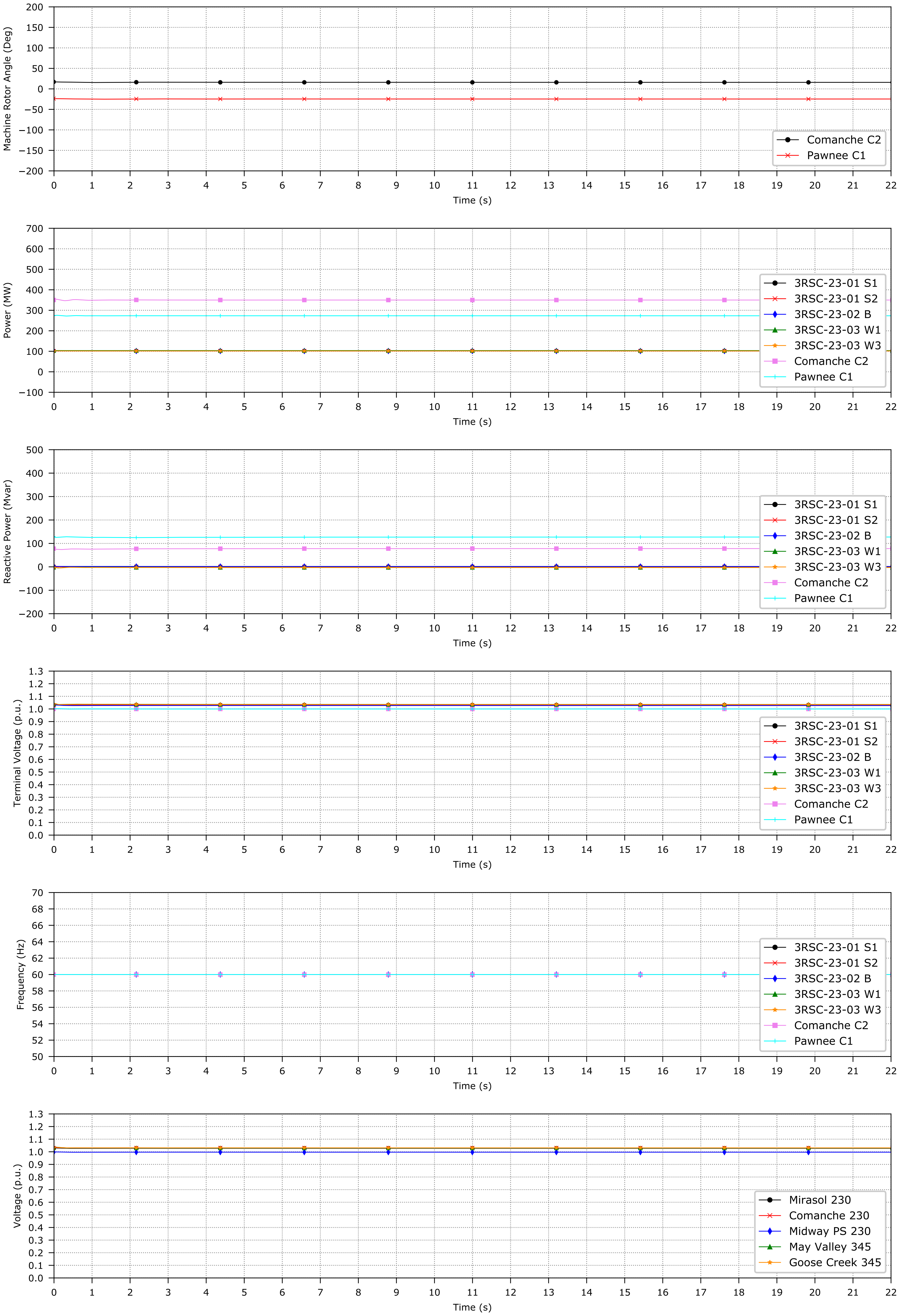


Figure 3 – Preliminary One-line of the 3RSC-2023-3 POI – May Valley 345 kV

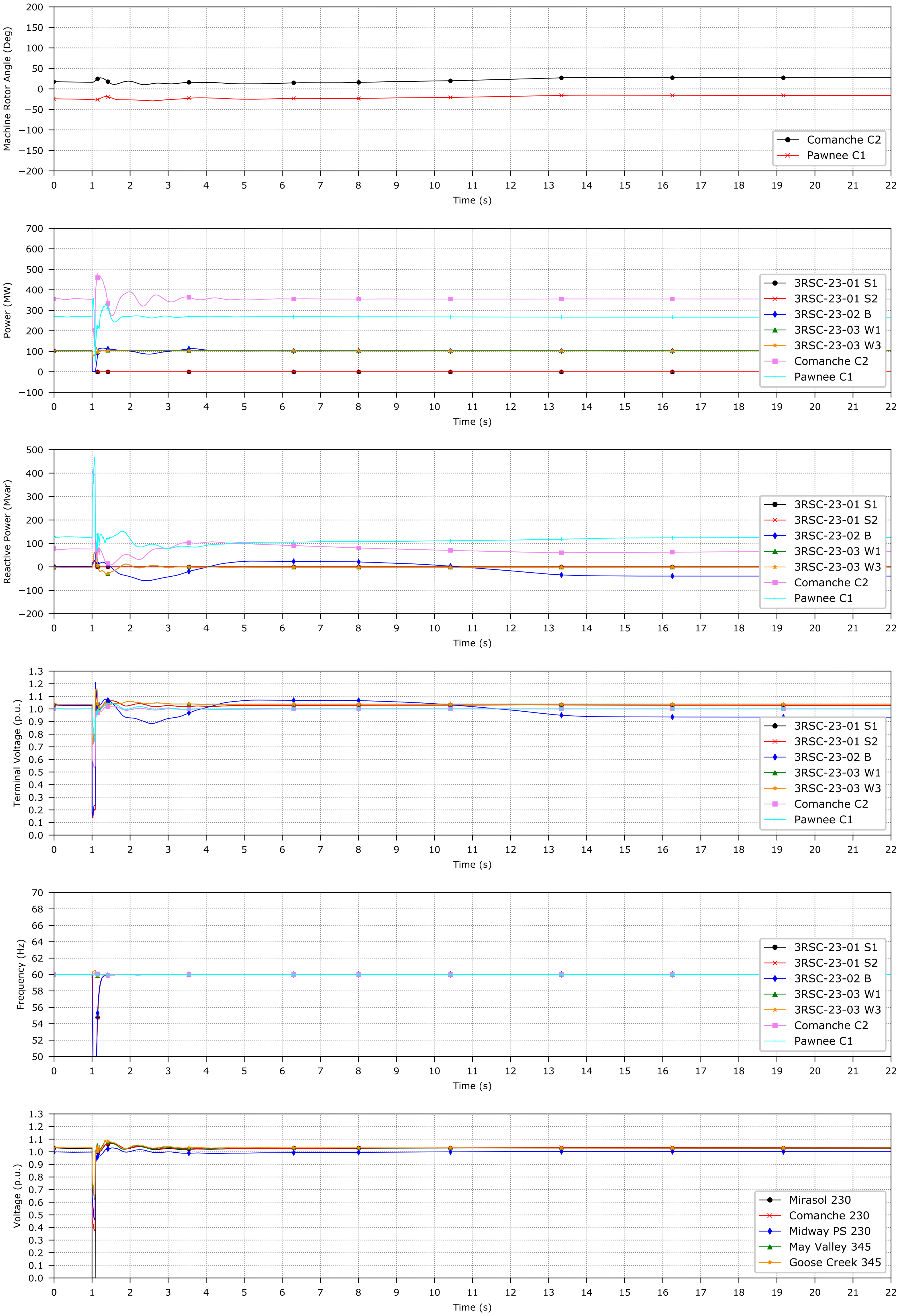
13.0 Appendices

Appendix A: Transient Stability Plots – Discharging Scenario	Appendix A - Transient Stability Pl
Appendix B: Transient Stability Plots – Grid Charging Scenario	Appendix B - Transient Stability Pl
Appendix C: Contingent Facility Study Results	Appendix C - Contingent Facility.p

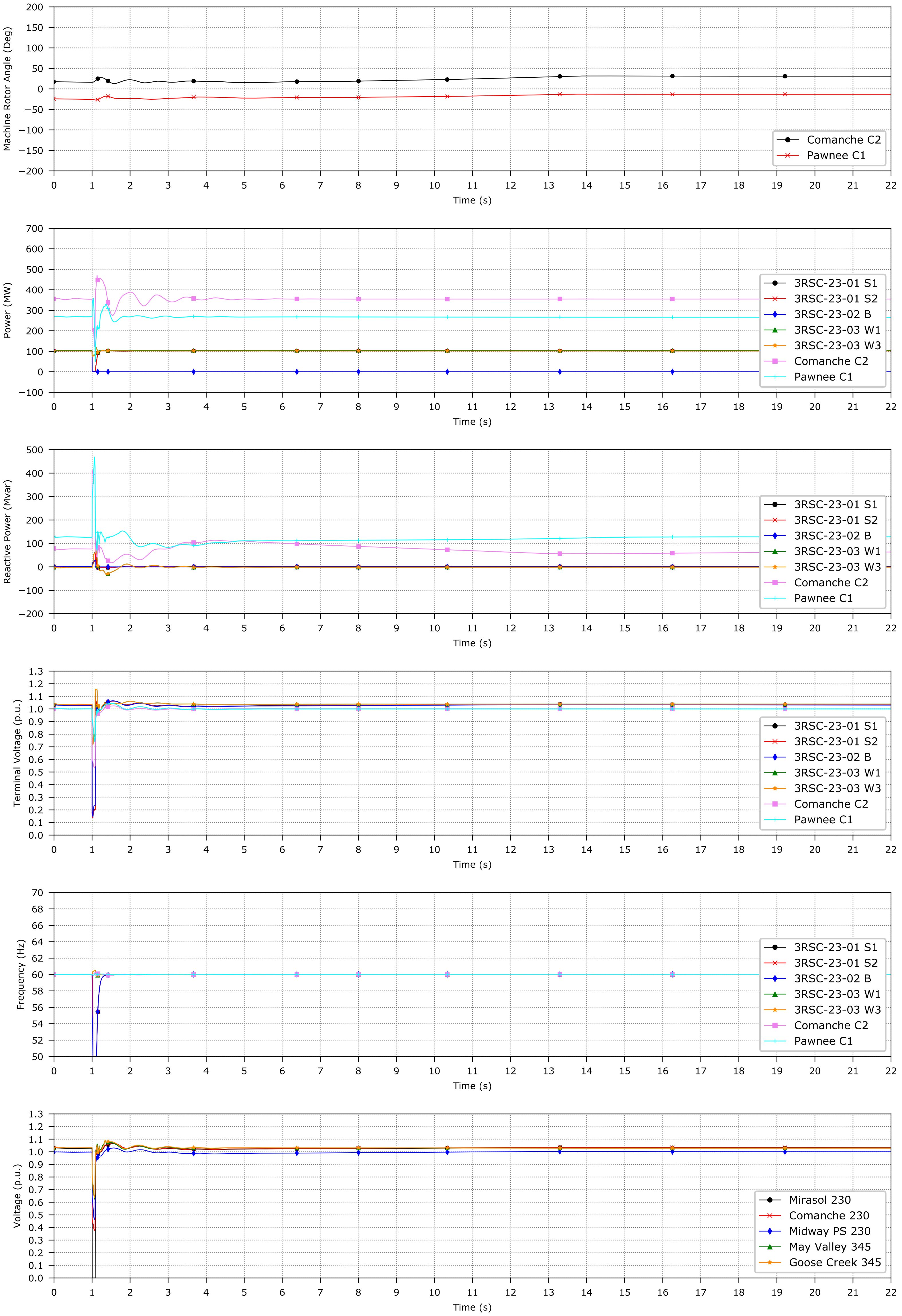
Flatrun


Machine Rotor Angle (Deg)
Time (s)
Comanche C2
Pawnee C1
Power (MW)
Time (s)
3RSC-23-01 S1
3RSC-23-01 S2
3RSC-23-02 B
3RSC-23-03 W1
3RSC-23-03 W3
Comanche C2
Pawnee C1
Reactive Power (Mvar)
Time (s)
3RSC-23-01 S1
3RSC-23-01 S2
3RSC-23-02 B
3RSC-23-03 W1
3RSC-23-03 W3
Comanche C2
Pawnee C1
Terminal Voltage (p.u.)
Time (s)
3RSC-23-01 S1
3RSC-23-01 S2
3RSC-23-02 B
3RSC-23-03 W1
3RSC-23-03 W3
Comanche C2
Pawnee C1
Frequency (Hz)
Time (s)
3RSC-23-01 S1
3RSC-23-01 S2
3RSC-23-02 B
3RSC-23-03 W1
3RSC-23-03 W3
Comanche C2
Pawnee C1
Voltage (p.u.)
Time (s)
Mirasol 230
Comanche 230
Midway PS 230
May Valley 345
Goose Creek 345

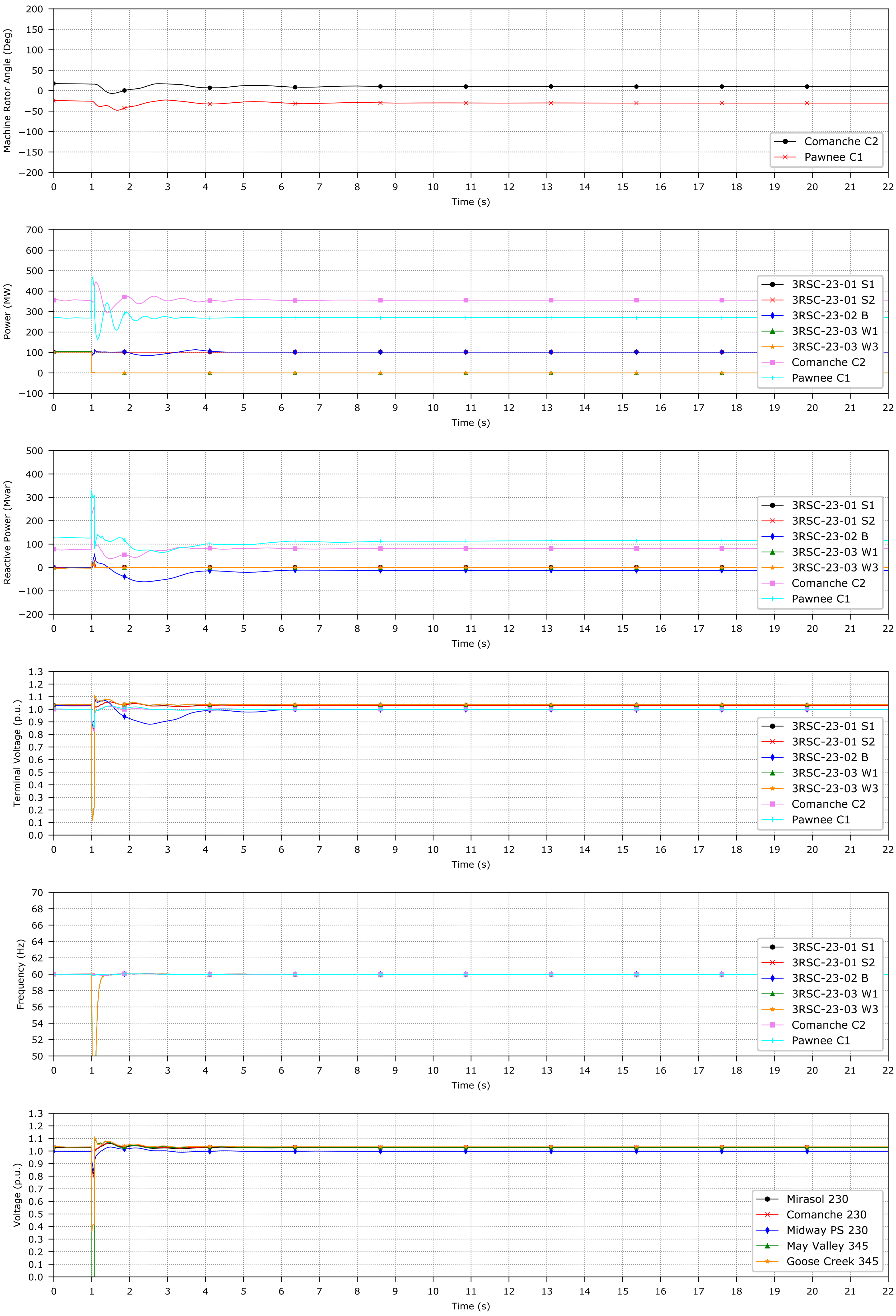
Gens 3RSC_23_1



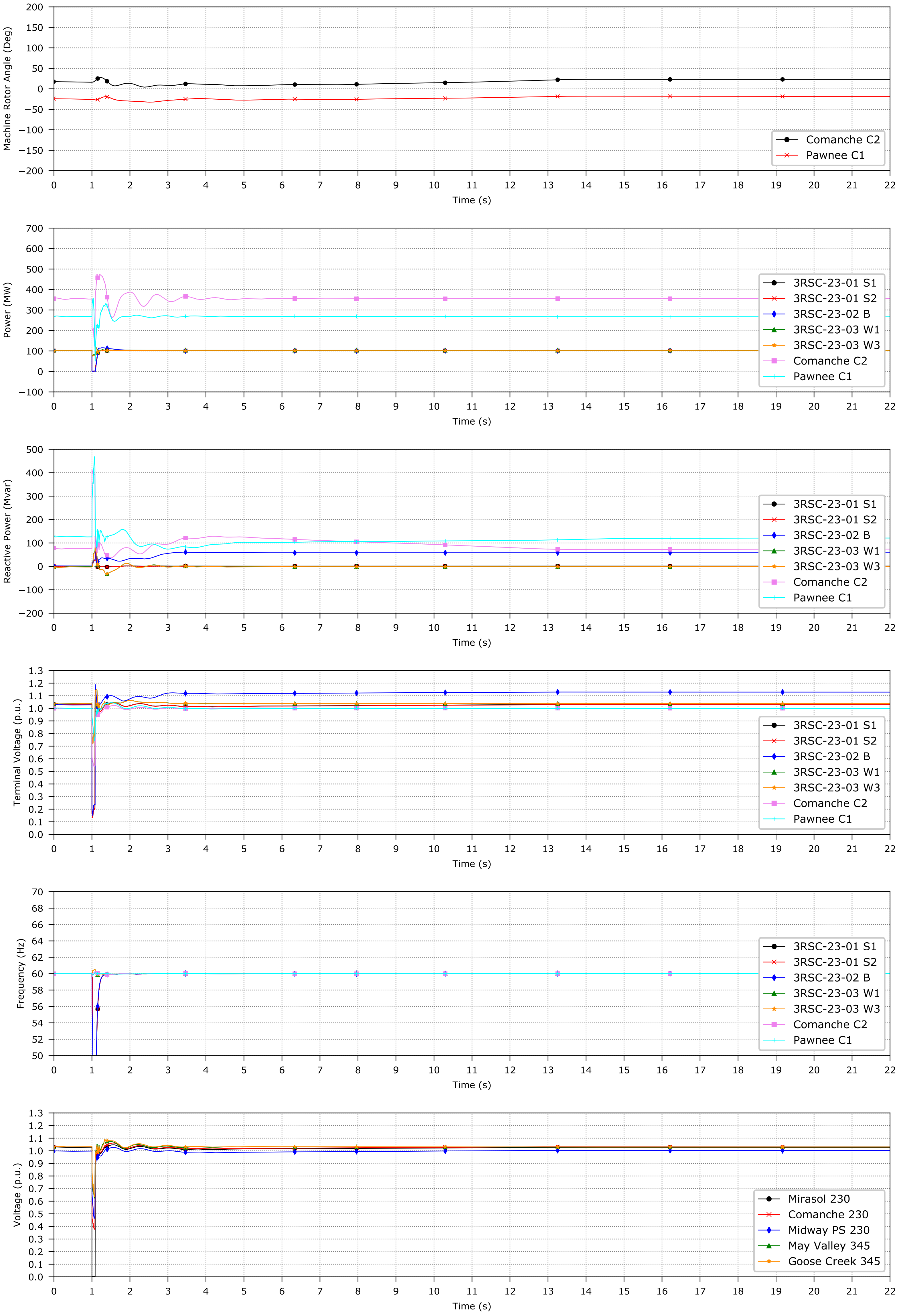
Gens 3RSC_23_2



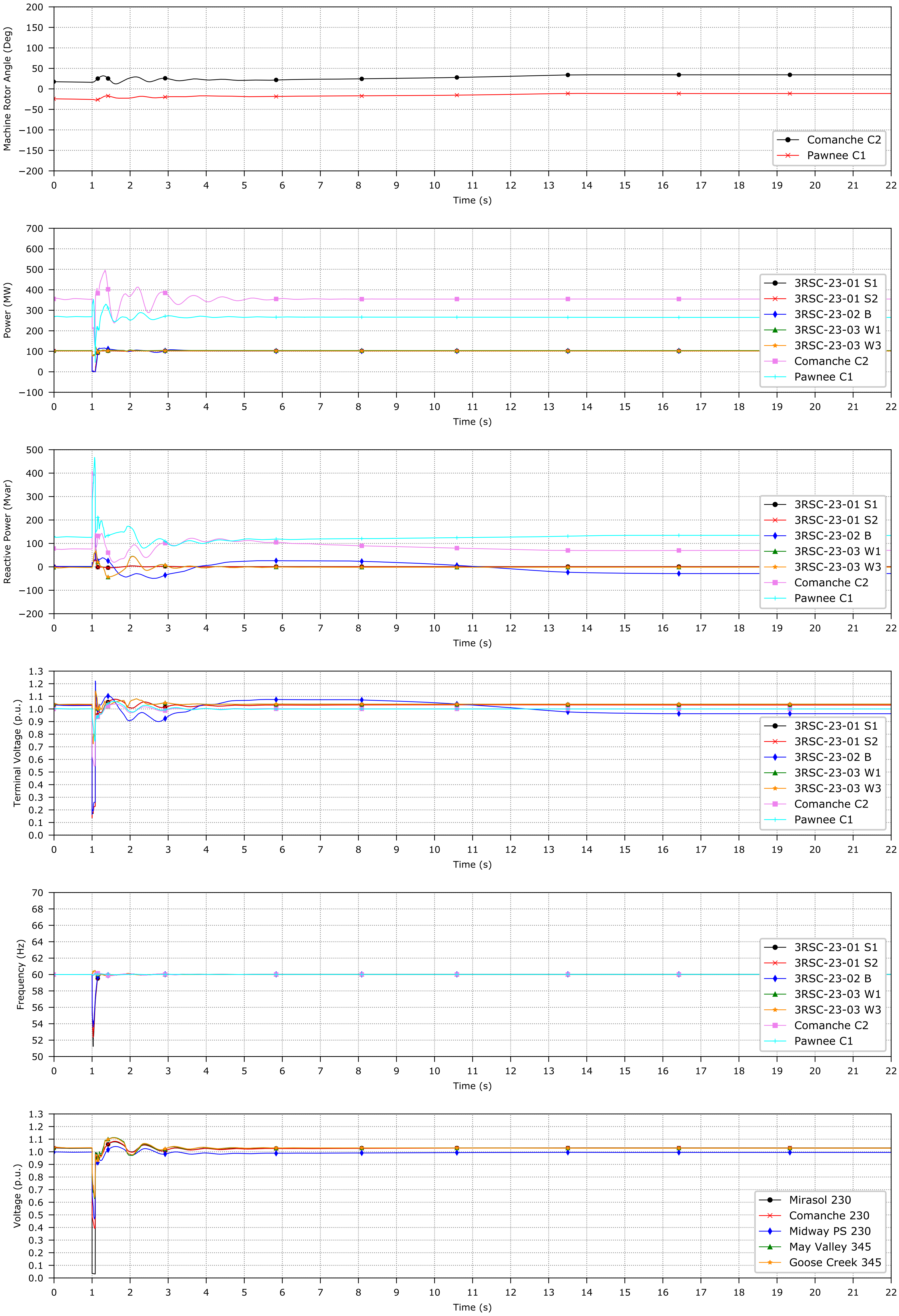
Gens 3RSC_23_3



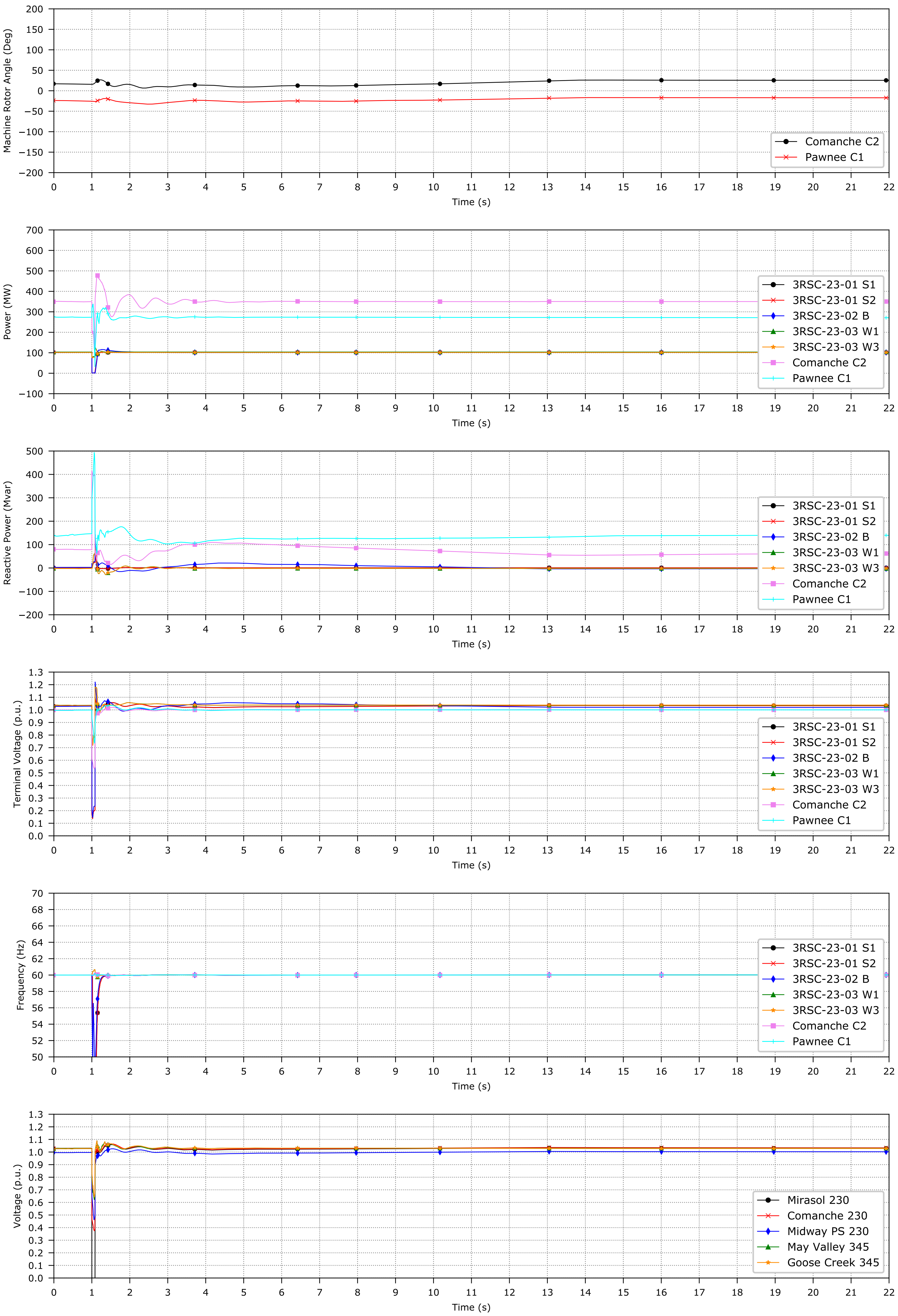
Comanche - Mirasol 230 kV



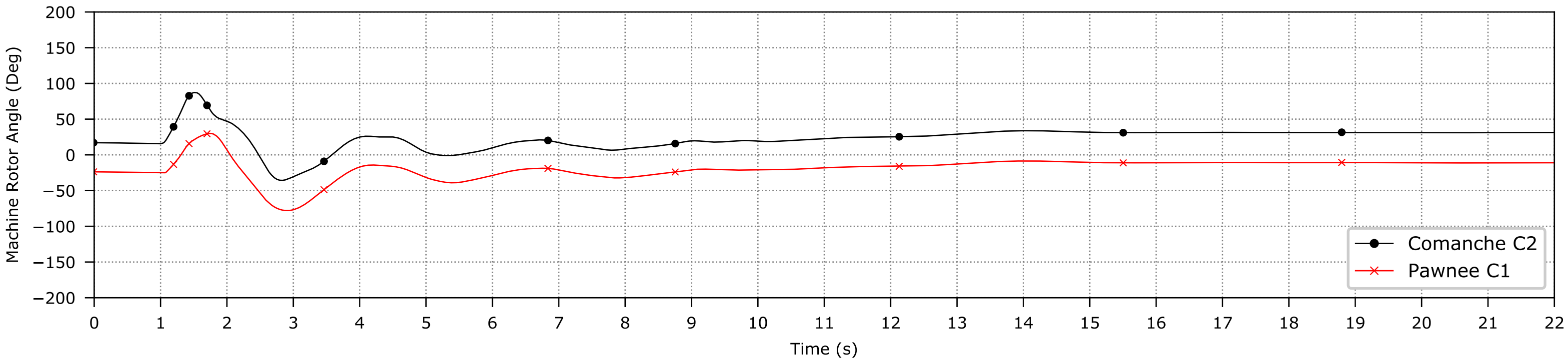
Midway - Mirasol 230 kV

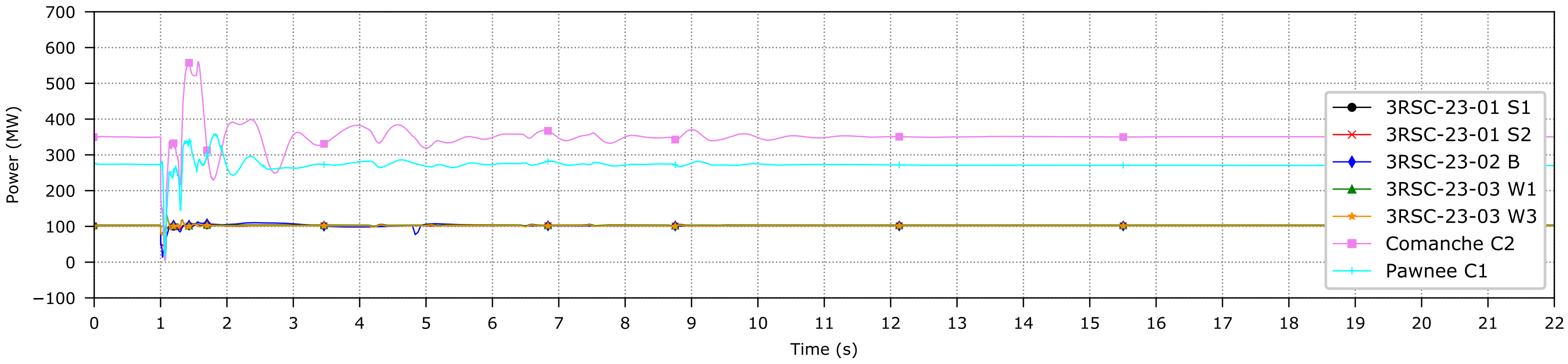


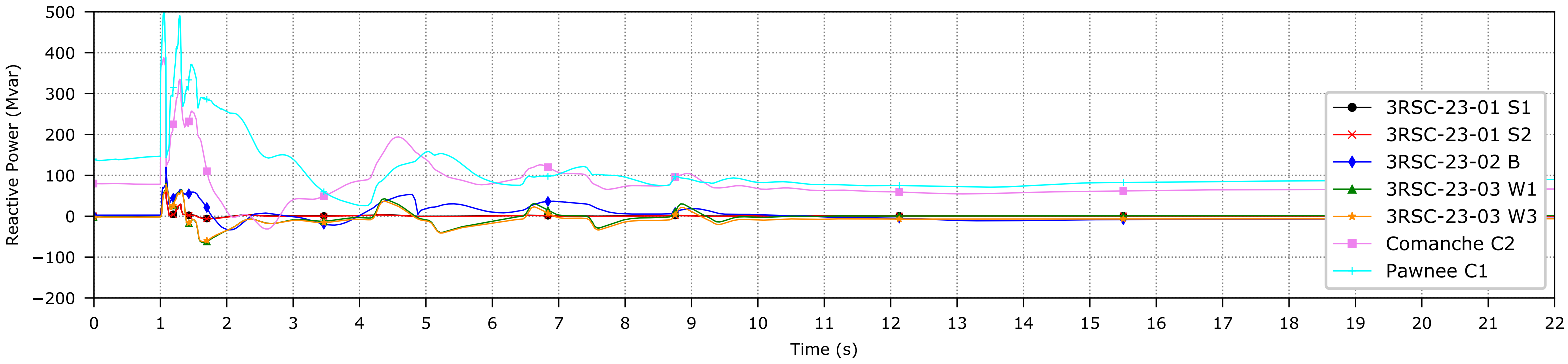
Mirasol - Thunderwolf 230 kV

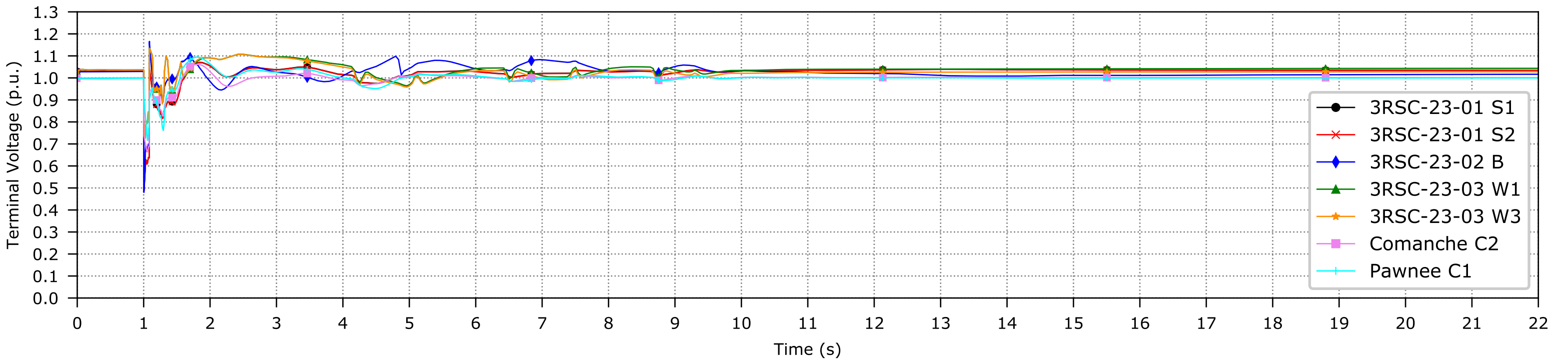


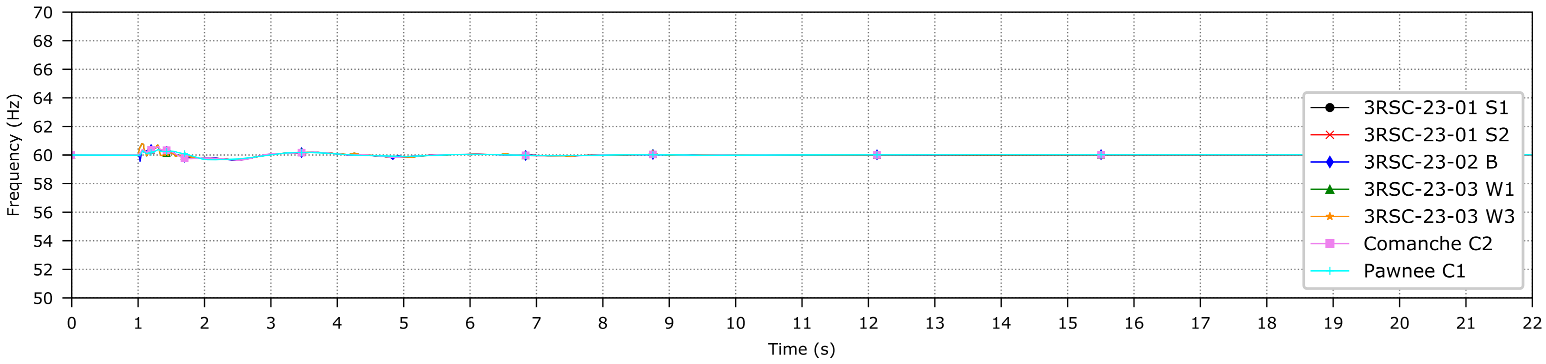
Midway - Fuller 230 kV

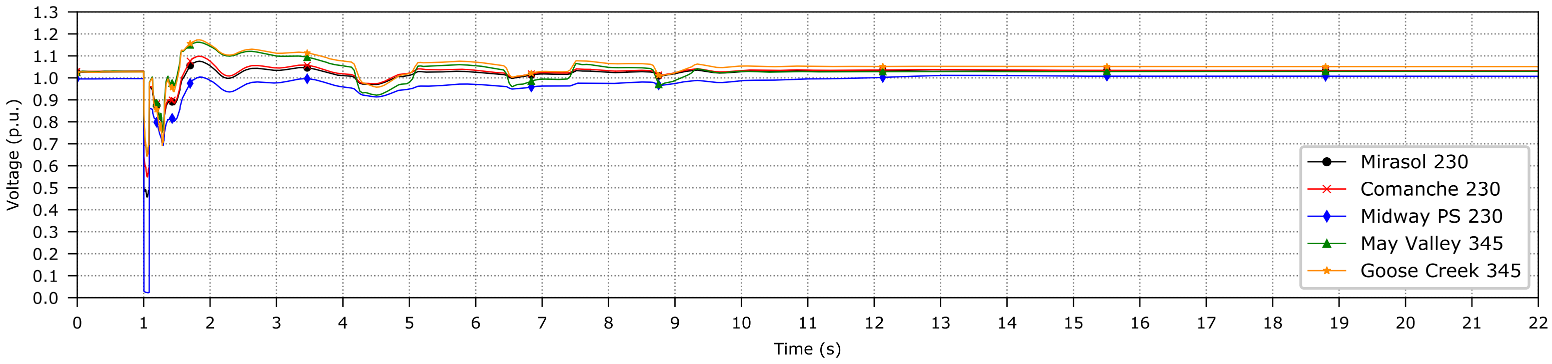




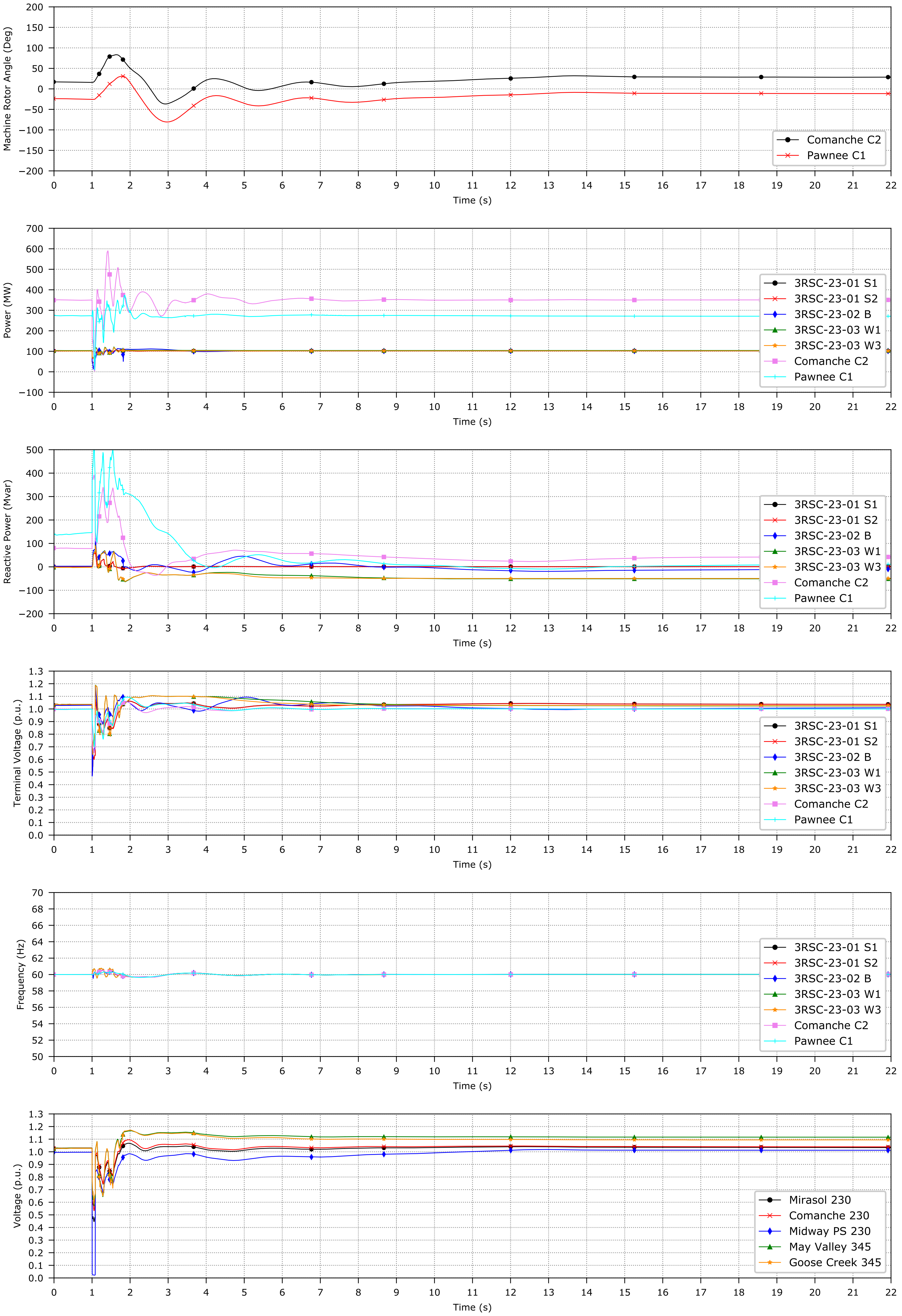




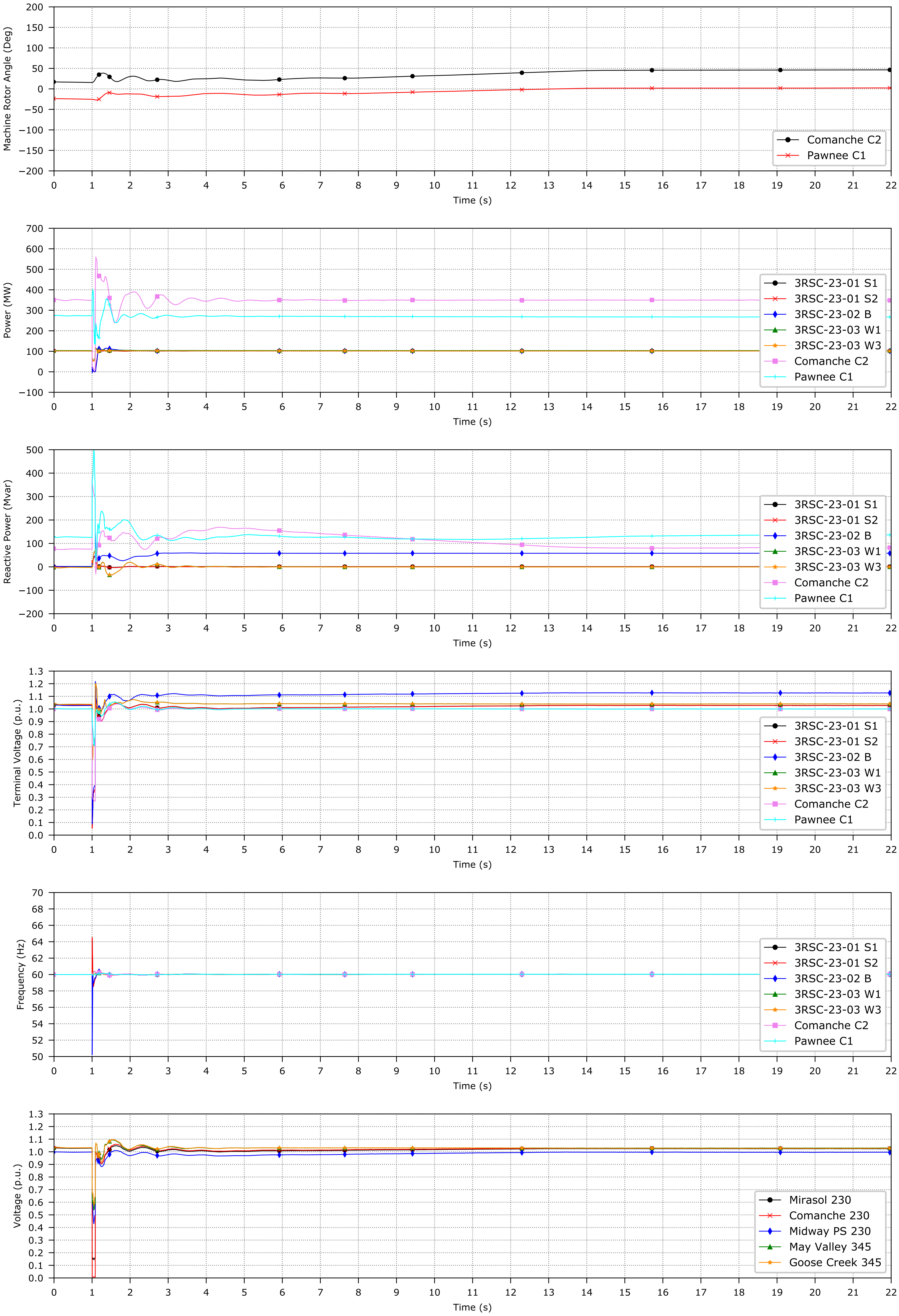




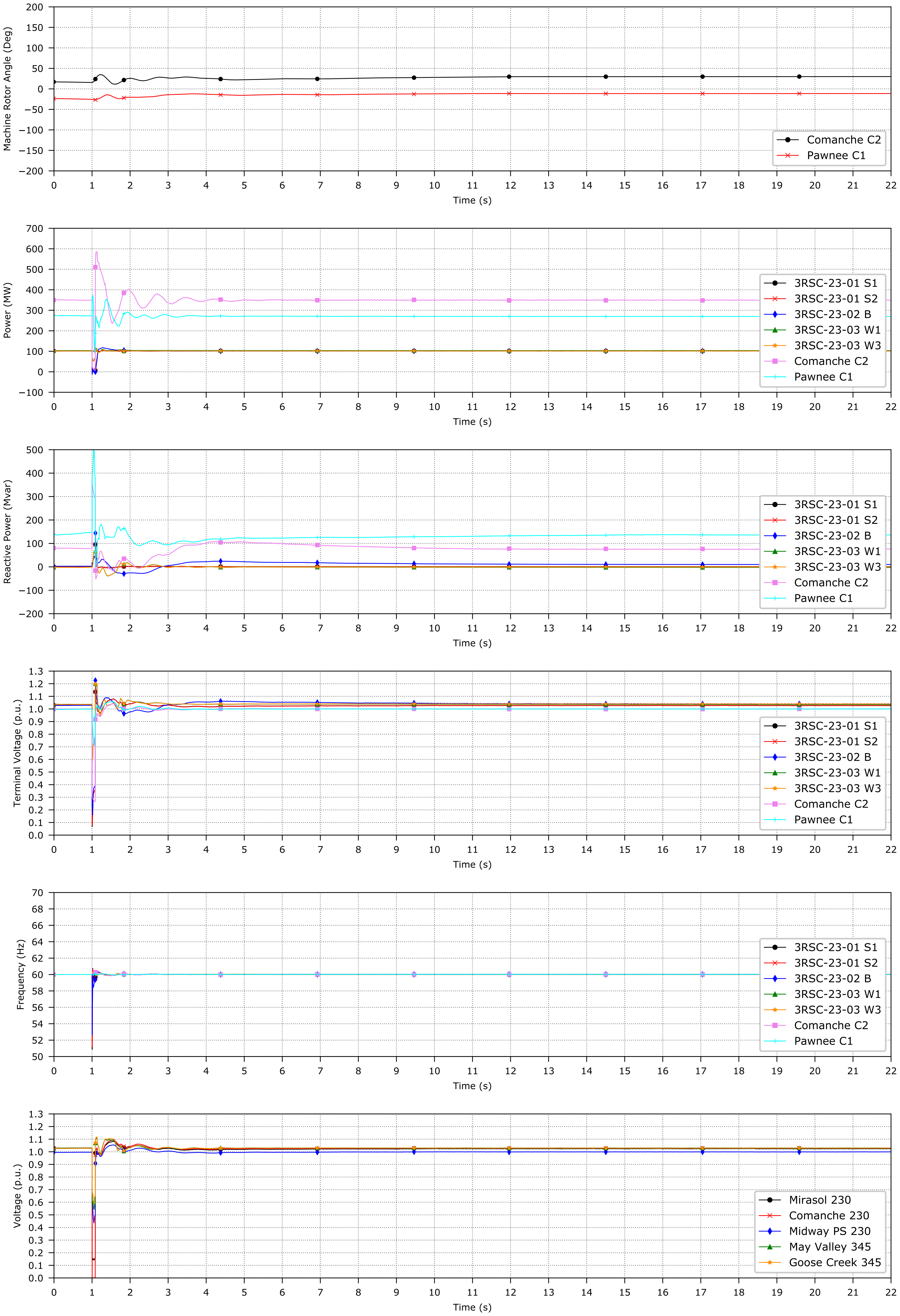
Midway - Boone 230 kV



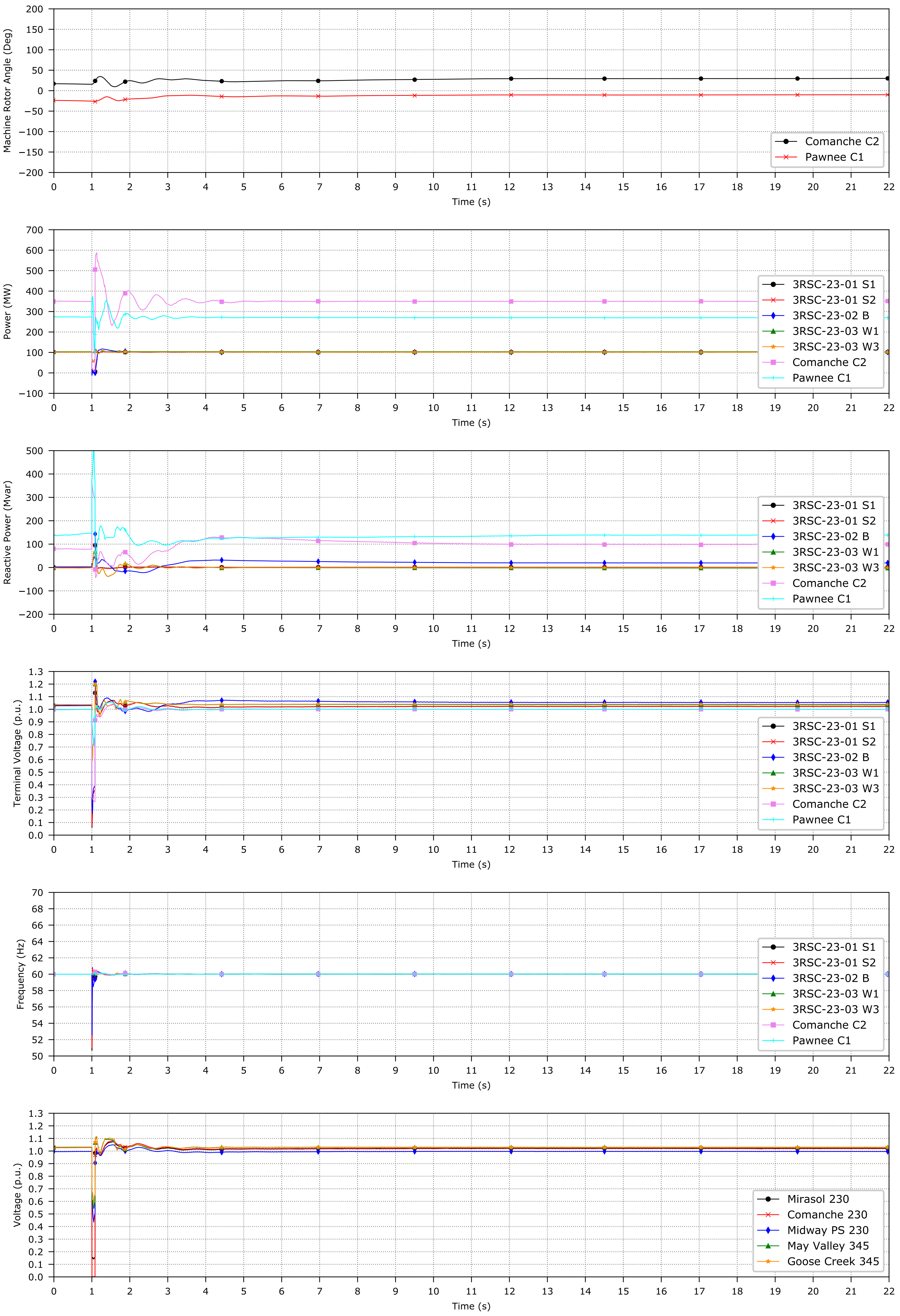
Comanche - Huckleberry 230 kV



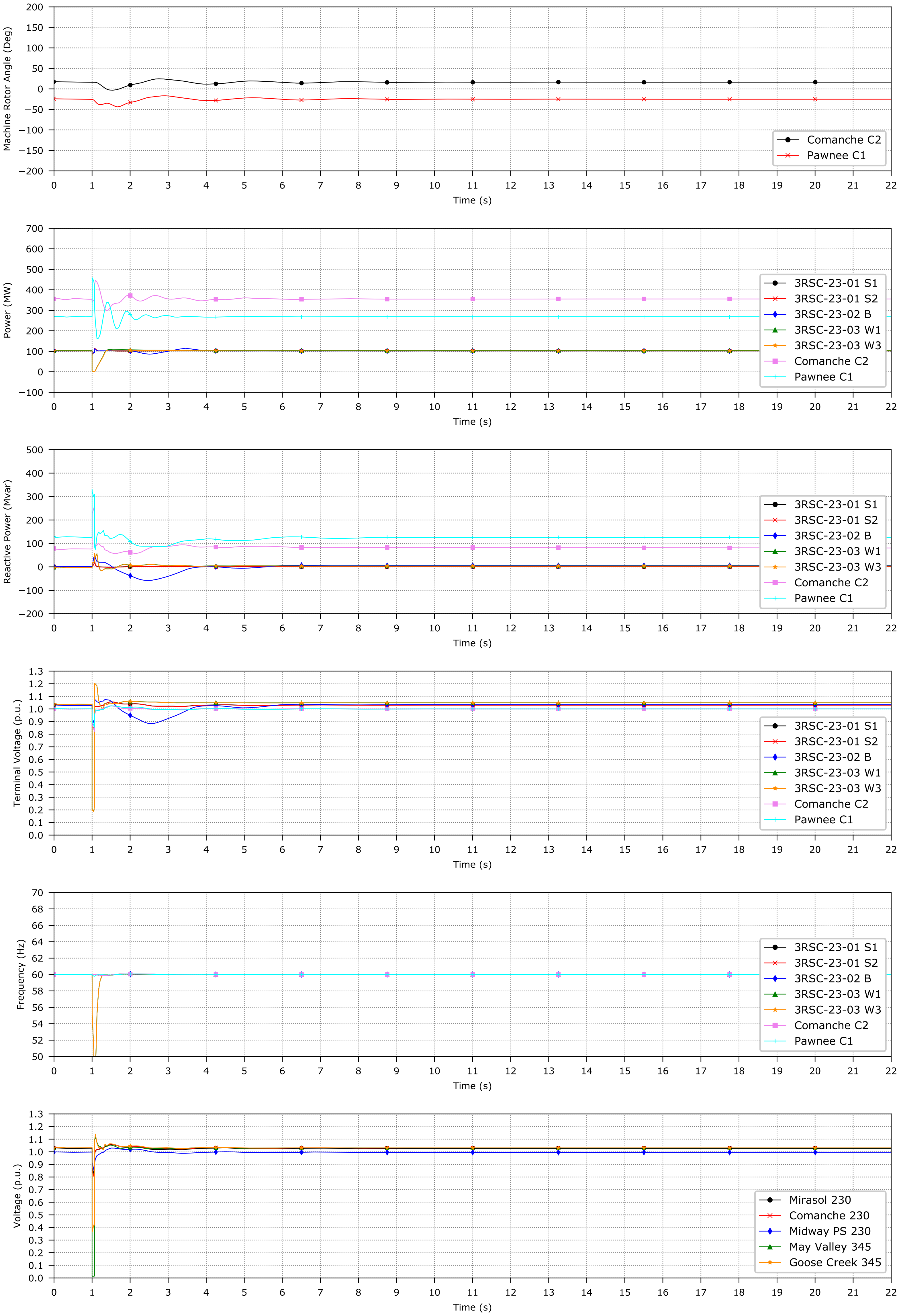
Comanche - Bighorn 230 kV



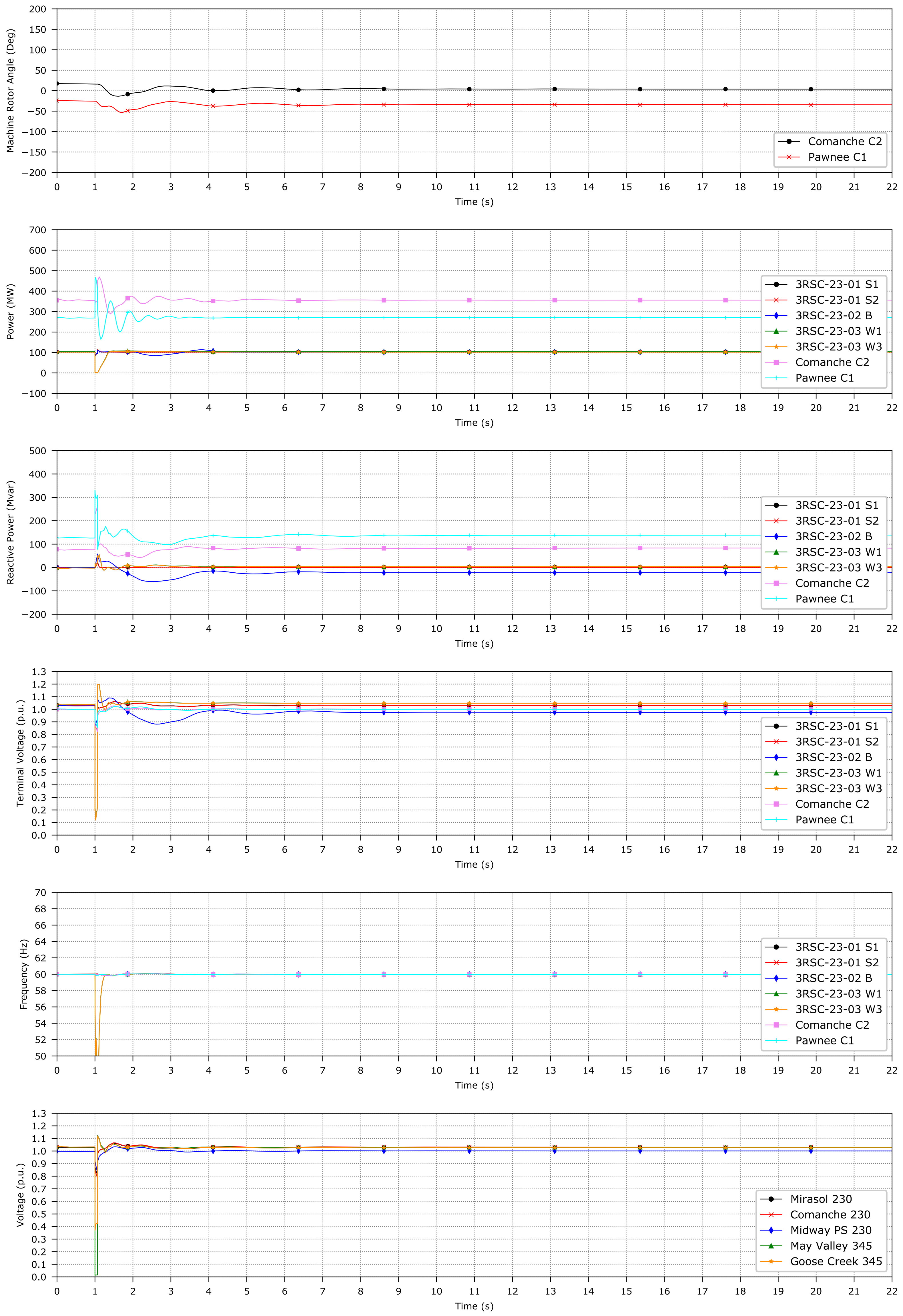
Comanche - Sun Mountain 230 kV



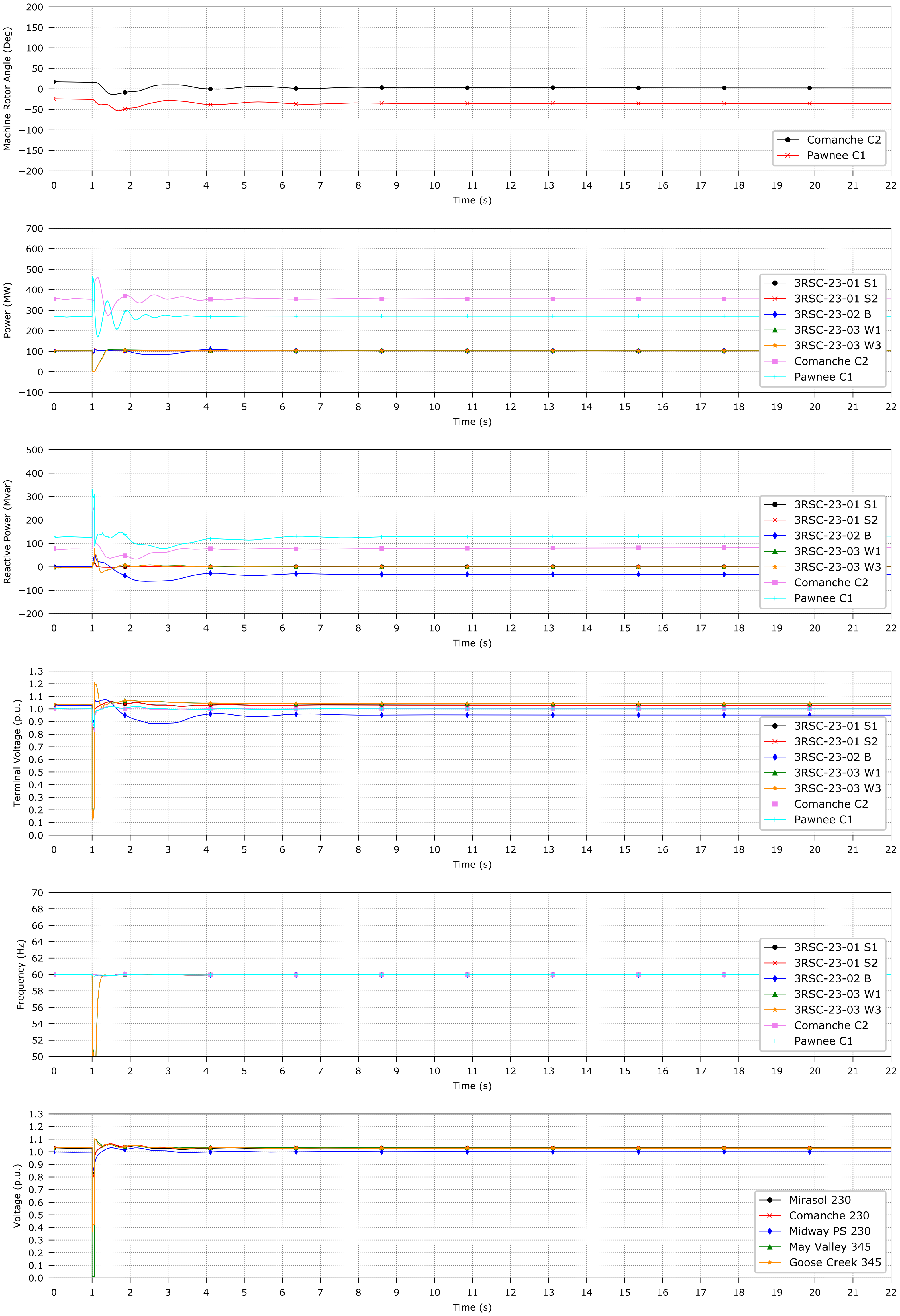
May Valley - Goose Ck. 345 kV



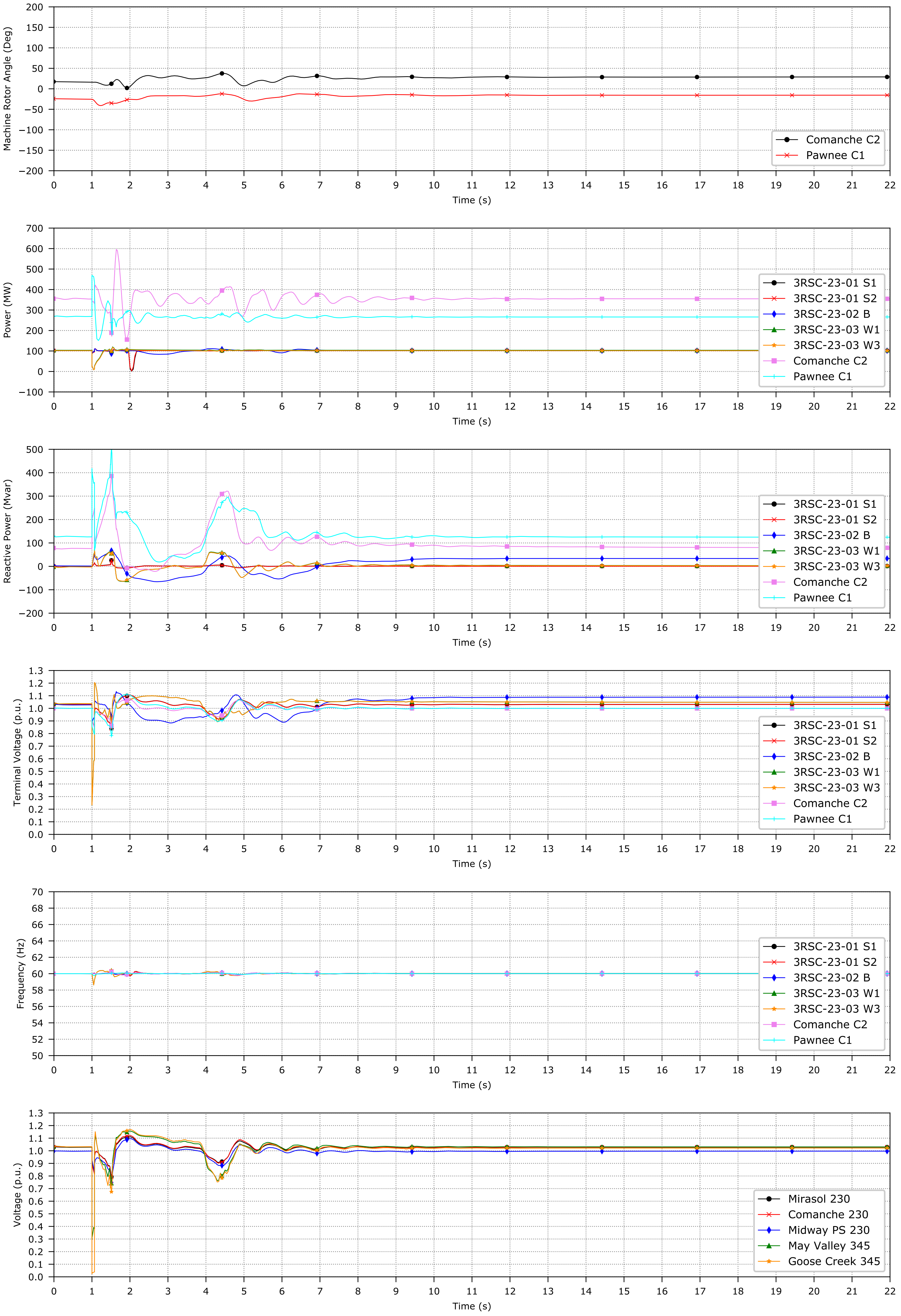
May Valley - Sandstone 345 kV CKT 1



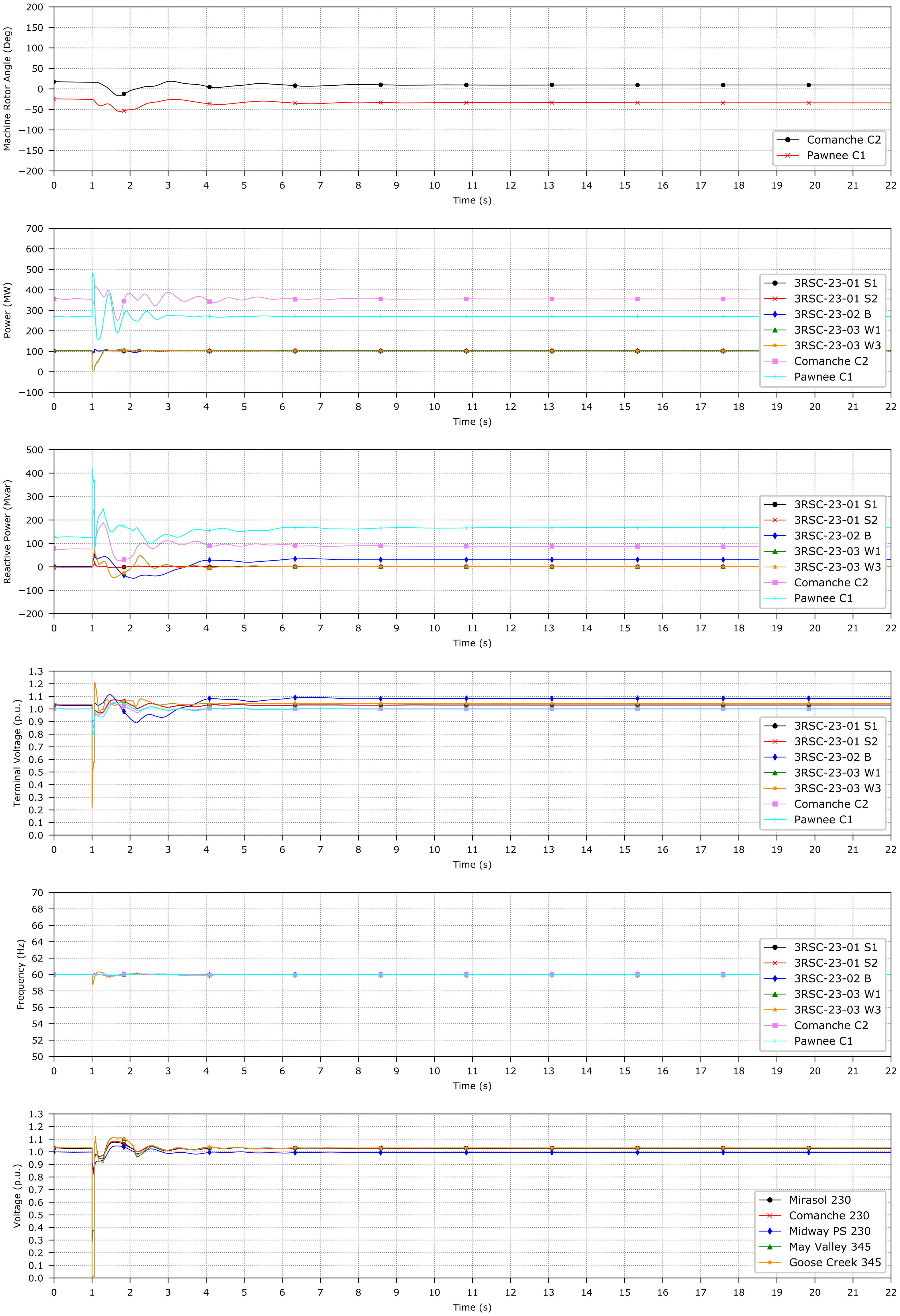
May Valley - Sandstone 345 kV CKT 2



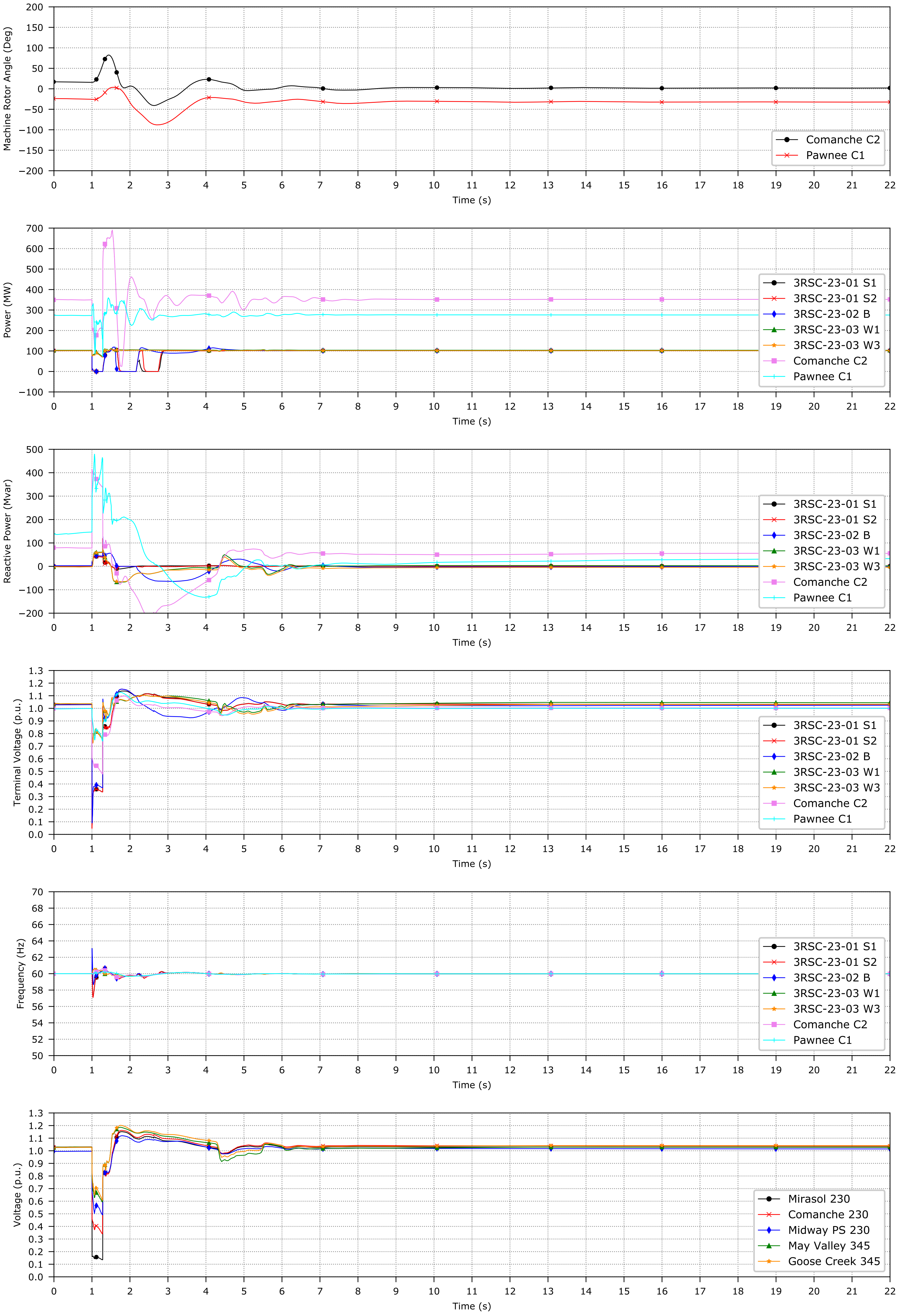
Goose Ck. - Canal Crossing 345 kV



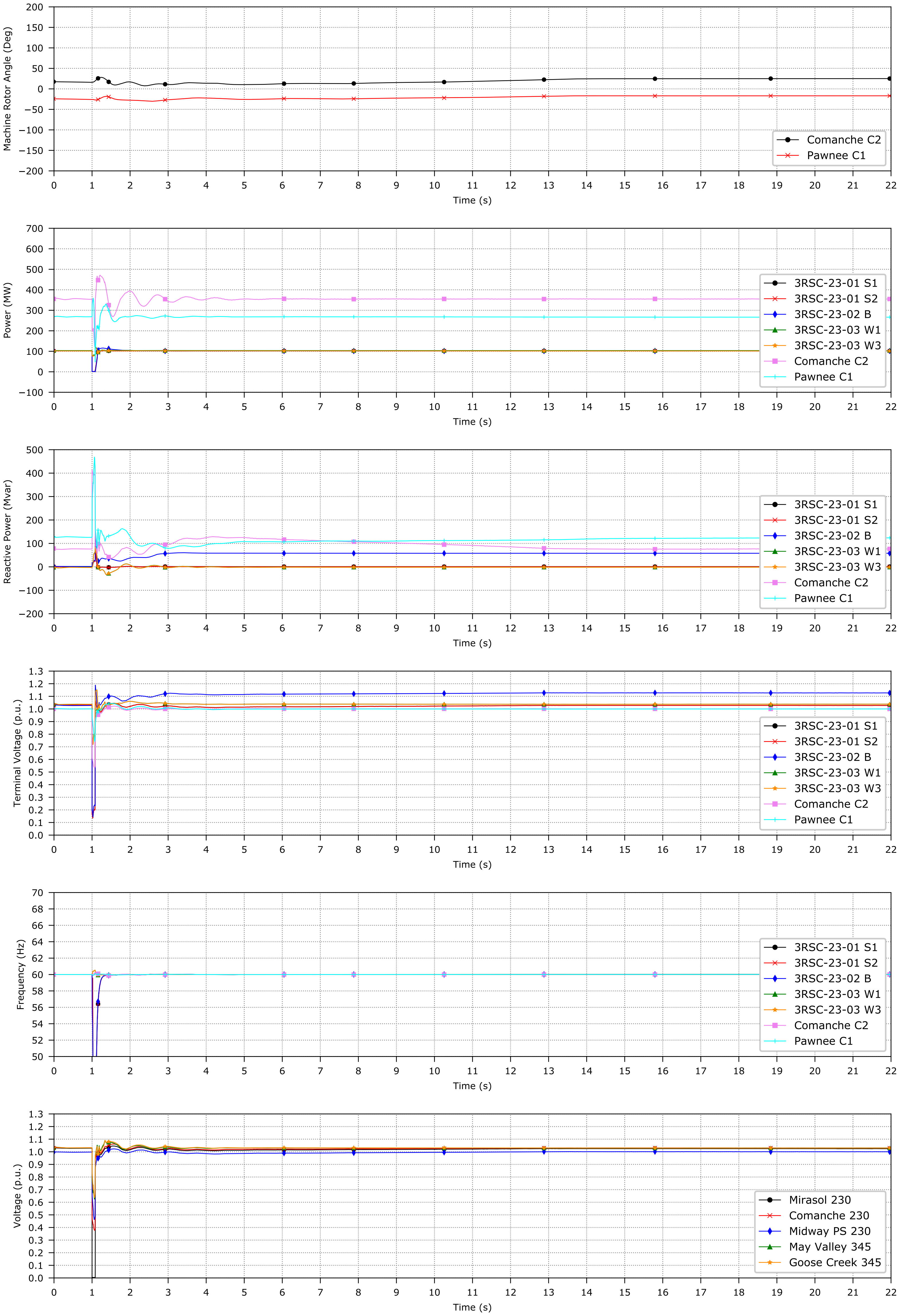
Goose Ck. - Shortgrass 345 kV



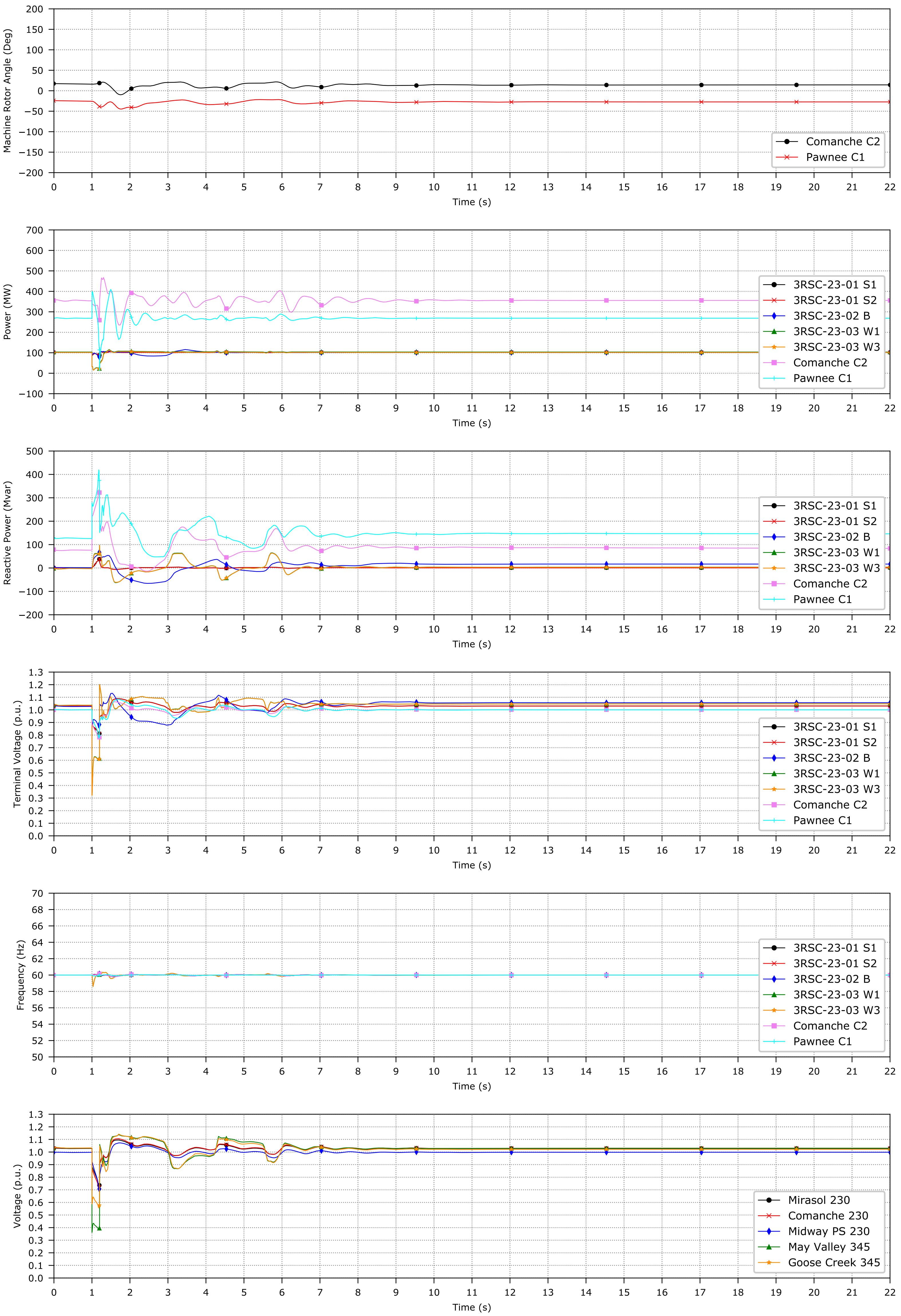
Mirasol 230 kV BF



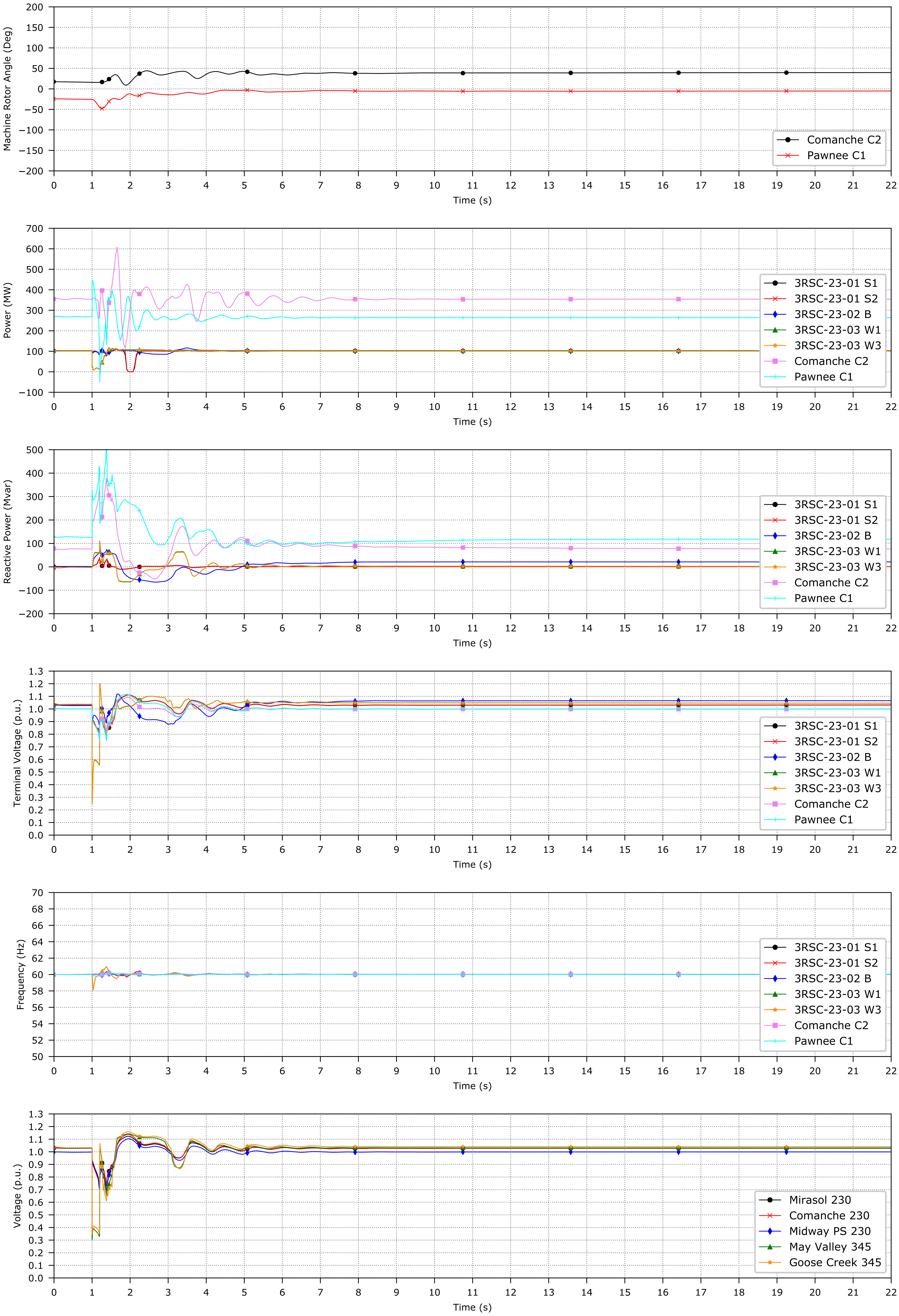
Mirasol 230 kV P7



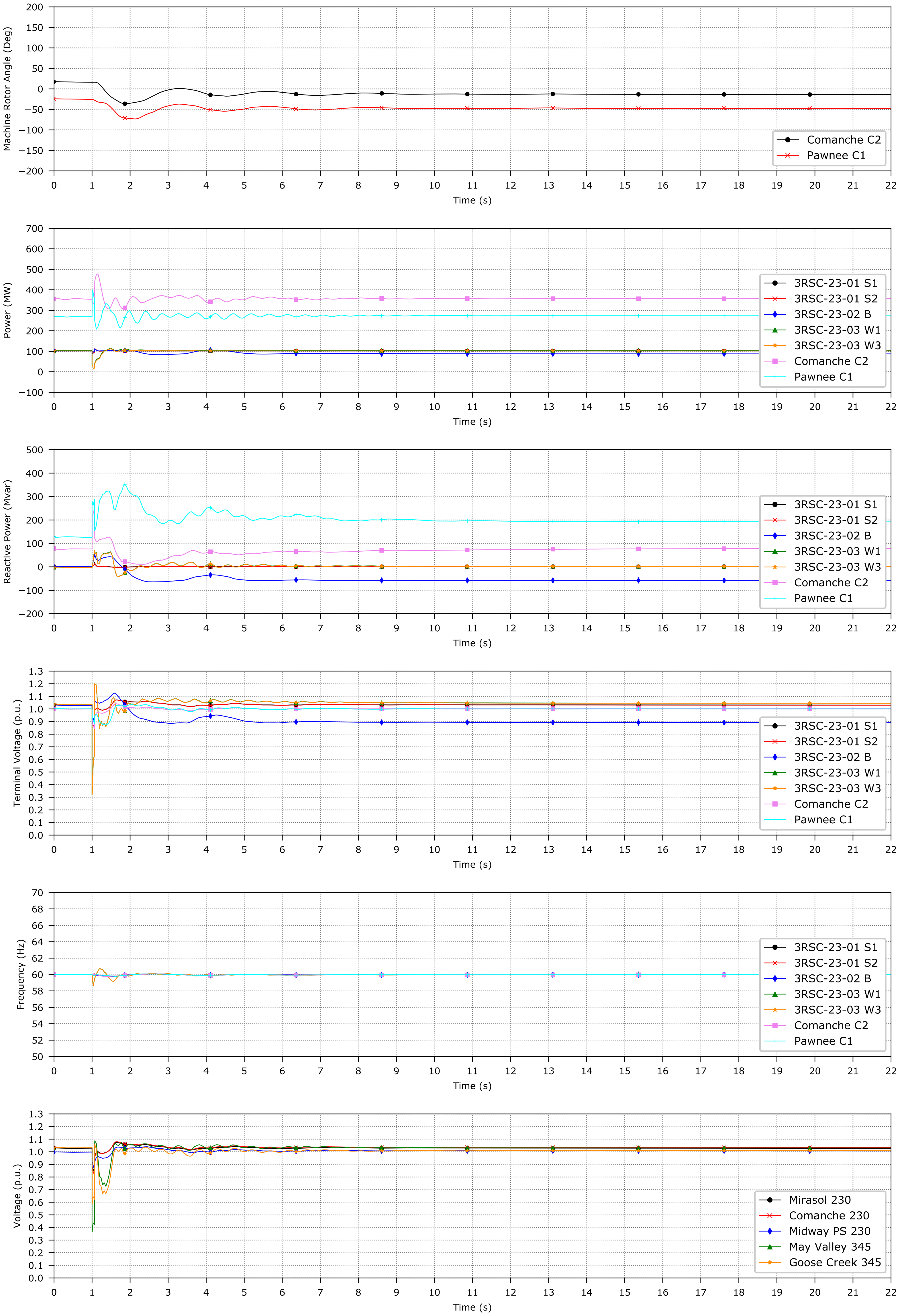
May Valley 345 kV BF 1



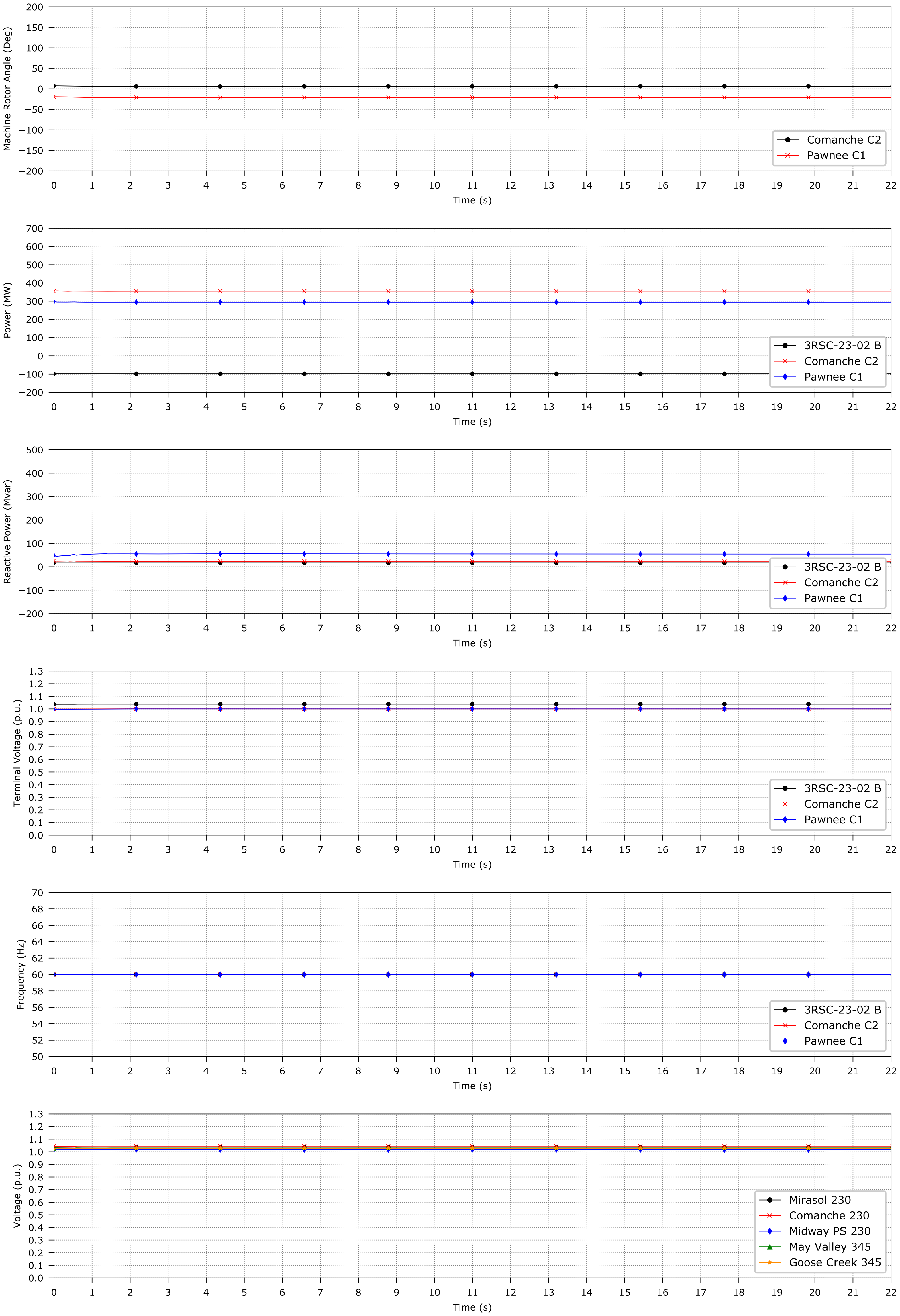
May Valley 345 kV BF 2



May Valley 345 kV P7

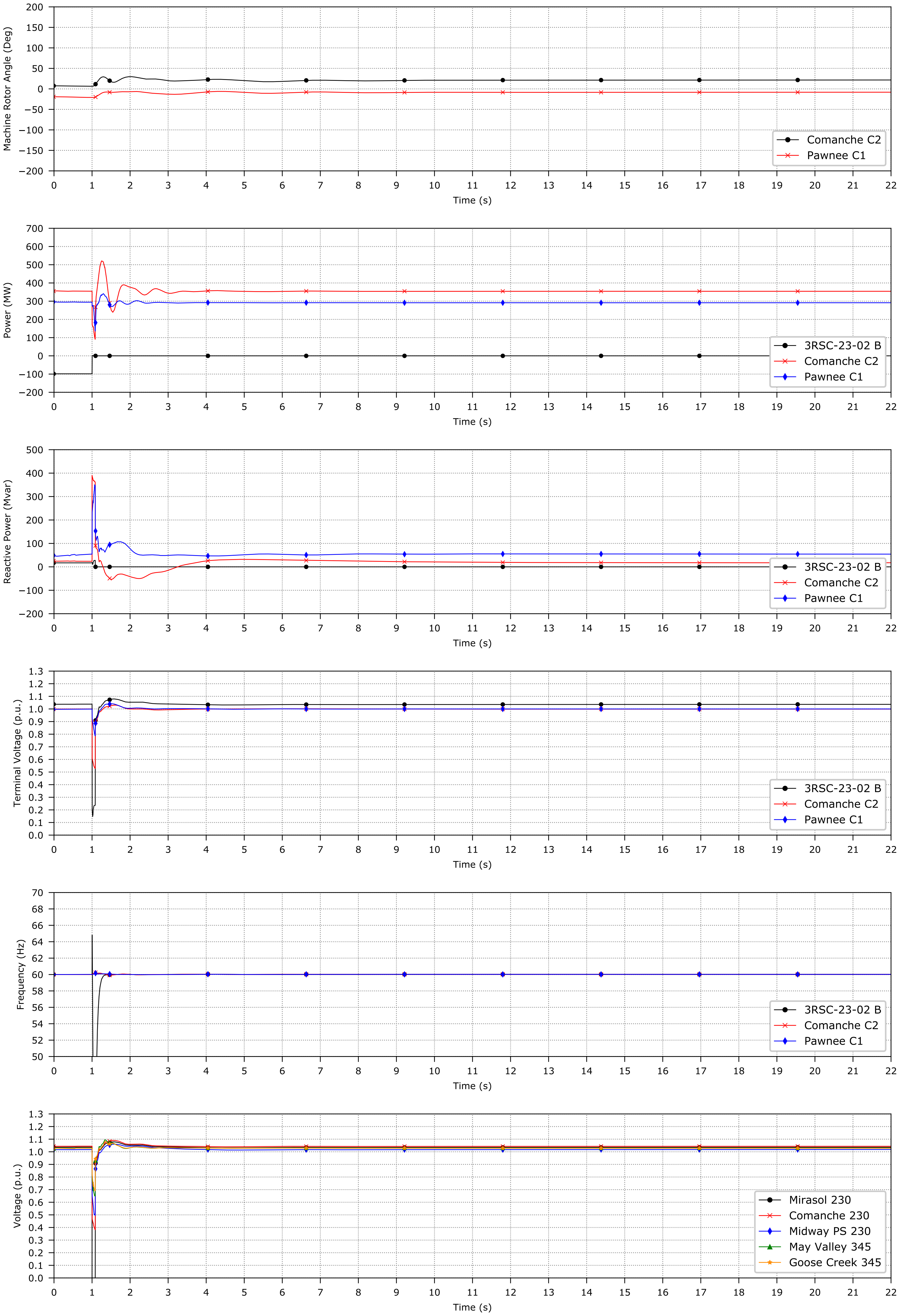


Flatrun

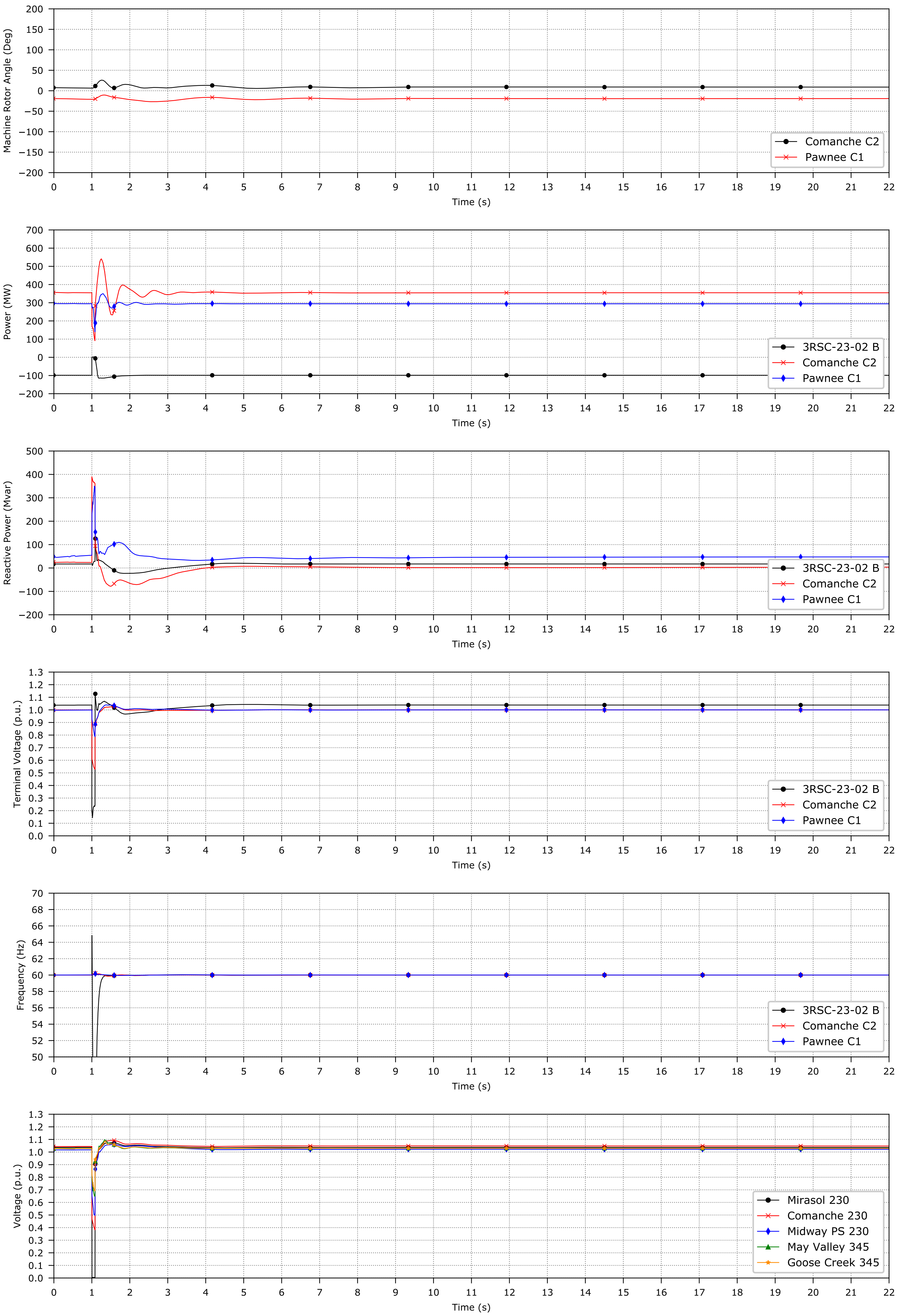


Machine Rotor Angle (Deg)
Time (s)
Comanche C2
Pawnee C1
Power (MW)
Time (s)
3RSC-23-02 B
Comanche C2
Pawnee C1
Reactive Power (Mvar)
Time (s)
3RSC-23-02 B
Comanche C2
Pawnee C1
Terminal Voltage (p.u.)
Time (s)
3RSC-23-02 B
Comanche C2
Pawnee C1
Frequency (Hz)
Time (s)
3RSC-23-02 B
Comanche C2
Pawnee C1
Voltage (p.u.)
Time (s)
Mirasol 230
Comanche 230
Midway PS 230
May Valley 345
Goose Creek 345

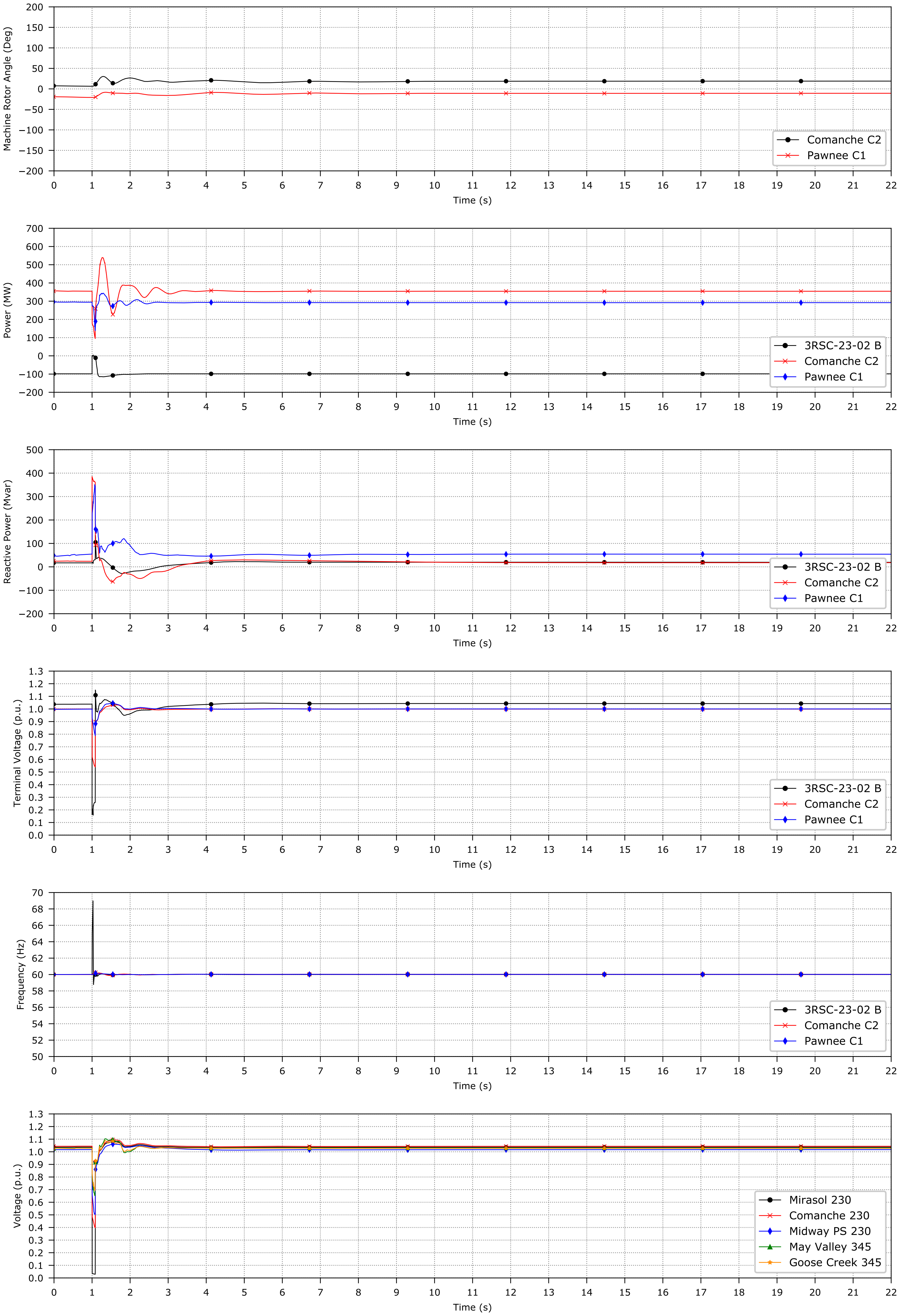
Gens 3RSC_23_2



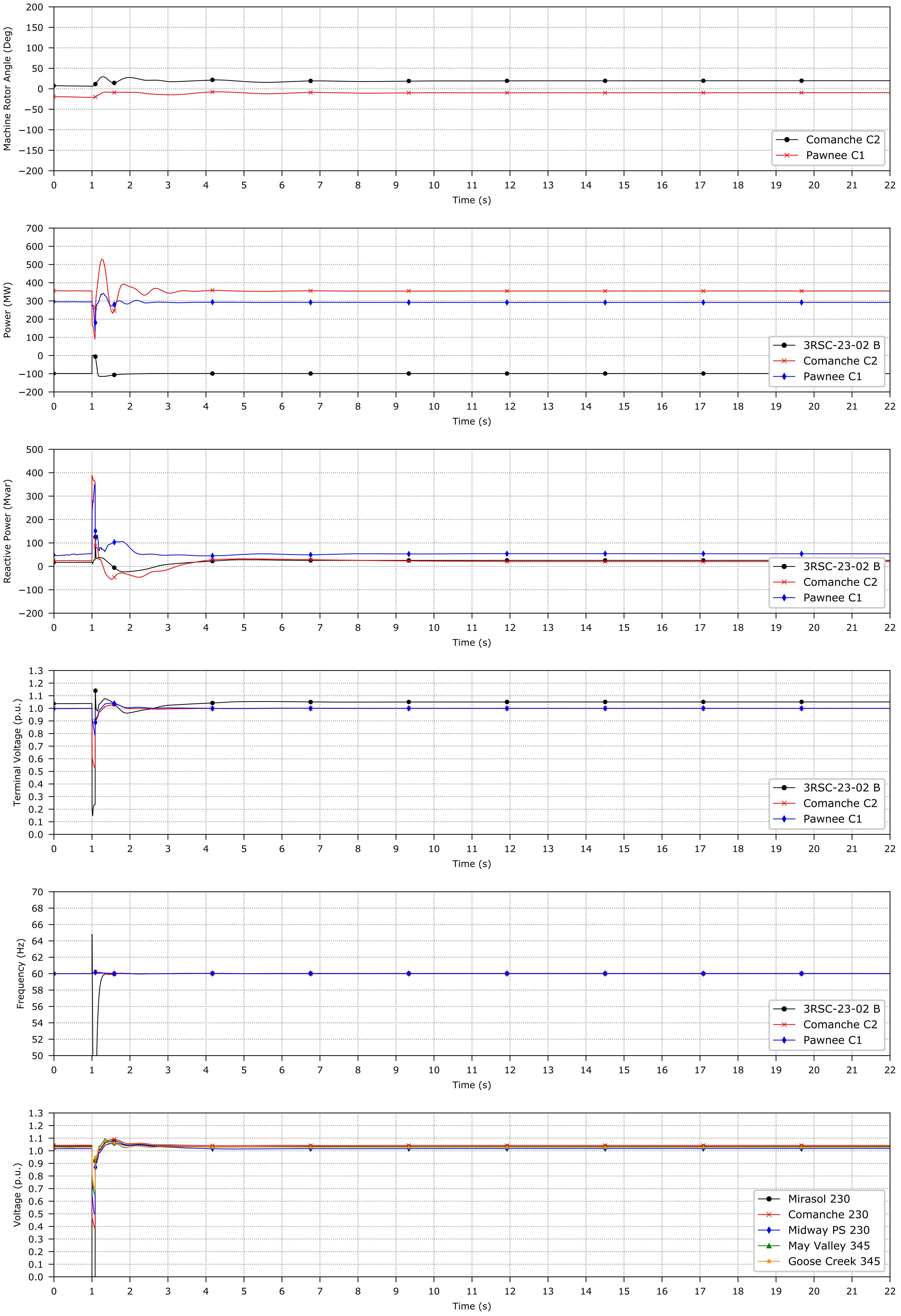
Comanche - Mirasol 230 kV



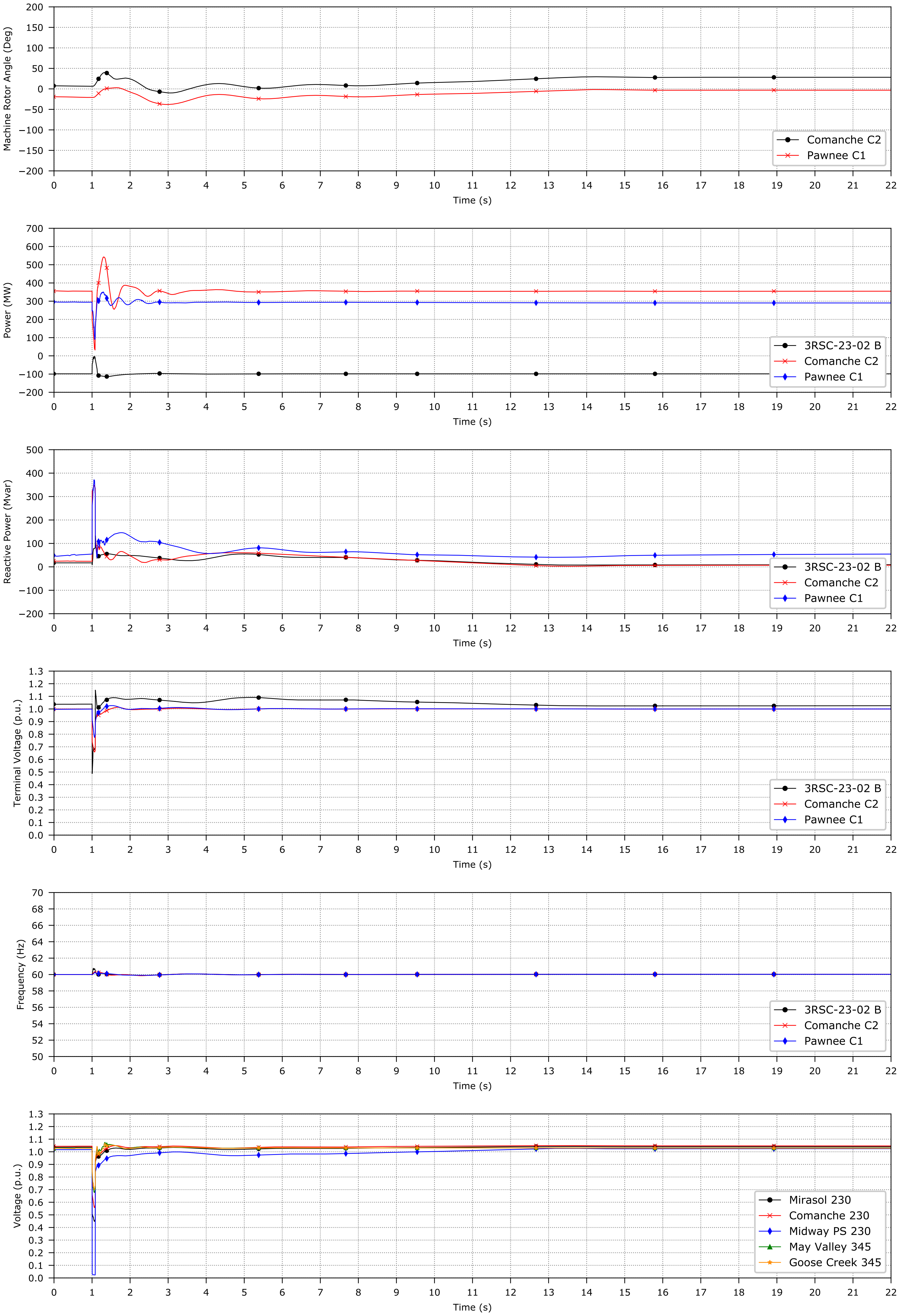
Midway - Mirasol 230 kV



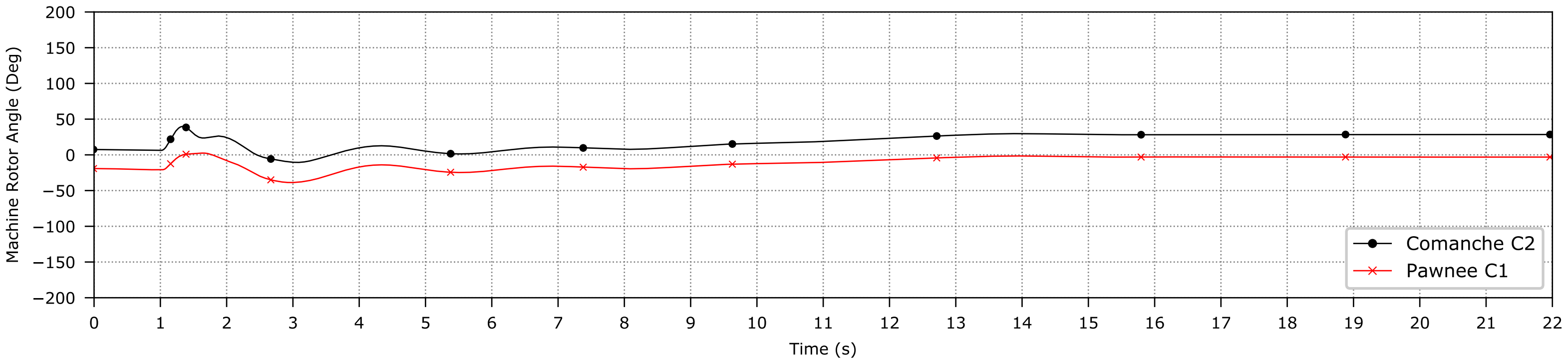
Mirasol - Thunderwolf 230 kV

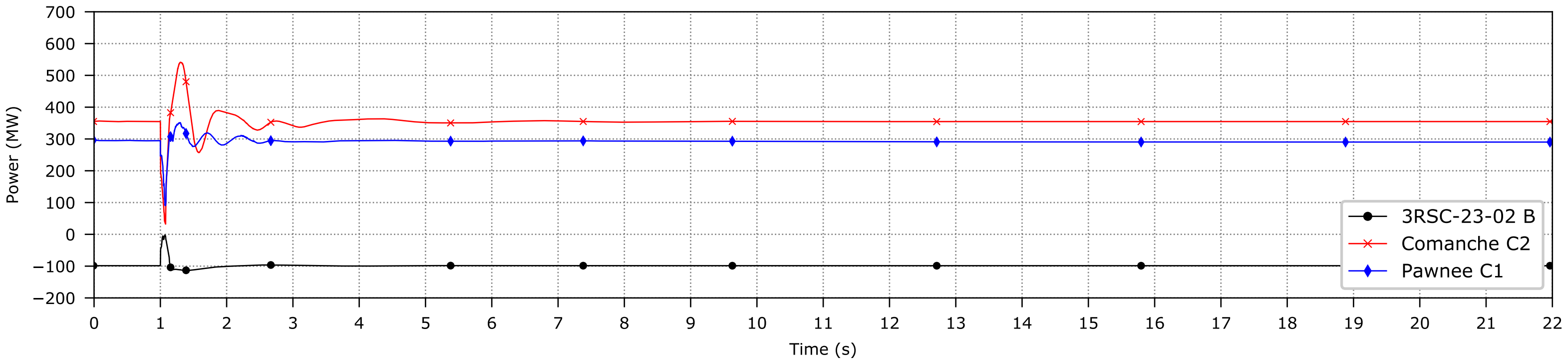


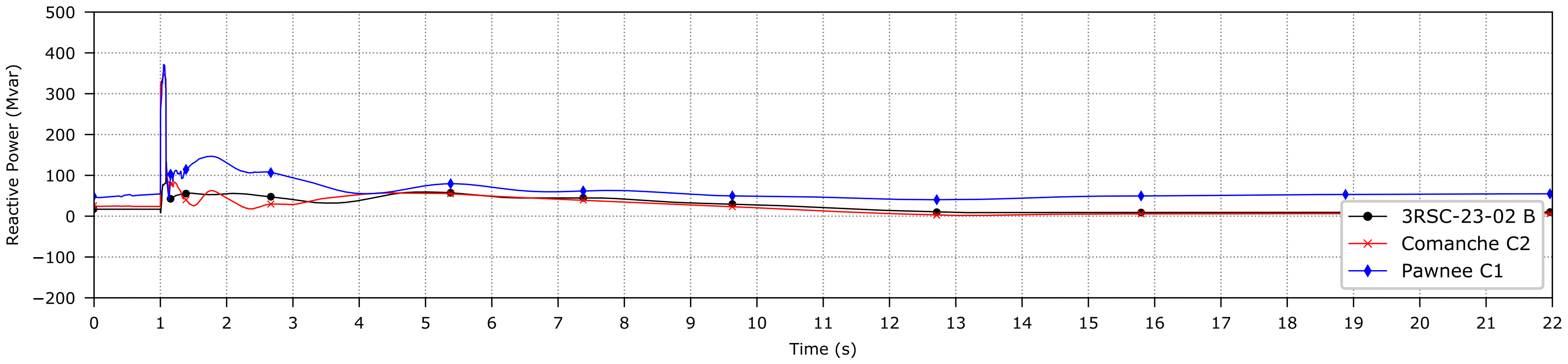
Midway - Fuller 230 kV

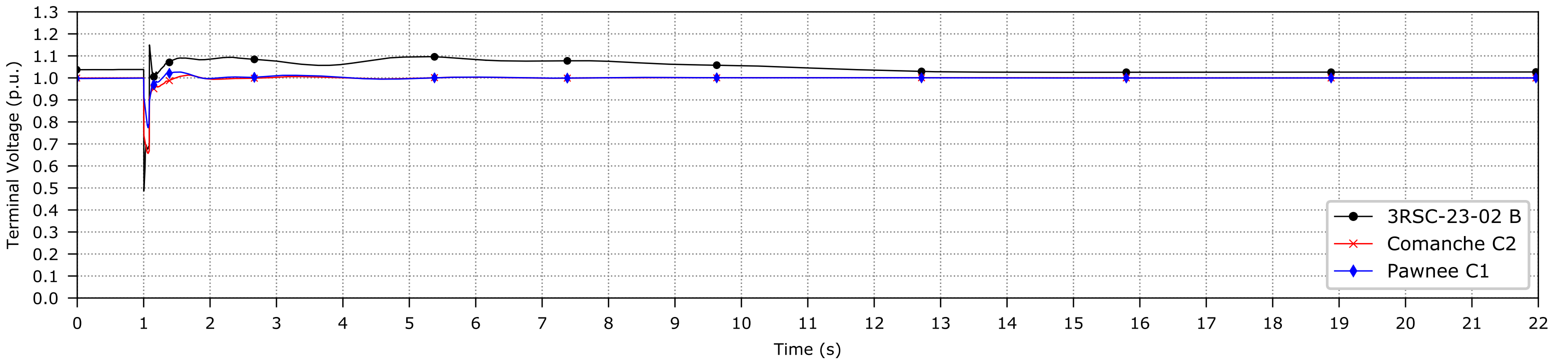


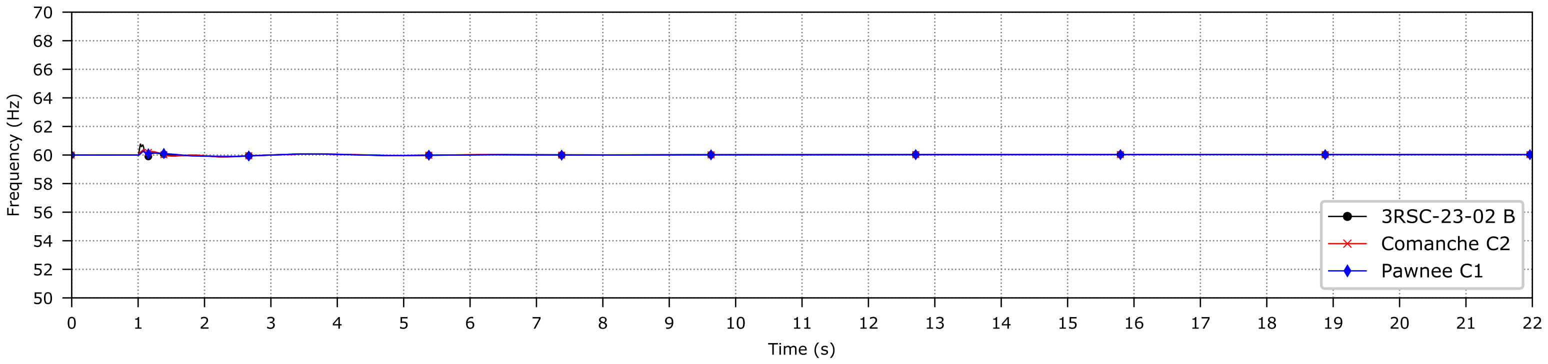
Midway - Boone 230 kV

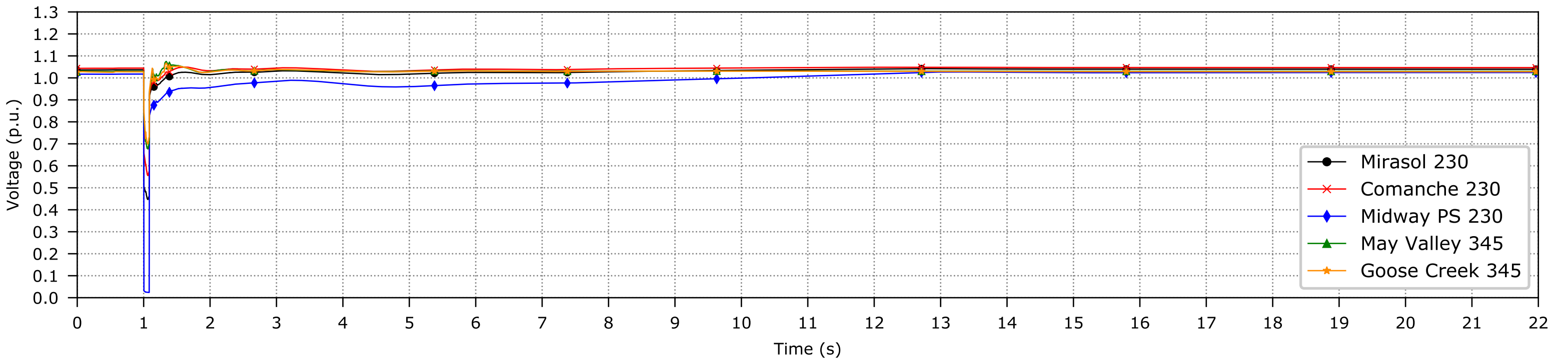




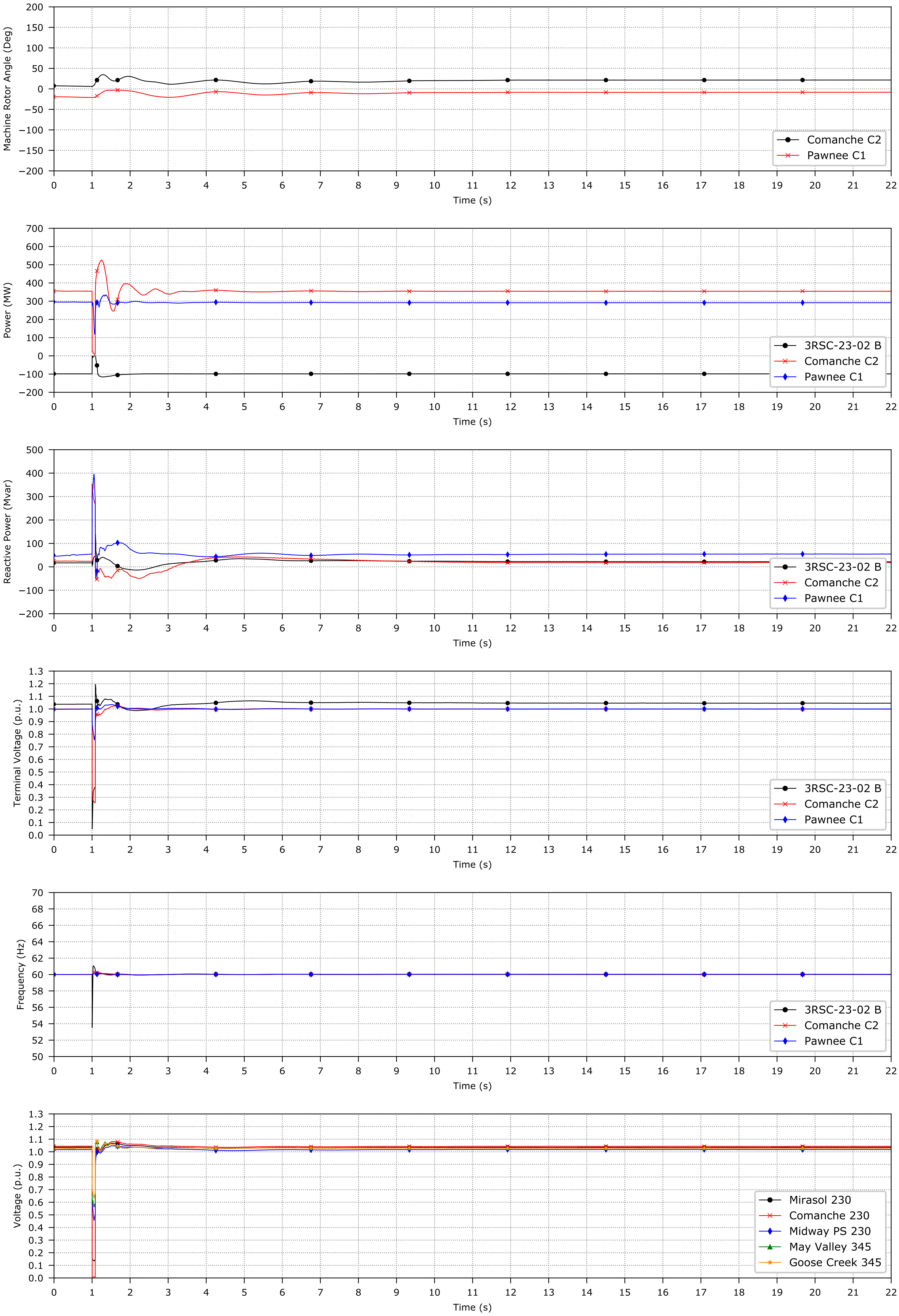




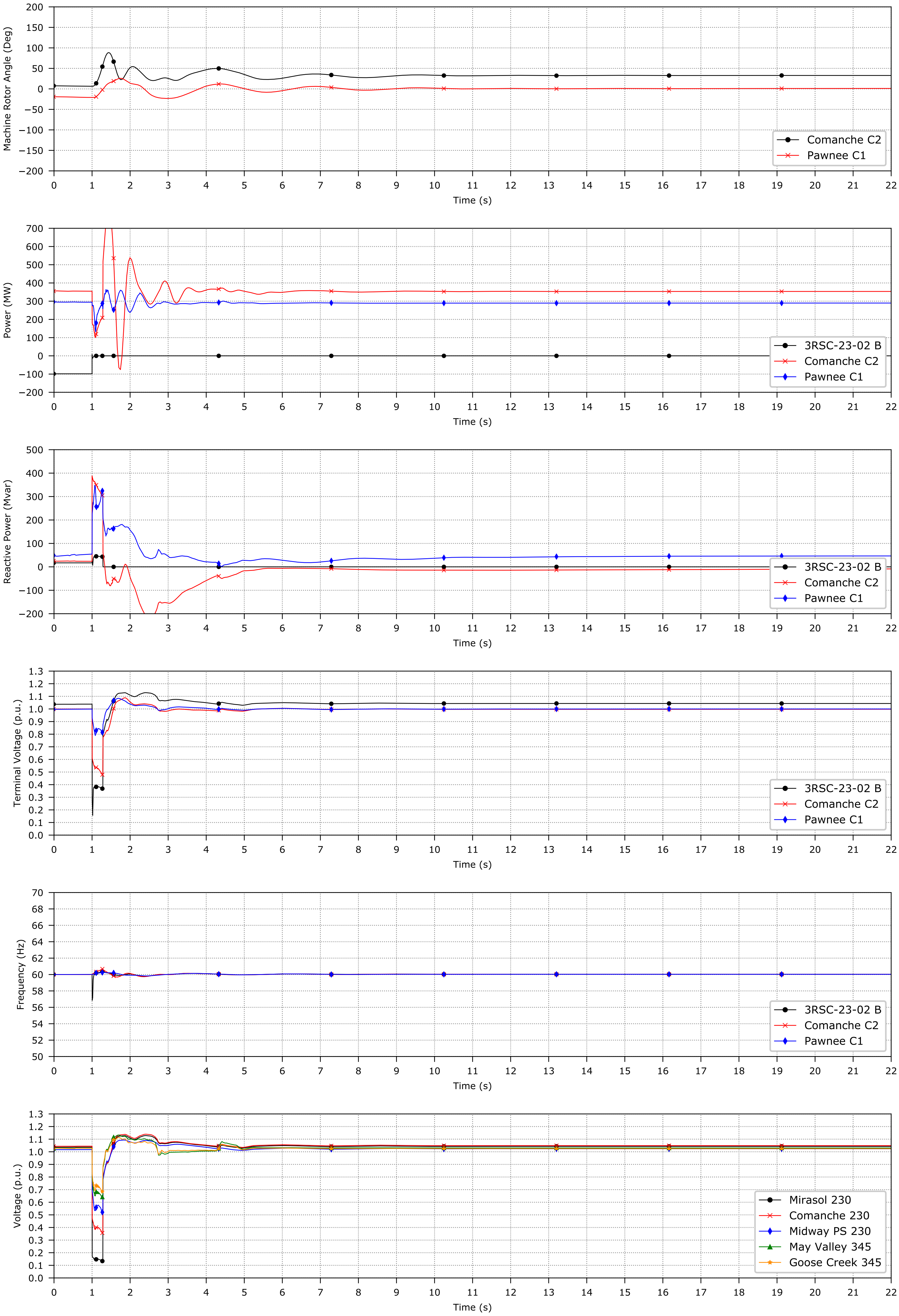




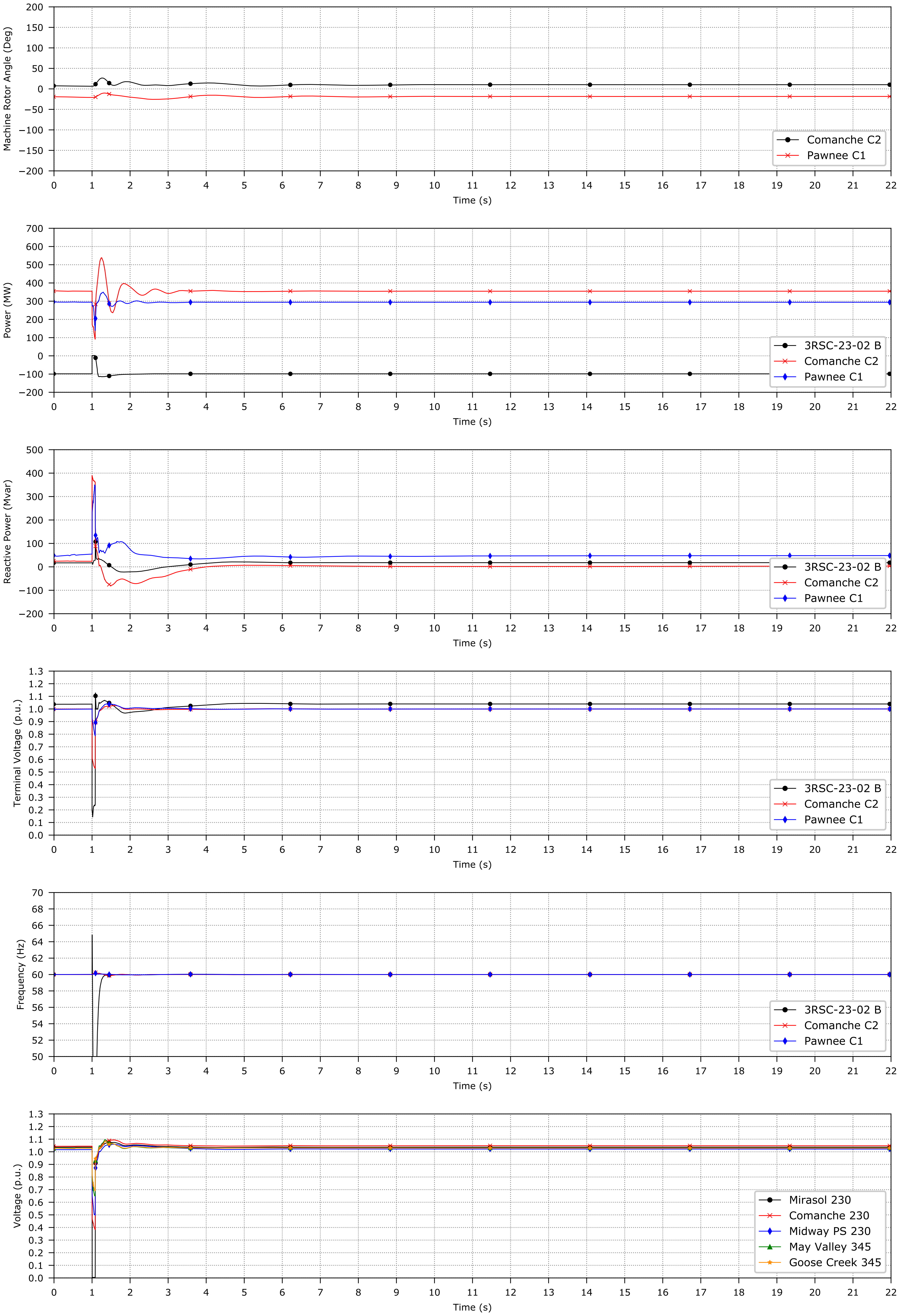
Comanche - Huckleberry 230 kV



Mirasol 230 kV BF



Mirasol 230 kV P7



Xcel Energy

Appendix C: Contingent Facility Study Results

South Colorado Study Pocket

Table C-1: Daniels Park – Jackson Fuller uprate to 637 MVA

Overloaded Facility	Type	Area	Upgraded Facility Rating (MVA)	Non-Upgraded Facility Rating (MVA)	Facility Loading in Study Case		Facility Loading in Study Case with Unbuilt Facility Reverted		Loading % Change Due to Facility Reversion	Single Contingency Definition	3RSC 23 1 DFAX	3RSC 23 2 DFAX	3RSC 23 3 DFAX
					MVA Flow	% Loading	MVA Flow	% Loading					
Daniel Park (70139) - Fuller (73477) 230 kV CKT 1	Line	70/73	637	478	532.79	83.64	532.78	111.46	27.82	Midway (70465) - Waterton (70466) 345 kV CKT 1	0.1105	0.1105	0.0018

Table C-2: Midway - Jackson Fuller uprate to 637 MVA

Overloaded Facility	Type	Area	Upgraded Facility Rating (MVA)	Non-Upgraded Facility Rating (MVA)	Facility Loading in Study Case		Facility Loading in Study Case with Unbuilt Facility Reverted		Loading % Change Due to Facility Reversion	Single Contingency Definition	3RSC 23 1 DFAX	3RSC 23 2 DFAX	3RSC 23 3 DFAX
					MVA Flow	% Loading	MVA Flow	% Loading					
Midway PS (70286) - Fuller (73477) 230 kV CKT 1	Line	70/73	637	478	559.22	87.79	559.21	116.99	29.20	Midway PS (70286) - Midway BR (73413) 230 kV CKT 1	0.1575	0.1575	0.0501

Table C-3: New Fort St. Vrain 230/345 kV 560 MVA Transformer T9

Overloaded Facility	Type	Area	Facility Normal Rating (MVA)	Facility Loading in Study Case		Facility Loading in Study Case with Unbuilt Facility Reverted		Loading % Change Due to Facility Reversion	Single Contingency Definition	3RSC 23 1 DFAX	3RSC 23 2 DFAX	3RSC 23 3 DFAX
				MVA Flow	% Loading	MVA Flow	% Loading					
Ft. St. Vrain (70410/70916) 230/345 kV Transformer T8	Transformer	70	560	494.65	88.33	851.26	152.01	63.68	Ft. St. Vrain (70410/70916) 230/345 kV Transformer T7	0.0828	0.0828	0.1533

Table C-4: Palmer Lake - Fox Run uprate to 239 MVA

Overloaded Facility	Type	Area	Upgraded Facility Rating (MVA)	Non-Upgraded Facility Rating (MVA)	Facility Loading in Study Case		Facility Loading in Study Case with Unbuilt Facility Reverted		Loading % Change Due to Facility Reversion	Single Contingency Definition	3RSC 23 1 DFAX	3RSC 23 2 DFAX	3RSC 23 3 DFAX
					MVA Flow	% Loading	MVA Flow	% Loading					
Palmer Lake (70308) – Fox Run (73414) 115 kV CKT 1	Line	70/73	239	156	186.78	78.15	186.78	119.73	41.58	Daniels Park (70139) - Fuller (73477) 230 kV CKT 1	0.0385	0.0385	-0.0025

Table C-5: Double Circuits for Cherokee - Sandown - Chambers - Harvest Mile upgraded substations

Overloaded Facility	Type	Area	Facility Normal Rating (MVA)	Facility Loading in Study Case		Facility Loading in Study Case with Unbuilt Facility Reverted		Loading % Change Due to Facility Reversion	Single Contingency Definition	3RSC 23 1 DFAX	3RSC 23 2 DFAX	3RSC 23 3 DFAX
				MVA Flow	% Loading	MVA Flow	% Loading					
Daniels Park (70139) - Prairie 3 (70323) 230 kV CKT 2	Line	70	916	830.45	90.66	1052.39	114.89	24.23	Daniels Park (70139) - Prairie 1 (70331) 230 kV CKT 1	0.0835	0.0835	0.0336