2023 Transitional Cluster Combined System Impact Study and Facilities Study Report

07/2/2024

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1.0 Summary

The analysis of the 2023 Transitional Cluster has three Generator Interconnection Requests (GIRs): GI-2021-1, GI-2022-1, and GI-2023-14.

GI-2021-1 is a 200 MW_{ac} net rated AC-Coupled Solar Photovoltaic (PV) Generating Facility requesting Energy Resource Interconnection Service (ERIS). The requested Point of Interconnection (POI) is a direct connection to Comanche 230 kV.

GI-2022-1 is a 52 MW_{ac} total increase to the Rocky Mountain Energy Center (RMEC) Unit 1 and Unit 2 requesting Energy Resource Interconnection Service (ERIS). The POI of these pre-existing units is RMEC 230 kV.

GI-2023-14 is a 400 MW_{ac} net rated AC-Coupled Wind Generating Facility requesting Energy Resource Interconnection Service (ERIS). The requested POI is a tap direct connection to Pawnee 345 kV.

GI-2021-1 and GI-2022-1 were not analyzed as part of this System Impact Study (SIS) because there were past studies of these requests that were sufficient in determining their impact. Each of these GIRs has executed their Provisional Large Generation Interconnection Agreement (PLGIA). A new study was not required for either GI-2021-1 or GI-2022-1 because their respective study pockets, South and North, were not impacted from the Provisional Interconnection analysis performed. Therefore, the full output, that was determined in the Provisional Interconnection requests, is still valid. The past studies can be found at the following locations:

- GI-2021-1 (PI-2021-1)
  - Provisional Study Report PI-2021.pdf (rmao.com)
- GI-2022-1 (PI-2021-4)
  - Provisional Study Report PI-2021-4.pdf (rmao.com)

GI-2023-14 was studied under the Eastern Colorado study pocket. Per Section 3.11 in the BPM, this pocket is comprised of the eastern Colorado transmission system with major generation injecting into Pawnee, Beaver Creek and Missile Site substations.

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

1.1 GI-2023-14

The total cost of the upgrades required to interconnect GI-2023-14 at the Pawnee 345 kV substation for ERIS is $6.727 million (Table 11 and Table 12).

The maximum allowed output of GI-2023-14 without requiring additional Network Upgrades is 400 MW.

1.2 GI-2022-1

The total cost of the upgrades required to interconnect GI-2022-1 at the RMEC 230 kV substation for ERIS is $0.05 million (Table 13). For GI-2022-1, the cost estimates were prepared to support the Provisional study. Since the project is in service, the cost estimates were not updated for this Transition Cluster Study Report.

The maximum allowed output of GI-2022-1 without requiring additional Network Upgrades is 52 MW.

1.3 GI-2021-1

The total cost of the upgrades required to interconnect GI-2021-1 at the Comanche 230 kV substation for ERIS is $2.398 million (Table 14 and Table 15). For GI-2021-1, the cost estimates were prepared to support the Provisional study. Since the project is in service, the cost estimates were not updated for this Transition Cluster Study Report.

The maximum allowed output of GI-2021-1 without requiring additional Network Upgrades is 200 MW.

2.0 Introduction

The Definitive Interconnection Study Cluster consists of one GIR, GI-2023-14, shown in the summary Table 1 below. The total Interconnection Service requested is 400 MW.

GI-2023-14 requested Energy Resource Interconnection Service (ERIS)[1]. The project has a requested Commercial Operation Date (COD) of October 2, 2026.

GI-2021-1 and GI-2022-1 were not analyzed as part of this System Impact Study (SIS) because there were past studies of these requests that were sufficient in determining their impact. The past studies can be found at the following locations:

- GI-2021-1 (PI-2021-1)
  - Provisional Study Report PI-2021-1.pdf (rmao.com)
- GI-2022-1 (PI-2021-4)
  - Provisional Study Report PI-2021-4.pdf (rmao.com)

Table 1: Summary of Analyzed GIR in 2023 Transitional Cluster

GI#	Resource Type	Interconnection Service (MW)	Requested COD	POI	Location	Service Type
GI-2023-14	Wind	400	10/2/2026	Pawnee 345 kV	Morgan County, CO	ERIS
Total		400	-			

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

[1] 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 or non-firm capacity of the Transmission Provider's Transmission System on an "as available" basis. Energy Resource Interconnection Service in and of itself does not convey transmission service.

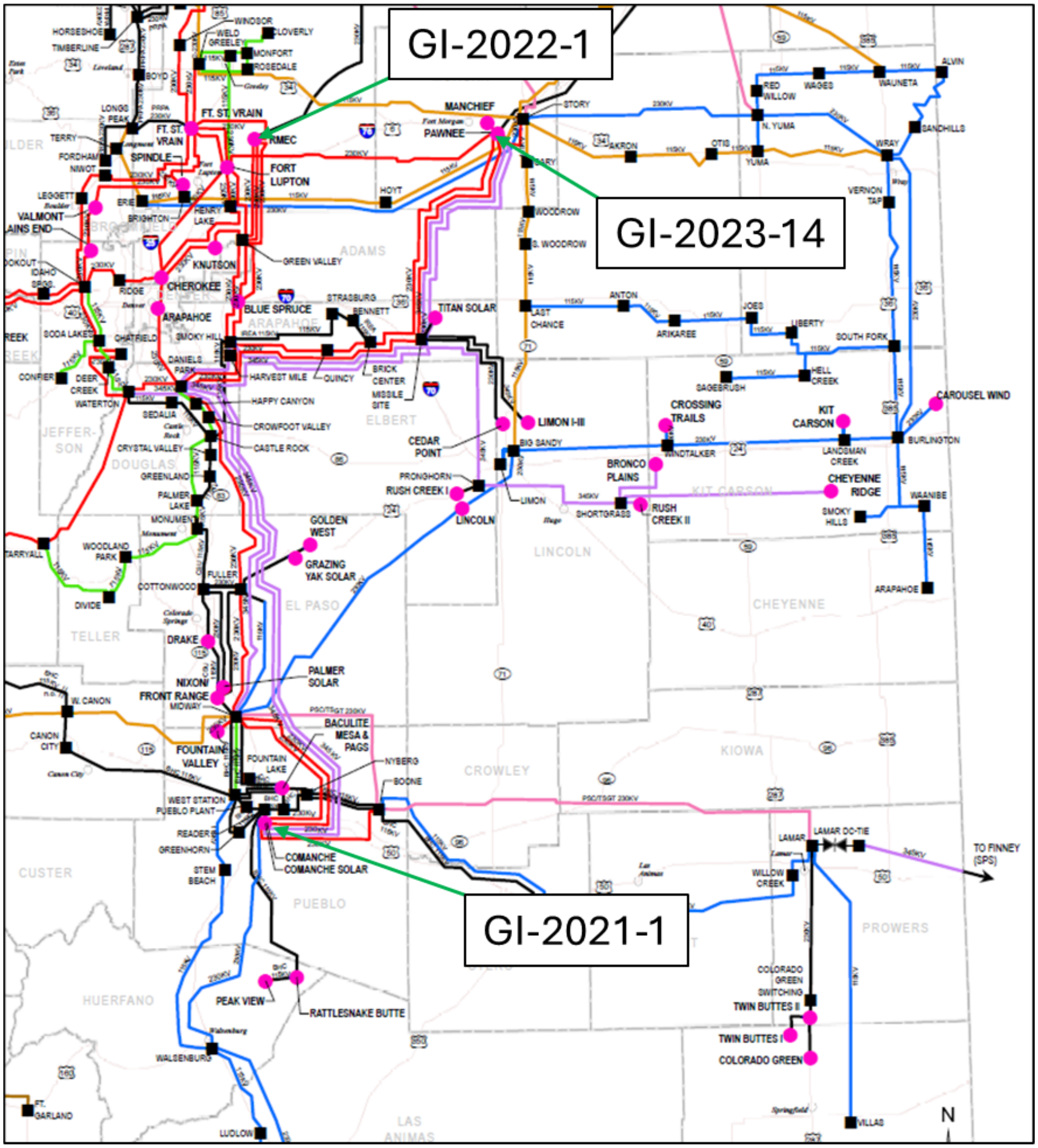


Figure 1 – Approximate Locations of the 2023 Transitional Cluster GIR POIs

3.0 Description of the GIRs

3.1 GI-2023-14

GI-2023-14 is a 400 MW_{ac} Wind Generating Facility located in Morgan County, Colorado. The wind facility has net output at the POI limited to 400 MW_{ac} using a Power Plant Controller. The Wind Generating Facility will consist of ninety-four (94) Vesta V163-4.5 MW turbines, each with its own 34.5/0.72 kV, 5.3 MVA Delta/Wye-grounded, Z=9.9% and X/R=13.9 pad-mount transformer. The 34.5 kV Collector system of the wind generators will connect to two (2) 135/180/225 MVA, 345/34.5/13.8 kV Wye-grounded/Wye-grounded/Delta, Z=12% and X/R=58.9 main step-up transformers which will connect to the PSCo transmission system via a 93-mile, 345 kV generation tie-line. The POI requested is the Pawnee 345 kV substation.

The proposed COD of GI-2023-14 is October 1, 2026. For the study purpose, the back-feed date is assumed to be April 1, 2026, approximately six (6) months before the COD.

4.0 Study Scope

The Transitional Cluster Study (TCS) follows the same study scope as the Definitive Interconnection System Impact Study (DISIS) which consists of:

a. Steady-state analysis, Transient stability analysis, and Short-circuit analysis,
b. Non-binding Scoping level cost estimates for the Transmission Provider's Interconnection Facilities, Station Network Upgrades and System Network Upgrades required to reliably interconnect the GIR(s),
c. Each Interconnection Customer's assigned costs based on the total non-binding cost estimates determined above, and
d. Identification of Contingent Facilities applicable to each GIR.

4.1 Study Pockets

As shown in Figure 1,

- GI-2023-14 is in the Eastern Colorado study pocket. Per Section 3.11 in the BPM, this pocket is comprised of the eastern Colorado transmission system with major generation injecting into Pawnee, Beaver Creek and Missile Site substations.

4.2 Study Areas

The study area for the Eastern Colorado study pocket includes the WECC base case zone 706, which is within Area 70 in the PSCo Balancing Authority.

4.3 Study Criteria

The following steady-state analysis criteria is used to identify violations on the PSCo system and the Affected Systems:

<u>P0 - System Intact conditions:</u>

Thermal Loading:	≤ 100% of the normal facility rating
Voltage range:	0.95 to 1.05 per unit

<u>P1 & P2-1 – Single Contingencies:</u>

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.

The following criteria is 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. 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 shall not exceed 100% of the breaker duty rating.

4.4 Study Methodology

4.4.1 Steady-State Assessment Methodology

The steady-state power flow assessment is performed using the PowerGEM TARA software. The generation redispatch for ERIS is identified using TARA's Security Constrained Redispatch (SCRD) tool.

Thermal violations are identified if a facility (i) resulted in a thermal loading >100% in the Study Case after the study pocket GIR cluster addition and (ii) contributed to an incremental loading increase of 1% or more to the benchmark case loading.

Voltage violations are identified if a bus (i) resulted in a bus voltage >1.1 p.u. (or <0.9 p.u.) in the Study Case after the study pocket GIR cluster addition and (ii) contributed to an adverse impact of +0.01 p.u. (or -0.01 p.u.) compared to the Benchmark Case voltage.

Distribution Factor(s) (DFAX) criteria for identifying contribution to thermal overloads is ≥1%. Criteria for identifying contribution to the voltage violations is +/-0.01 p.u.

The resources included in the Optimal Power Flow (OPF) redispatch are:

1. All PSCo and non-PSCo resources connected to the PSCo Transmission System.
2. Higher-queued NRIS generation in the PSCo queue.
3. Generation connected to an Affected System Transmission System if that generation is a designated network resource to serve load connected to PSCo.
4. All other generation connected to an Affected System Transmission System and Stressed in the Study Case may be dispatched to the Base Case level.

The maximum allowable ERIS generation is calculated for each GIR using its DFAX for overloads identified at full output, such that all identified overloads are eliminated.

4.4.2 Transient Stability Study Methodology

All generators in the study pocket shall 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 conducted by performing select single and multiple contingencies in the study pocket.

4.4.3 Short-Circuit and Breaker-Duty Study Methodology

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 is 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 X/R 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 derating, the equivalent current that the breaker is required to interrupt is simply the fault current multiplied by the XR factor (Ibreaking). 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).

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.

Positive, negative, and zero sequence impedances from the fault studies are given in the tables shown in Section 4.8.5. Fault currents at the POI are also given.

Then, cost allocation is determined as follows:

$$Allocation\% = \frac{Fault\ Current\ Reduction\ due\ to\ Removal\ of\ GI\ of\ interest}{\sum Fault\ Current\ Reduction, All\ GIs} * 100$$

Where,

$$Fault\ Current\ Reduction = (Fault\ Current\ at\ Breaker, All\ GIs\ connected\ ) - (Fault\ Current\ at\ Breaker, All\ GIs\ connected\ except\ GI\ of\ interest)$$

And,

the Fault Type matches the fault type (3-phase or phase-to-ground) causing the breaker to be overstressed.

Figure 2 – Cost Allocation Calculation

4.5 Study Analyses

Steady-state power flow analyses were performed using PowerGEM TARA software. The generation redispatch for ERIS is identified using TARA.

Short-circuit analyses studies were performed using Siemens PSS®CAPE short-circuit analysis software (CAPE). Short-circuit current and equivalent system impedances were obtained for both the Benchmark Case and the Study Case from CAPE for three-phase and single-line-to-ground faults at the POIs for GIRs in the 2023 Transitional Cluster.

Transient stability analysis was performed using a transient stability Study Case developed in GE PSLF corresponding to the steady-state PSLF Study Case.

4.6 Base Case Modeling Assumptions

The 2029HS2a WECC case released on May 3, 2023, was selected as the Starting Case. The Base Case was created from the Starting Case by including the following modeling changes.

- Shortgrass to Goose Creek uprate to 1439 MVA – ISD TBD
- Poncha – San Luis Valley 115 kV L9811 uprate to 239 MVA – ISD 8/20/2025.
- Daniels Park-Prairie-Greenwood Uprate L5707 to 956 MVA – ISD 6/1/2026.
- Leetsdale-Monroe-Elati line 5283 uprate to 956 MVA – ISD 5/31/2026.
- Uprate Lines 6935/6936 69 kV from Alamosa - Mosca - San Luis Valley to 800 A, 95 MVA – ISD 5/15/2026.
- Daniels Park-Prairie-Greenwood Uprate L5111 to 956 MVA – ISD 10/21/2026.
- Additional Harvest Mile to Smoky Hill 230 kV Line – ISD 5/14/2027.
- Leetsdale to University Line 9338 – ISD 9/9/2026.
- Tollgate Load Shift – ISD 7/7/2026.

- New Arapahoe T6 230/115 kV, 272/319 MVA – ISD 2/10/2027.
- Cherokee-Federal Heights-Broomfield L9558 Line rebuild – ISD 11/18/2026.
- MidwayPS 230/115 T1 Transformer Replacement with 280 MVA – ISD 10/7/2026.
- Leetsdale-Harrison L9955 Uprate to 1900 A – ISD 11/16/2027.
- Uprate Line 9255 115kV from Poncha Junction to Otero Tap 1200A 239 MVA – ISD 5/1/2028.
- Cherokee-Federal Heights-Semper Line 9055 rebuild – ISD 6/1/2029.
- Semper-Broomfield Line 9464 rebuild – ISD 6/1/2029.
- Add Smoky Hill 345/230 T6 Transformer – ISD 9/27/2028.
- San Luis Valley – Blanca Peak Line 9431 115kV uprate to 800A, 159 MVA – ISD 6/20/2028.
- Poncha – San Luis Valley 230 kV L3006 Uprate to 478 MVA – ISD 5/11/2029.
- New Line (second circuit) 115kV from Alamosa Terminal - San Luis Valley 1200 A 239MVA – ISD 6/15/2028.
- Cherokee-Lacombe 230 kV L5057 Uprate to 1900 A, 756 MVA – ISD 9/13/2029.
- Daniels Park 345/230 kV Transformer #4 – ISD 9/13/2029.
- Add Chambers T3 230/115 Transformer – ISD 9/13/2029.
- Capital-Denver Terminal L9007 Uprate to 1900 A – ISD 9/13/2029.
- Havana-Chambers 115 kV L9543 & L9544 Uprate - ISD 9/13/2029.
- New double circuit from Cherokee-Sandown-Chambers-Harvest Mile 230 kV – ISD 9/13/2029.
- Sandown 230/115 kV Transformer #1 Uprate to 560/756 MVA – ISD TBD.
- New Fort Lupton 230/115 kV, 273/319 MVA Transformer #4 – ISD TBD.
- New Allison to Chatfield 230 kV transmission line rated at 283 MVA – ISD TBD.

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

- Segment #1: Fort St. Vrain – Canal Crossing 345 kV Double Circuit
- Segment #2: Canal Crossing – Goose Creek 345 kV Double Circuit
- Segment #3: Goose Creek – May Valley 345 kV Double Circuit

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

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

4.7 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.

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 the 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 the range of 0.95 p.u. to 1.05 p.u. are highlighted in yellow to provide additional information.

4.7.1 GI-2023-14

The GI-2023-14 GIR is modeled as follows:

Wind Generator Lumped Equivalent #1: Pmax = 211.5 MW, Pmin = 0.0 MW, Qmax = 119.85 MVar, Qmin= -86.01 MVar

Wind Generator Lumped Equivalent #2: Pmax = 211.5 MW, Pmin = 0.0 MW, Qmax = 119.85 MVar, Qmin= -86.01 MVar

The summary for the Voltage and Reactive Power Capability Evaluation for GI-2023-14 is:

- The GIR is **not capable** of meeting 0.95 lagging pf at the high side of the main step-up transformer, but it was capable of meeting 0.95 leading pf at the high side of the main step-up transformer.
- The GIR is capable of meeting ±0.95 pf at its terminals while meeting the interconnection service request.
- The reactive power exchange and voltage change across the gen-tie are acceptable under no load conditions.

The Voltage and Reactive Power Capability tests performed for GI-2023-14 are summarized in Table 2. An additional 4.23 MVar of capacitive reactive support will be necessary to meet the 0.95 lagging pf requirement. A potential solution to resolve this could be an appropriately sized shunt capacitor bank.

Table 2: Reactive Capability Evaluation of GI-2023-14

Generator 1 Terminals					Generator 2 Terminals					High Side of Main Transformer				POI			
Pgen (MW)	Qgen (Mvar)	Qmax (Mvar)	Qmin (Mvar)	V (p.u.)	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
207.9	119.9	119.9	-86.0	1.14	207.9	119.9	119.9	-86.0	1.14	408.4	130.0	1.11	0.9529	400.2	147.5	1.03	0.9383
207.9	14.3	119.9	-86.0	0.99	207.9	14.3	119.9	-86.0	0.99	408.7	-136.7	0.98	-0.9484	399.2	-142.9	1.02	-0.9415
0.0	-47.8	119.9	-86.0	0.96	0.0	-47.8	119.9	-86.0	0.96	-1.1	-94.8	1.00	-0.0116	-1.5	-14.1	1.03	-0.1058

4.8 Eastern Colorado Study Pocket Analysis

The Study Case modeled GI-2023-14 at Pawnee 345 kV. This study report consists of steady-state power flow analysis, transient stability analysis, and short-circuit analysis.

4.8.1 Benchmark Case Modeling

To resolve Benchmark Case overloads and diverged category P1 contingencies, the following additional projects, shown in Table 3 below, were included in the Benchmark Case modeling, after discussion with Xcel PSCo. These upgrades are not attributable, nor will their costs be assigned to the Study GIR.

Table 3: Benchmark Case Upgrades Included in Modeling

Ref. No.	Facility	Owner	Type
1	Missile Site (70624) - Pronghorn (70628) 345 kV ckt 1	PSCo	Line
2	STORY (73192) - PAWNEE (70311) 230 kV ckt 1	PSCo	Line
3	COMANCHE (70122) - COMANCHE (70654) 345/230 kV T4	PSCo	Transformer

The Benchmark Case was created from the Base Case by changing the study pocket generation dispatch to reflect heavy generation in the East study pocket. This was accomplished by adopting the generation dispatch in Table 4. Additionally, 4050 MW of Native Load Priority (NLP) was modeled on the CPP, as shown in Table 5.

Table 4: Generation Dispatch Used to Create the Eastern Colorado Benchmark Case (MW is Gross Capacity)

Gen Bus Number	Name	ID	Status	Pgen (MW)	Pmax (MW)
70310	PAWNEE	C1	1	526.00	526.00
70314	MANCHEF1	G1	1	118.35	131.50
70315	MANCHEF2	G2	1	117.90	131.00
70767	RUSHCK1_W1	W1	1	161.60	202.00
70770	RUSHCK1_W2	W2	1	142.40	178.00
70771	RUSHCK2_W3	W3	1	176.00	220.00
70739	CHEYRGW_W1	W1	1	109.12	136.40
70742	CHEYRGW_W2	W2	1	105.60	132.00
70733	CHEYRGE_W1	W1	1	43.20	54.00
70736	CHEYRGE_W2	W2	1	88.00	110.00

Gen Bus Number	Name	ID	Status	Pgen (MW)	Pmax (MW)
70775	CHEYRGE_W3	W3	1	52.80	66.00
70818	MTNBRZ_W1	W1	1	126.32	157.90
70817	MTNBRZ_W2	W2	1	11.04	13.80
70670	CEDARPT_W1	W1	1	99.36	124.20
70671	CEDARPT_W2	W2	1	100.80	126.00
70635	LIMON1_W	W1	1	160.80	201.00
70636	LIMON2_W	W2	1	160.80	201.00
70637	LIMON3_W	W3	1	160.80	201.00
70753	BRONCO_W1	W1	1	117.28	146.60
70749	BRONCO_W2	W2	1	128.96	161.20
70710	PTZLOGN1	W1	1	160.80	201.00
70712	PTZLOGN2	W2	1	96.00	120.00
70713	PTZLOGN3	W3	1	63.60	79.50
70714	PTZLOGN4	W4	1	140.00	175.00
70721	SPRNGCAN1_W1	W1	1	51.84	64.80
70715	SPRNGCAN2_W2	W2	1	50.16	62.70
70723	RDGCREST	W1	1	23.76	29.70
70443	Arriba W1	W1	1	80.04	100.05
70442	Arriba W2	W2	1	80.04	100.05
Total (MW)				**3453.37**	**4152.40**

Table 5: NLP Generation on CPP

Generator Bus No.	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**

4.8.2 Study Case Modeling

The East study pocket Study Case was developed from the Benchmark Case by modeling GI-2023-14 at its POI directly connecting to Pawnee 345 kV. The total 400 MW generation from GI-

2023-14 was balanced against all PSCo generation connected to the PSCo Transmission System outside the study pocket on a pro-rata basis.

4.8.3 Steady-State Analysis

The power flow analysis showed that the category P1 contingency outage of Missile Site – Smoky Hill 345 kV circuit #1 was divergent in the Study Case. To resolve this 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 re-dispatched unit was balanced against PSCo generation outside of the Eastern Colorado study pocket. The following single and multiple contingency analyses are conducted with the dispatch change presented in the last column of Table 6.

Table 6: Generation Dispatch to Resolve the Diverged Contingencies

Bus No.	Bus Name	Base kV	ID	Original Pgen (MW)	Modified Pgen (MW)
70310	PAWNEE	22	C1	526.00	200.00

Contingency analysis was performed on this East pocket ERIS Study Case.

- Results for the system-intact analysis showed no violations attributable to GI-2023-14.
- Results for the single contingency analysis showed no violations attributable to GI-2023-14.
- Results for the multiple contingency analysis showed no violations attributable to GI-2023-14. Note there were a few diverged category P7 contingencies that occurred, however, these are not attributable to the Study GIR.

Per TPL-001-5, multiple contingency overloads are mitigated using system adjustments, including generation redispatch (includes GIRs under study) and/or operator actions.

- None of the multiple contingency overloads are attributed to the study GIRs.
- Single contingency and multiple contingency analysis showed no voltage violations attributed to the Study GIR.

The maximum output of the ERIS GI-2023-14 project without requiring additional Network Upgrades is 400 MW.

- No Affected Systems were identified in this study.

4.8.4 Transient Stability Analysis

The transient stability analysis was performed in the east pocket using the case analyzed in the steady-state analysis. Table 7 is a summary of the contingencies studied and the corresponding stability results.

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

The following results were obtained for the disturbances analysis:

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

The transient stability plots are shown in Section 9.0 of this report.

Table 7: Eastern Colorado Transient Stability Analysis Results

Ref. No.	Contingency Name	Fault Location	Outage(s)	Clearing Time (Cycles)	Study Post-Fault Voltage Recovery	Angular Stability
1	Flat Run	-	Flat run	-	Satisfactory	Satisfactory
2	Pawnee-CanalXing_345kV	Pawnee 345 kV	Pawnee - Canal Crossing 345 kV CKT 1	4	Satisfactory	Satisfactory
3	Pawnee_Xfmr	Pawnee 345 kV	Pawnee 345/230 kV Transformer T2	4	Satisfactory	Satisfactory
4	GI-2023-14_Gen	Pawnee 345 kV	GI-2023-14 Generation	4	Satisfactory	Satisfactory
5	MS-CanalXing_345kV	Missile Site - Canal Crossing 345 kV Line	Missile Site - Canal Crossing 345 kV CKT 1	4	Satisfactory	Satisfactory
6	FSV-CanalXing_345kV	FSV - Canal Crossing 345 kV Line	Fort Saint Vrain - Canal Crossing 345 kV CKT 1	4	Satisfactory	Satisfactory
7	Rush Creek - BF123a	Pronghorn 345 kV	Pronghorn 345 kV Gen Tie Line Rush Creek Generation	12	Satisfactory	Satisfactory
8	Canal Crossing - BF210	Canal Crossing 345 kV	Canal Crossing - Goose Creek 345 kV CKT 1 Canal Crossing - Goose Creek 345 kV CKT 2 Canal Crossing 345 kV Capacitor Bank	12	Unsatisfactory	Satisfactory

4.8.5 Summary of Eastern Colorado Study Pocket Analysis

The ERIS study showed no violations that were attributable to the Study GIR.

The maximum allowed output of the ERIS GI-2023-14 project without requiring additional Network Upgrades is 400 MW.

No Affected Systems were identified.

The GIR is not capable of meeting the 0.95 lagging power factor (p.f.) at the high side of the main step-up transformer. An additional 4.23 MVar of capacitive reactive support will be necessary to meet the 0.95 lagging p.f. requirement. A potential solution to resolve this could be an appropriately sized shunt capacitor bank.

4.9 Short-Circuit Analysis Results

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.

Positive, negative, and zero sequence impedances from the fault studies are given in the tables below. Fault currents at the POI are also given.

A breaker duty study on the PSCo transmission system did not identify any circuit breakers that became over-dutied because of adding the cluster. Note that GI-2022-1 is an incremental capacity increase in the output of the existing generation with no anticipated changes to the electrical generator set. There is no fault current contribution from this GI over the base case.

Table 8: Short Circuit Parameters at GI-2021-1 POI (Comanche 230 kV)

	Before the Cluster addition	After the Cluster addition
Three Phase		
Three Phase Current	20380A	19810A
Positive Sequence Impedance	0.54927 + j6.88269 ohms	0.54927 + j6.88269 ohms
Negative Sequence Impedance	0.57352 + j6.91167 ohms	0.57352 + j6.91167 ohms
Zero Sequence Impedance	0.33719 + j4.00089 ohms	0.30548 + j3.78265 ohms
Phase-to-Ground		
Single Line to Ground Current	23930A	24000A
Positive Sequence Impedance	0.54927 + j6.88269 ohms	0.54927 + j6.88269 ohms
Negative Sequence Impedance	0.57352 + j6.91167 ohms	0.57352 + j6.91167 ohms
Zero Sequence Impedance	0.33719 + j4.00089 ohms	0.30548 + j3.78265 ohms

Table 9: Short Circuit Parameters at GI-2022-1 POI (RMEC 230 kV)

	Before the Cluster addition	After the Cluster addition
Three Phase		
Three Phase Current	24420A	24390A
Positive Sequence Impedance	0.38845 + j5.42307 ohms	0.38845 + j5.42307 ohms
Negative Sequence Impedance	0.48767 + j5.29514 ohms	0.48767 + j5.29514 ohms
Zero Sequence Impedance	0.49594 + j5.82216 ohms	0.49594 + j5.82210 ohms
Phase-to-Ground		
Single Line to Ground Current	24000A	23960A
Positive Sequence Impedance	0.38845 + j5.42307 ohms	0.38845 + j5.42307 ohms
Negative Sequence Impedance	0.48767 + j5.29514 ohms	0.48767 + j5.29514 ohms
Zero Sequence Impedance	0.49594 + j5.82216 ohms	0.49594 + j5.82210 ohms

Table 10: Short Circuit Parameters at GI-2023-14 POI (Pawnee 345 kV)

	Before the Cluster addition	After the Cluster addition
Three Phase		
Three Phase Current	20330A	19950A
Positive Sequence Impedance	0.61723 + j9.80510 ohms	0.61723 + j9.80510 ohms
Negative Sequence Impedance	0.69238 + j9.77676 ohms	0.69238 + j9.77676 ohms
Zero Sequence Impedance	1.33579 + j13.4511 ohms	1.28462 + j12.8352 ohms
Phase-to-Ground		
Single Line to Ground Current	18100 A	18630A
Positive Sequence Impedance	0.61723 + j9.80510 ohms	0.61723 + j9.80510 ohms
Negative Sequence Impedance	0.69238 + j9.77676 ohms	0.69238 + j9.77676 ohms
Zero Sequence Impedance	1.33579 + j13.4511 ohms	1.28462 + j12.8352 ohms

5.0 Cost Estimates and Assumptions

The total cost of the required Upgrades for GI-2023-14 to interconnect for Interconnection Service at the Pawnee 345 kV substation is estimated to be **$6.727 million**.

- **Cost of Transmission Provider's Interconnection Facilities (TPIF) is $2.960 million** (Table 11)
- **Cost of Station Network Upgrades is $3.767 million** (Table 12)
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the interconnection of GI-2023-14 is given in Table 11 and Table 12.

Since the POI is an existing substation, a Certificate of Public Convenience and Need (CPCN) would not be required to accommodate the interconnection.

Table 11: Transmission Provider's Interconnection Facilities – GI-2023-14

Element	Description	Cost Est. (Million)
PSCo's Pawnee 345 kV Substation	Interconnection of GI-2023-14 at the Pawnee 345 kV Substation. The new equipment includes: • (1) 345 kV monopole dead end structure • (1) 345 kV single bay dead end structure • (1) 345 kV 3-phase arrester • (1) 345 kV 3000A line disconnect switch • (3) 345 kV 1-phase CT for metering • (1) 345 kV 3-phase CCVT • Yard expansion including grading, ground grid, 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	$2.910
PSCo's Pawnee 345 kV Substation	Transmission line into substation from customer's dead end structure on gen-tie. Three spans, conductor, insulators, hardware and labor.	$0.050
Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities		**$2.960**

Table 12: Station Network Upgrades – GI-2023-14

Element	Description	Cost Est. (Million)
PSCo's Pawnee 345 kV Substation	Interconnection of GI-2023-14 at Pawnee 345 kV Substation. The new equipment includes: • (1) 345 kV dead end structure • (1) 345 kV 3000A SF6 circuit breaker • (3) 345 kV 3000A disconnect switches • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$3.532
PSCo's Pawnee 345 kV Substation	Install required communication in the EEE at the Pawnee 345 kV Substation	$0.235
Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities		**$3.767**

These cost estimates were prepared to support the Provisional study. Since the project is in service, the cost estimates were not updated for this Transition Cluster Study Report.

The total cost of the required Upgrades for GI-2022-1 to interconnect for Interconnection Service at the RMEC 230 kV substation is estimated to be **$0.05 million**.

- **Cost of Transmission Provider's Interconnection Facilities (TPIF) is $0.05 million** (Table 13)
- **Cost of Station Network Upgrades is $0**
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the interconnection of GI-2022-1 is given in Table 13.

Since the POI is an existing substation, a Certificate of Public Convenience and Need (CPCN) would not be required to accommodate the interconnection.

Table 13: Transmission Provider's Interconnection Facilities – GI-2022-1

Element	Description	Cost Est. (Million)
Existing RMEC Substation POI	Interconnect GI-2022-1 Generating Facility. The new equipment includes: Testing of communications, relays	$0.05
	Transmission line tap into substation	$0.00
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.00
	Total Cost Estimate for Transmission Provider's Interconnection Facilities	**$0.05**
Time Frame	Site, design, procure, and construct	12 Months

These cost estimates were prepared to support the provisional study. Since the project is in service, the cost estimates were not updated for this Transition Cluster Study Report.

The total cost of the required Upgrades for GI-2021-1 to interconnect for Interconnection Service at the Comanche 230 kV substation is estimated to be **$2.398 million**.

- **Cost of Transmission Provider's Interconnection Facilities (TPIF) is $1.139 million** (Table 14)
- **Cost of Station Network Upgrades is $1.259 million** (Table 15)
- **Cost of System Network Upgrades is $0**

The list of improvements required to accommodate the interconnection of GI-2021-1 is given in Table 14 and Table 15.

Since the POI is an existing substation, a Certificate of Public Convenience and Need (CPCN) would not be required to accommodate the interconnection.

Table 14: Transmission Provider's Interconnection Facilities – GI-2021-1

Element	Description	Cost Est. (Million)
Comanche Substation 230 kV bus	Interconnect Customer at the Comanche Substation 230 kV bus. The new equipment includes: • Three (3) 230 kV dead-end structures • Three (3) 230 kV arresters • One (1) 230 kV 3000 A Switch • One set (of three) high side metering units • Fiber communication equipment • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing	$1.064
	Transmission line tap into substation	$0.055
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Transmission Provider's Interconnection Facilities	**$1.139**
Time Frame	Site, design, procure, and construct	36 Months

Table 15: Station Network Upgrades – GI-2021-1

Element	Description	Cost Est. (Million)
Comanche Substation 230 kV bus	Interconnect GI-2021-1 at an existing bay at the Comanche 230 kV bus. The new equipment includes: • One (1) 230 kV, 3000 A Circuit Breakers • One (1) 230 kV 3000 A Switches • Station controls and wiring • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$1.239
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Transmission Provider's Interconnection Facilities	**$1.259**
Time Frame	Site, design, procure, and construct	36 Months

5.1 Summary of Generation Interconnection Costs

The total cost of the required upgrades for GI-2023-14 to interconnect to the Pawnee 345 kV substation is **$6.767 million**.

- **The cost of Transmission Provider's Interconnection Facilities is $2.960 million** (Table 11)
- **The cost of Station Network Upgrades is $3.767 million** (Table 12)
- **The cost of System Network Upgrades is $0 million**

The total cost of the required upgrades for GI-2022-1 to interconnect to the RMEC 230 kV substation is **$0.05 million**.

- **The cost of Transmission Provider's Interconnection Facilities is $0.05 million** (Table 13)
- **The cost of Station Network Upgrades is $0**
- **The cost of System Network Upgrades is $0**

The total cost of the required upgrades for GI-2021-1 to interconnect to the Comanche 230 kV substation is **$2.398 million**.

- **The cost of Transmission Provider's Interconnection Facilities is $1.139 million** (Table 14)
- **The cost of Station Network Upgrades is $1.259 million** (Table 15)
- **The cost of System Network Upgrades is $0 million**

Figure 3, Figure 4, Figure 5, and Figure 6 shown in Section 8.0, are conceptual one-lines and general arrangements of the GI-2021-1, GI-2022-1, and GI-2023-14 POIs.

5.2 Cost Estimate Assumptions

PSCo has developed cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of GI-2023-14 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) are 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.

For GI-2021-1 and GI-2022-1, the cost estimates were prepared to support the Provisional studies. Since the projects are in service, the cost estimates were not updated for this Transition Cluster Study Report.

The customer requirements include:

- Customer will install two (2) redundant fiber optic circuits (one primary circuit with a redundant backup) 48-fiber single mode OPGW cables into the Transmission Provider's substation as part of its interconnection facilities construction scope.
- Power Quality Metering (PQM) will be required on the Customer's generation tie-line terminating into the POI.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer substation. PSCo will be provided with indications, readings, and data from the LF/AGC RTU.
- The Interconnection Customer will comply with the Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW, as amended from time to time, and available at: XEL-POL-Transmission Interconnection Guideline Greater 20MW

5.3 Schedule

This section provides proposed milestones for the interconnection of GI-2023-14 to the Transmission Provider's Transmission System. The customer requested a COD of October 2, 2026. This is not attainable by the Transmission Provider, based upon the current schedule developed for this interconnection request. The Transmission Provider proposes the milestones provided below in Table 16.

Table 16: Proposed Milestones for GI-2023-14

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

6.0 Summary of Generation Interconnection Service

The Interconnection Customer is required to design their inverter-based resource (wind, solar or hybrid) Generating Facility to eliminate or mitigate potential for inverter or plant controller instability and/or controller response interactions with the plant controllers of existing inverter-based resource (wind, solar or hybrid) Generating Facilities.

This study only evaluated Interconnection Service of the GIR in the 2023 Transitional Cluster and Interconnection Service in and of itself does not convey transmission service.

6.1 GI-2023-14

The total cost of the upgrades required to interconnect GI-2023-14 to Pawnee 345 kV for ERIS is $6.767 million (Table 11 and Table 12).

The maximum allowable output of GI-2023-14 without requiring additional Network Upgrades is 400 MW.

6.2 GI-2022-1

The total cost of the required Upgrades for GI-2022-1 to interconnect for Interconnection Service at the RMEC 230 kV substation is estimated to be $0.05 million (Table 13).

The maximum allowable output of GI-2022-1 without requiring additional Network Upgrades is 52 MW.

6.3 GI-2021-1

The total cost of the required Upgrades for GI-2021-1 to interconnect for Interconnection Service at the Comanche 230 kV substation is estimated to be $2.398 million (Table 14 and Table 15).

The maximum allowable output of GI-2021-1 without requiring additional Network Upgrades is 200 MW.

7.0 Contingent Facilities

Contingent Facilities identified for GI-2023-14 include the TPIF and Station Network Upgrades identified in Table 11 and Table 12, respectively.

Short-Circuit Contingent Breakers: There were no breakers identified requiring upgrades as a result of a short-circuit analysis performed by Xcel Energy System Protection Engineering.

Transient Stability: As may be determined, the Corrective Action Plan (CAP) identified as a potential mitigation during the transient stability analysis may be required as a contingent facility. At this time, no Corrective Action Plan or other mitigation has been implemented.

8.0 Preliminary One-Line Diagrams and General Arrangements for 2023 Transitional Cluster GIR Interconnection Facilities

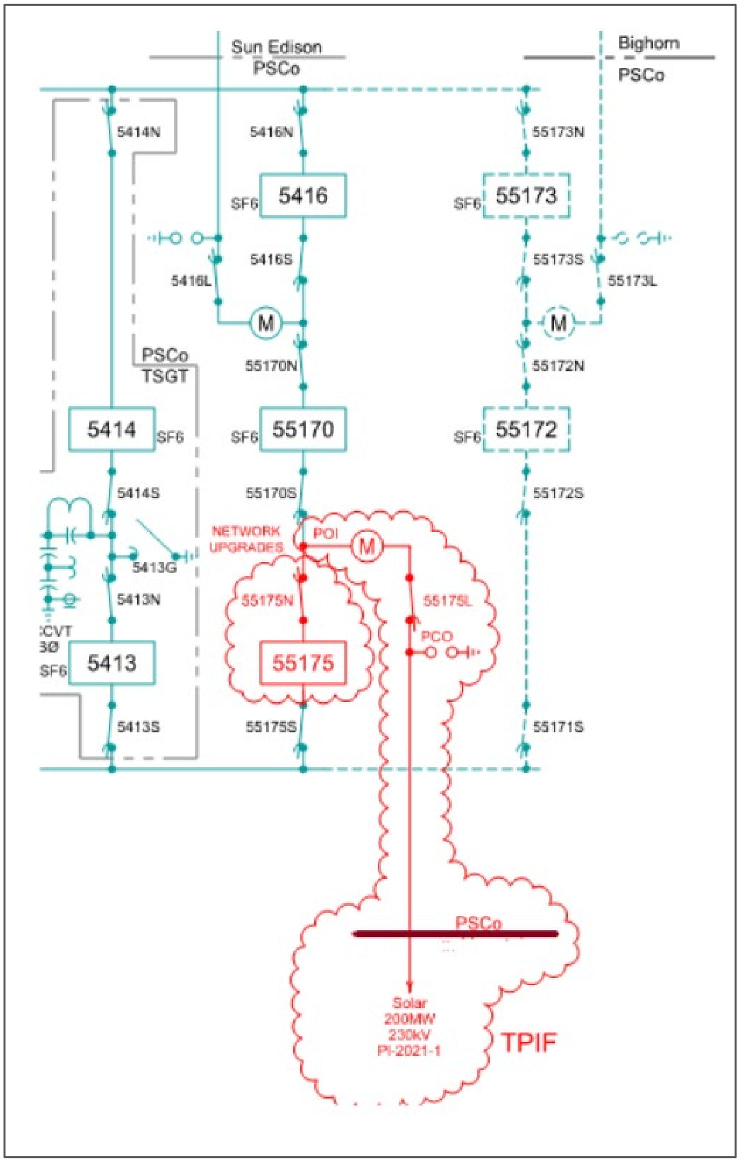


Figure 3 – Preliminary One-line of the GI-2021-1 POI at Comanche 230 kV

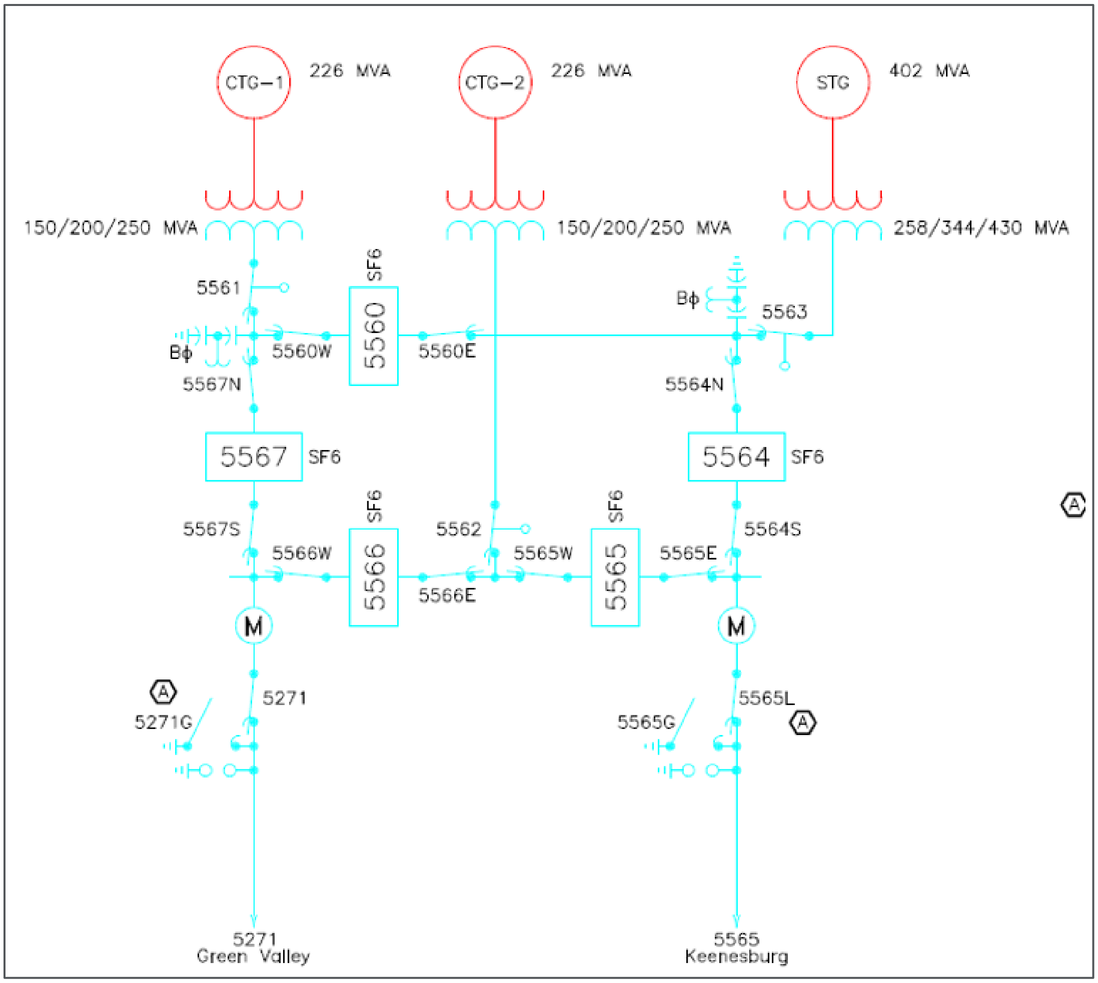


Figure 4 – Preliminary One-line of the GI-2022-1 POI at RMEC 230 kV

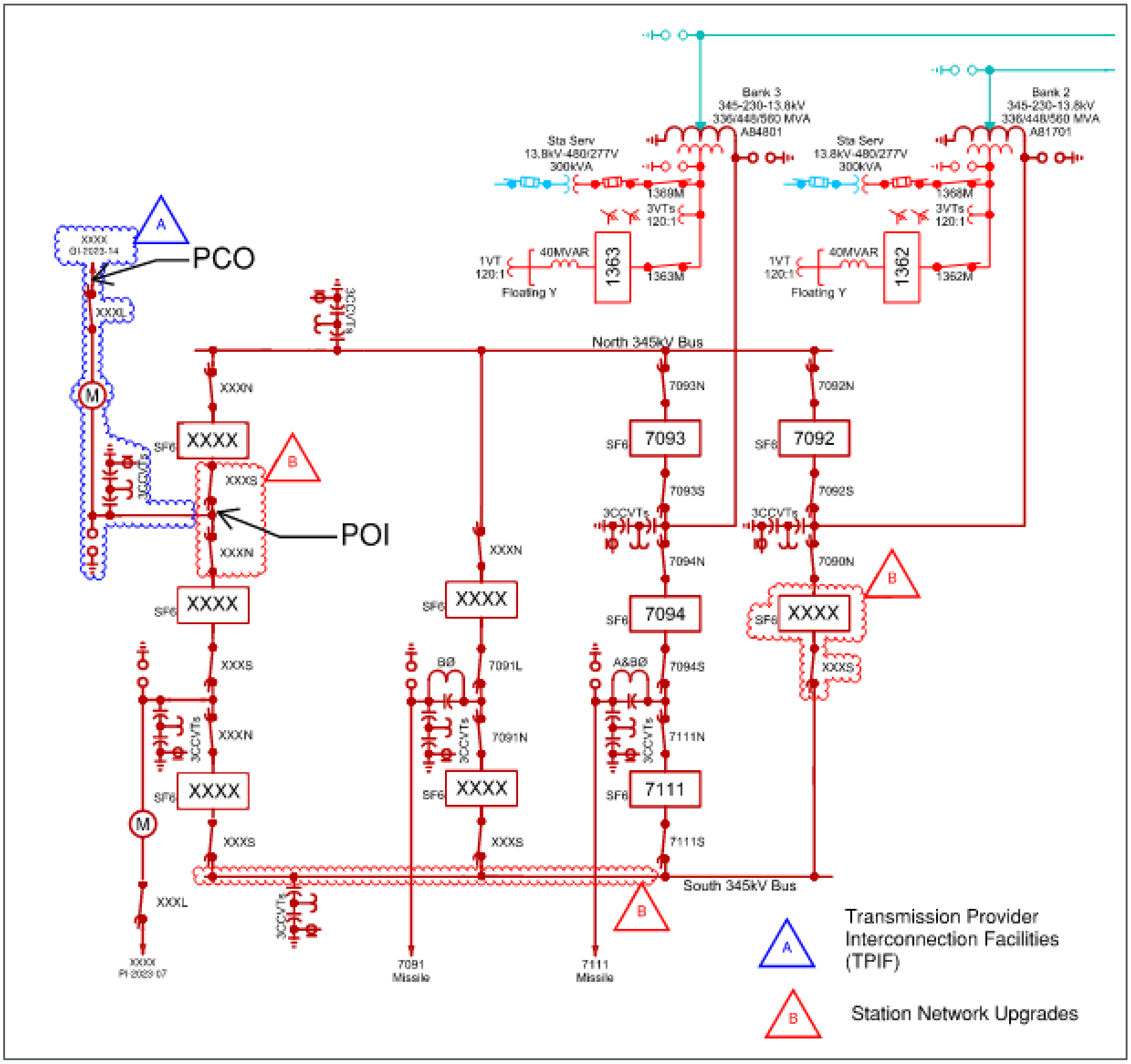


Figure 5 – Preliminary One-line of the GI-2023-14 POI at Pawnee 345 kV

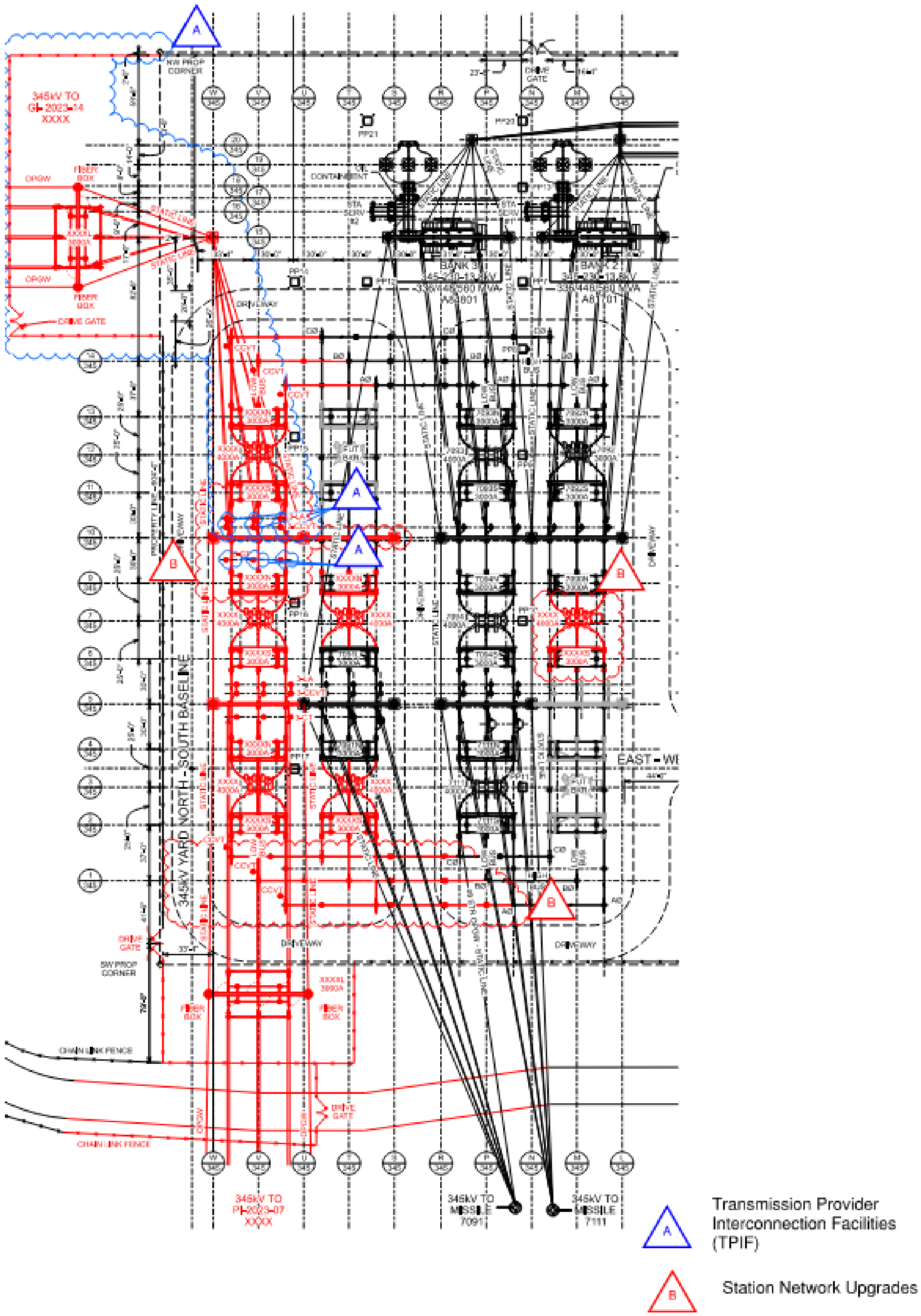
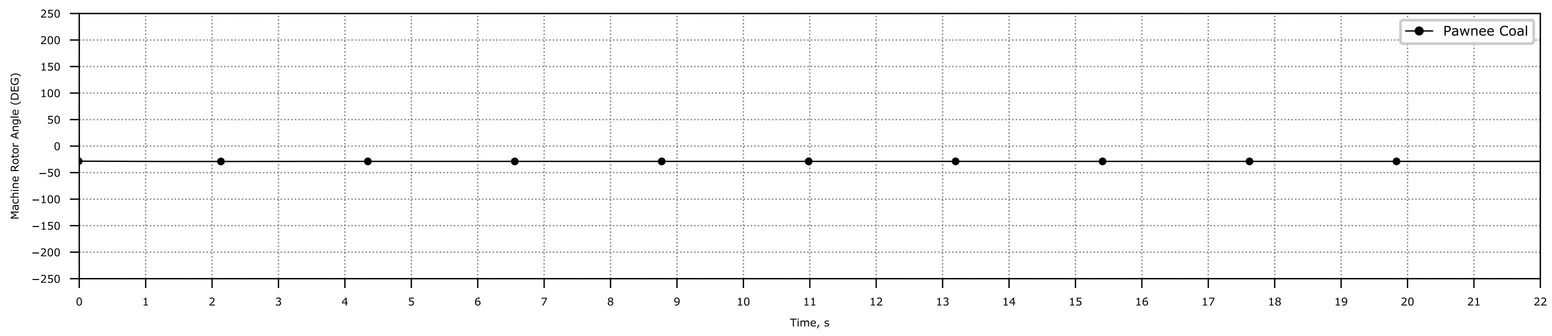


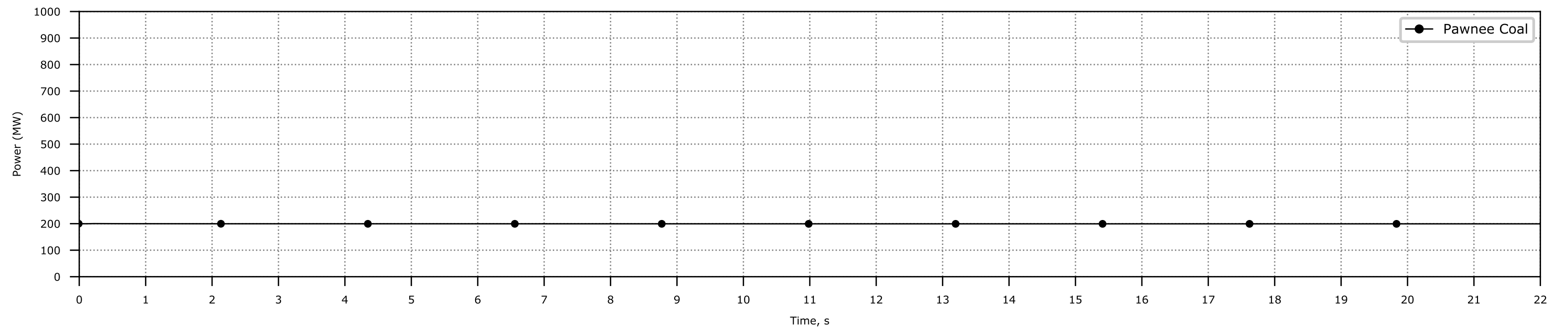
Figure 6 – Preliminary General Arrangement for GI-2023-14 Interconnection Facilities at Pawnee 345 kV

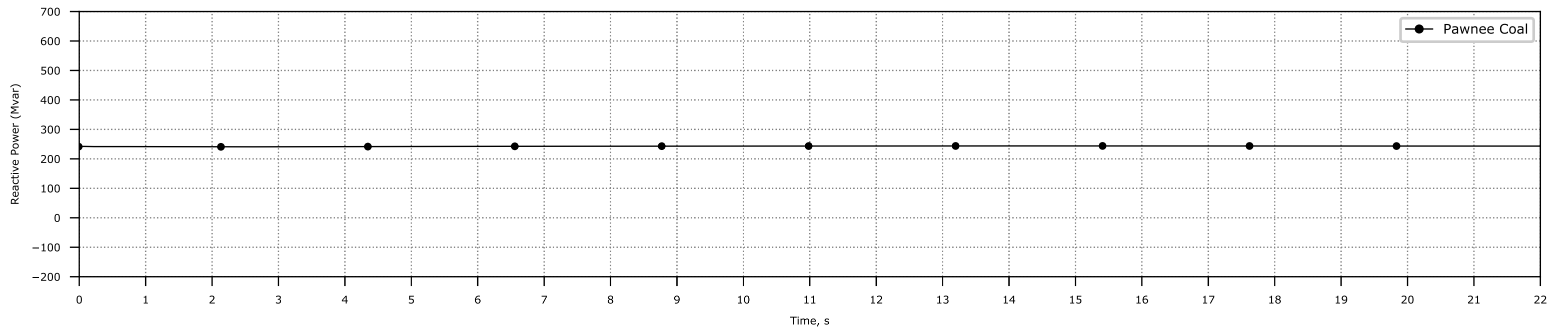
9.0 Appendices

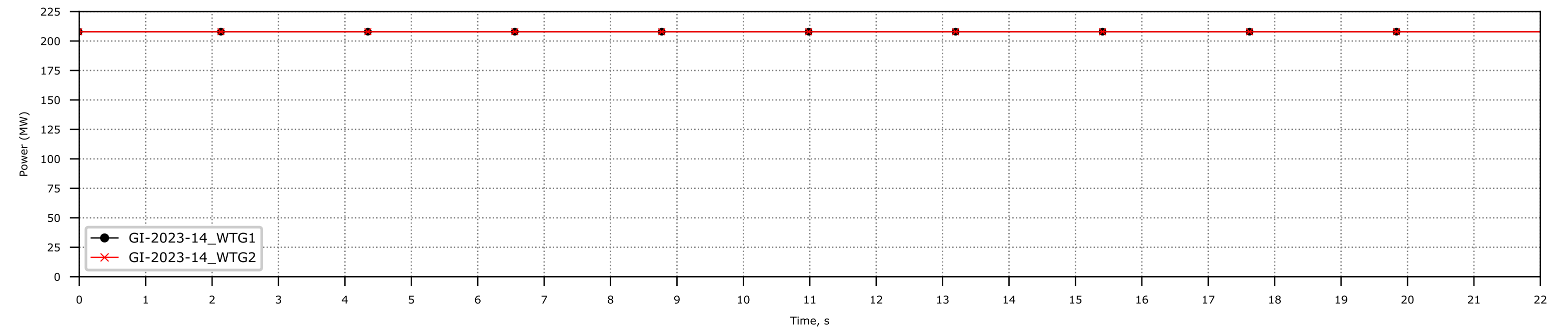
Appendix A: Transient Stability Plots	TC1_GI-2023-14_Transient Stability Plots.p

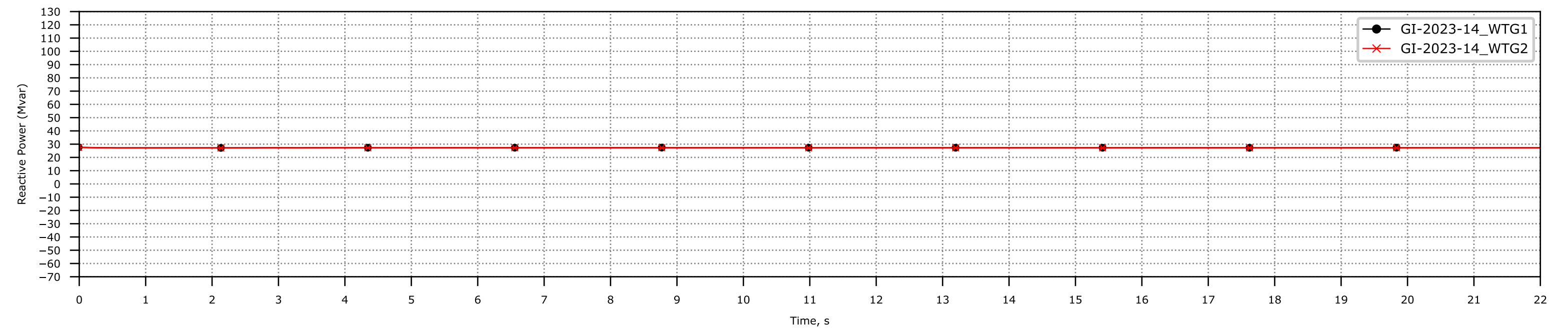
TC1_GI-2023-14_Study_East_flatrun

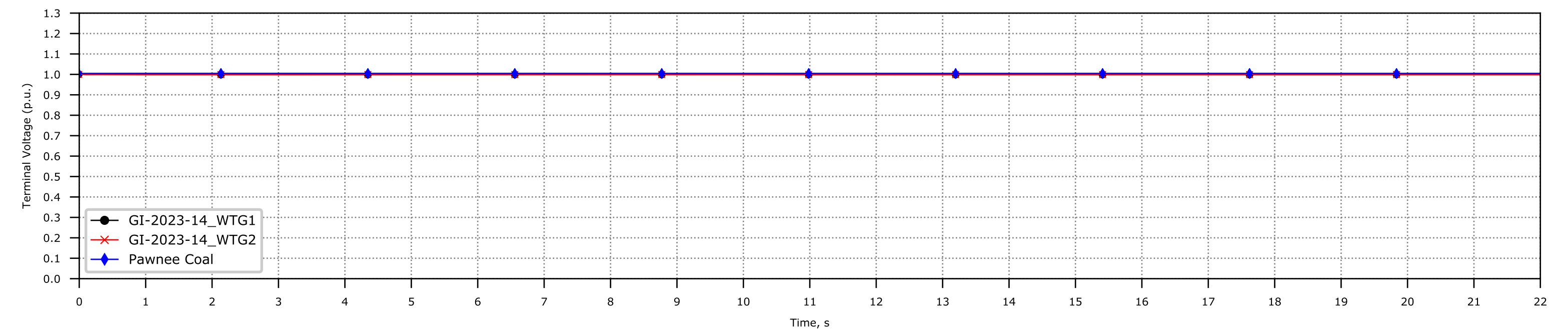


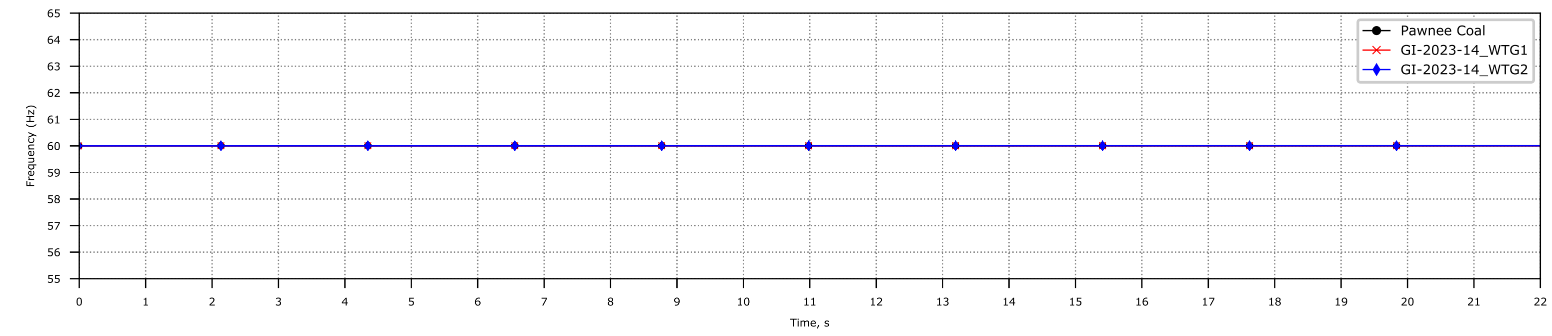


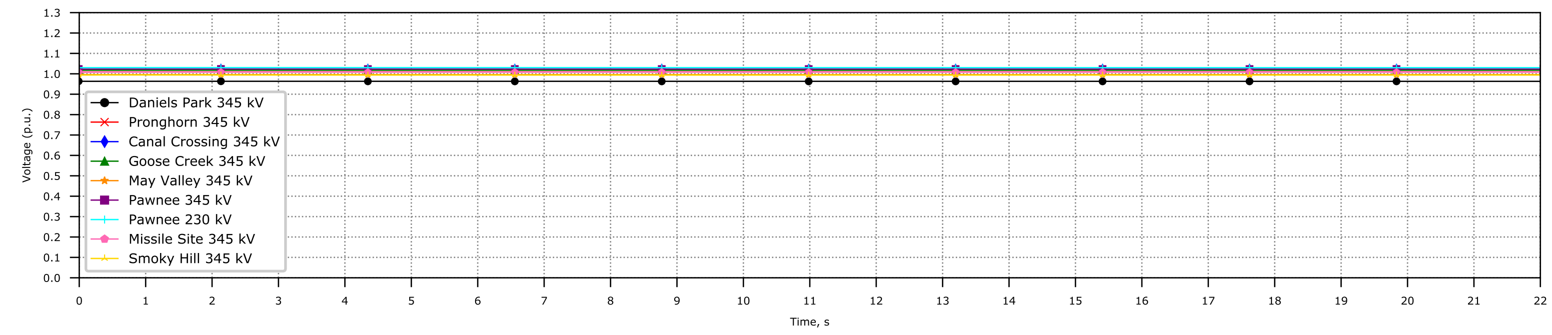




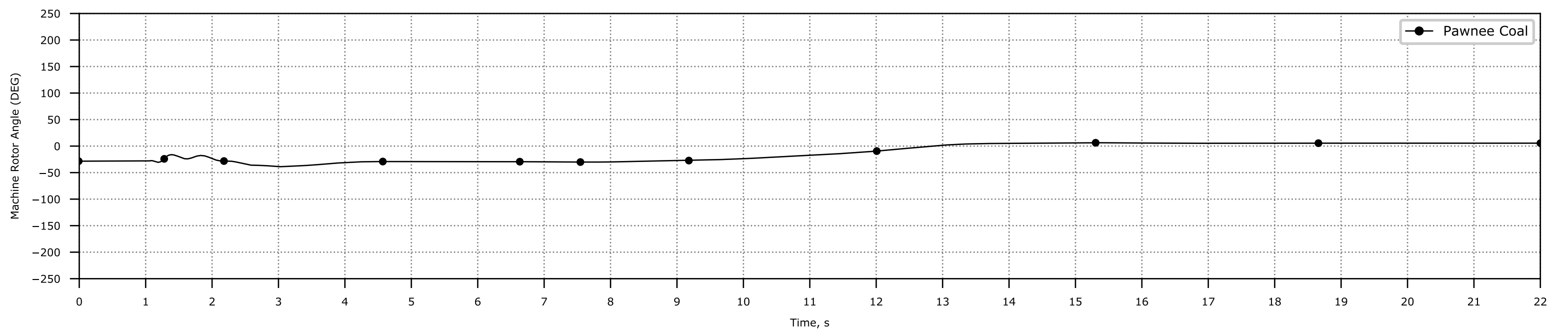


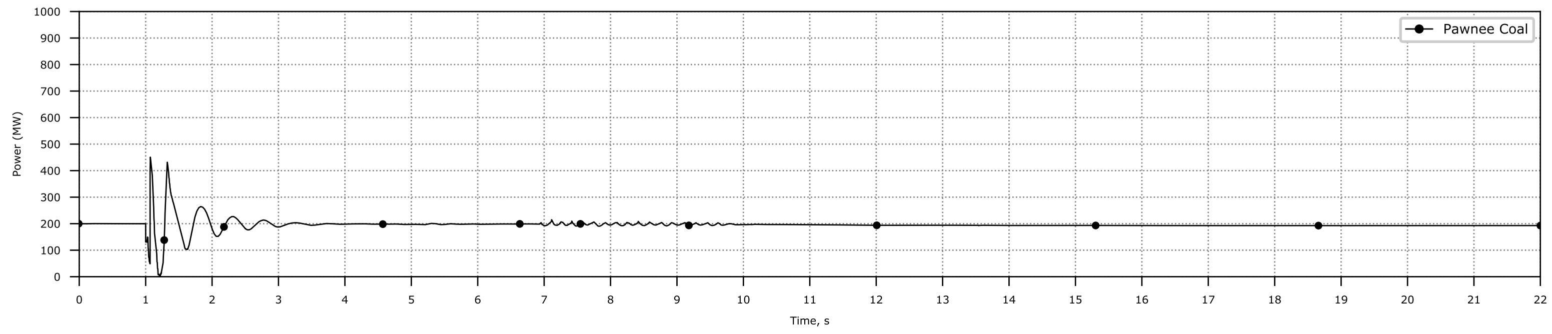


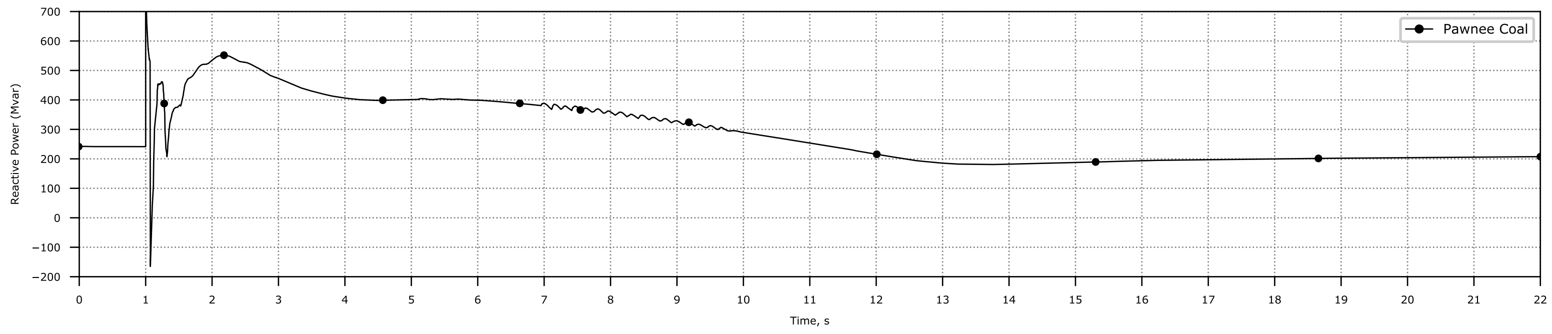


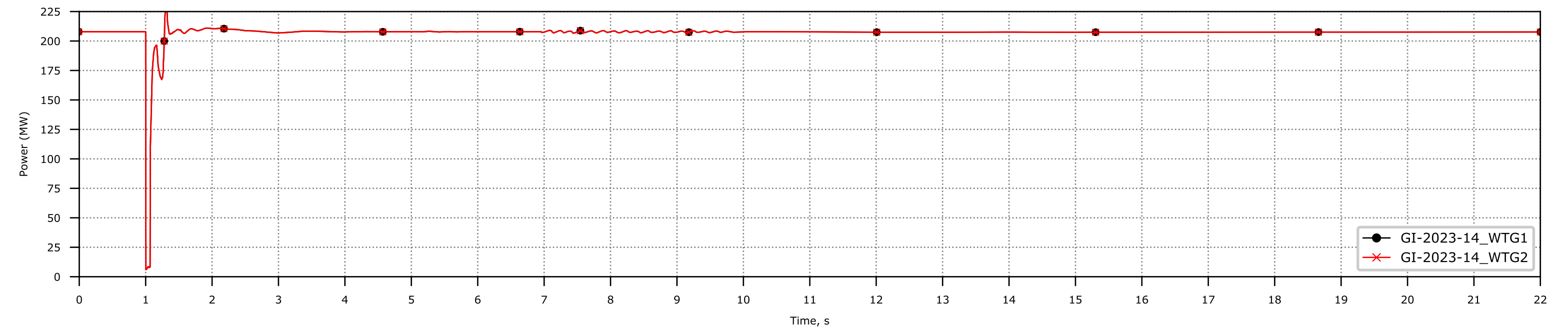


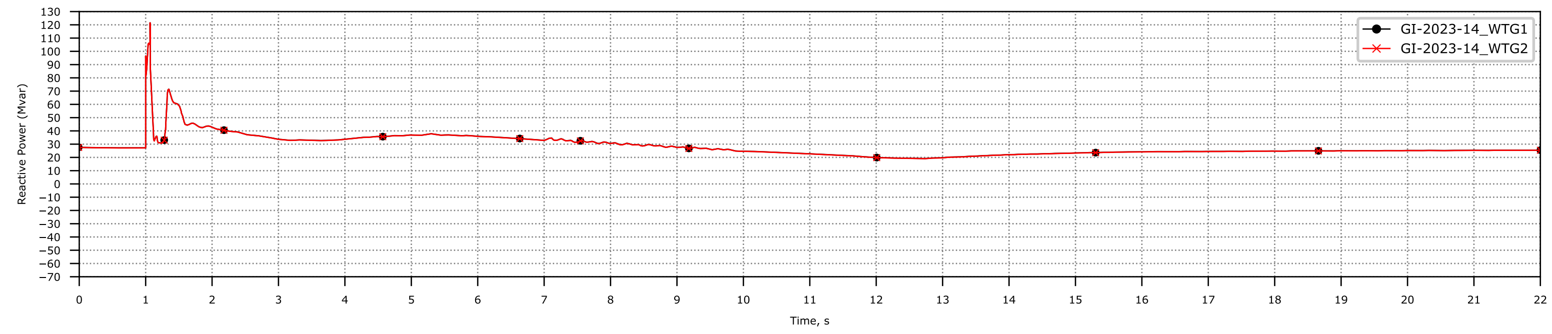
TC1_GI-2023-14_Study_East_Pawnee-CanalXing_345kV

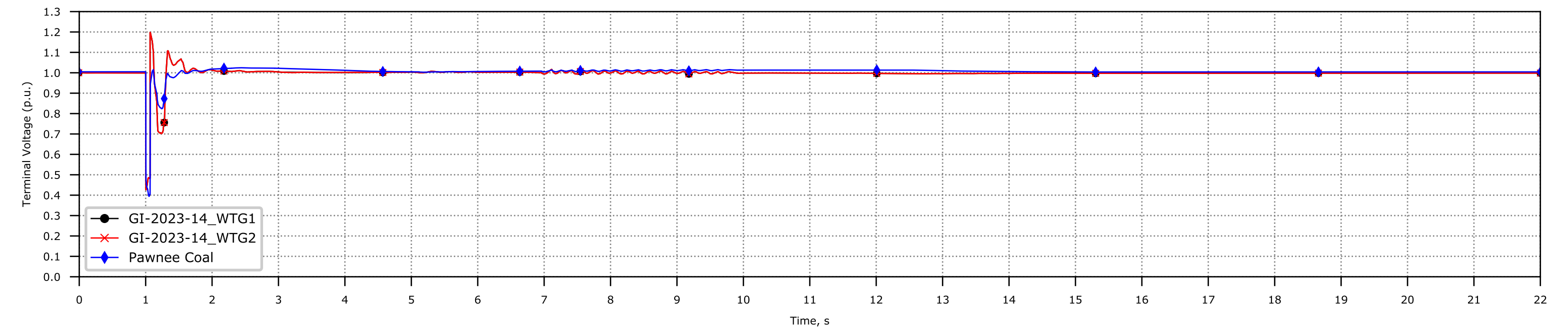


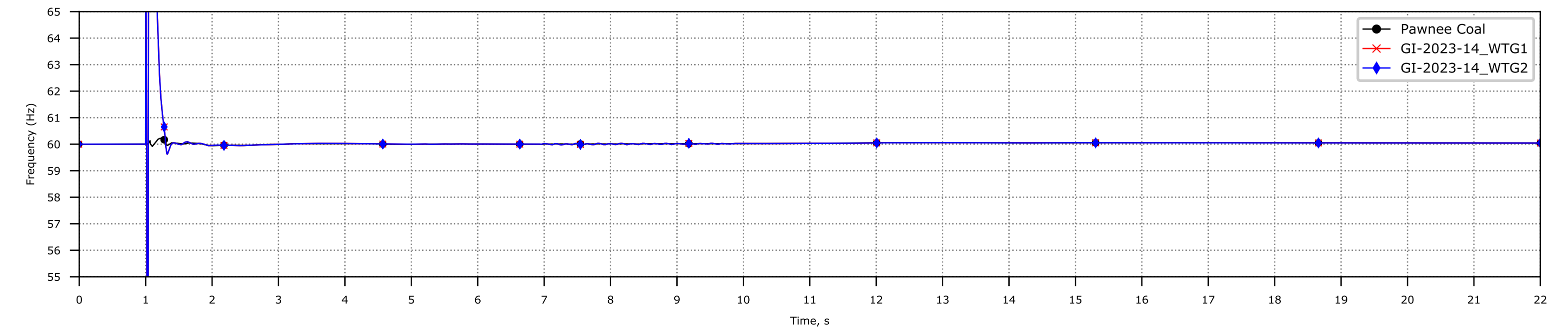


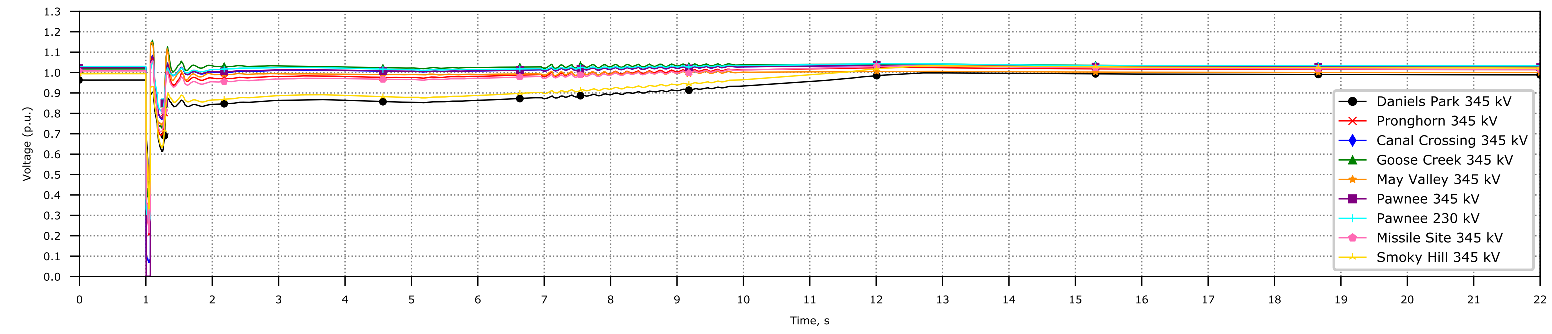




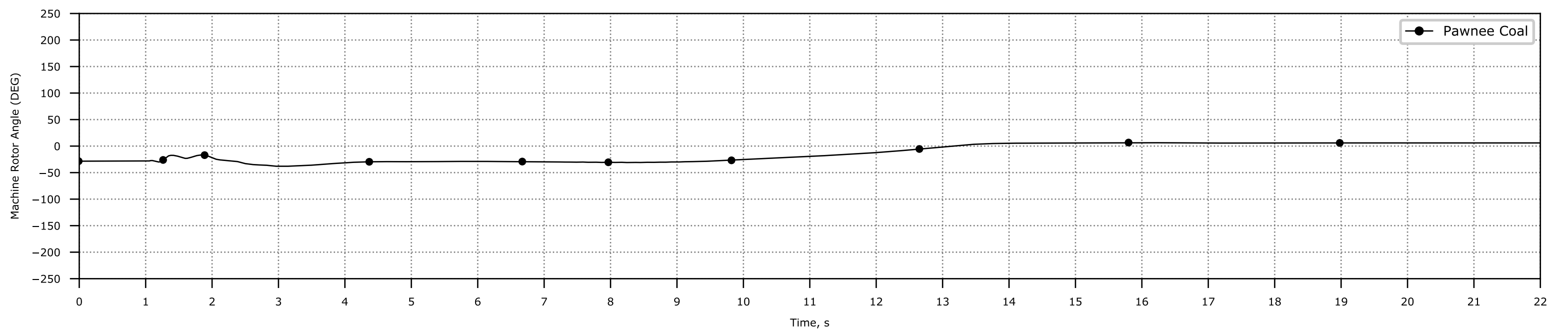


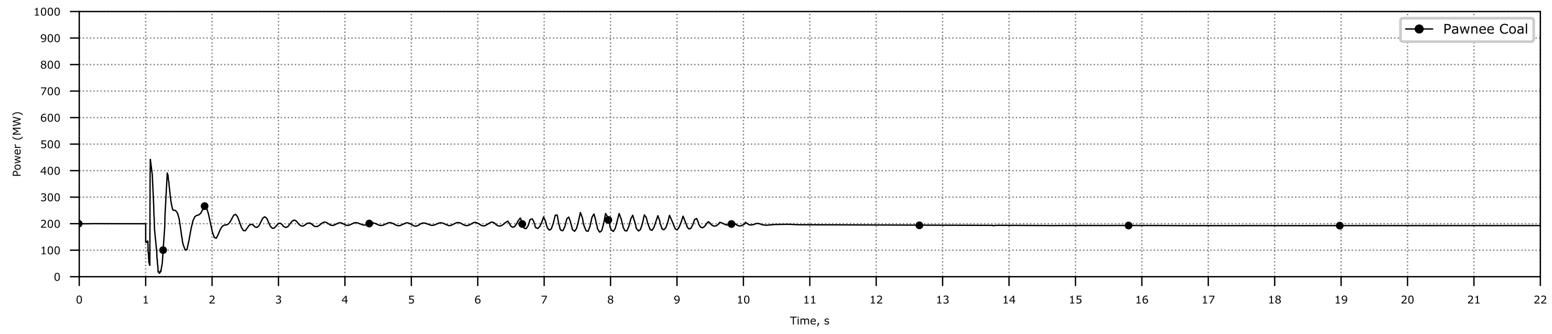


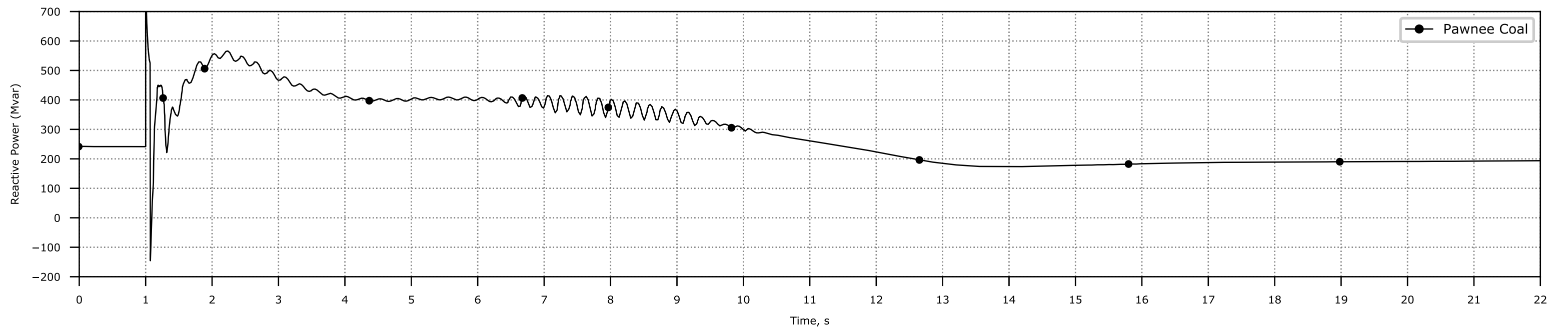


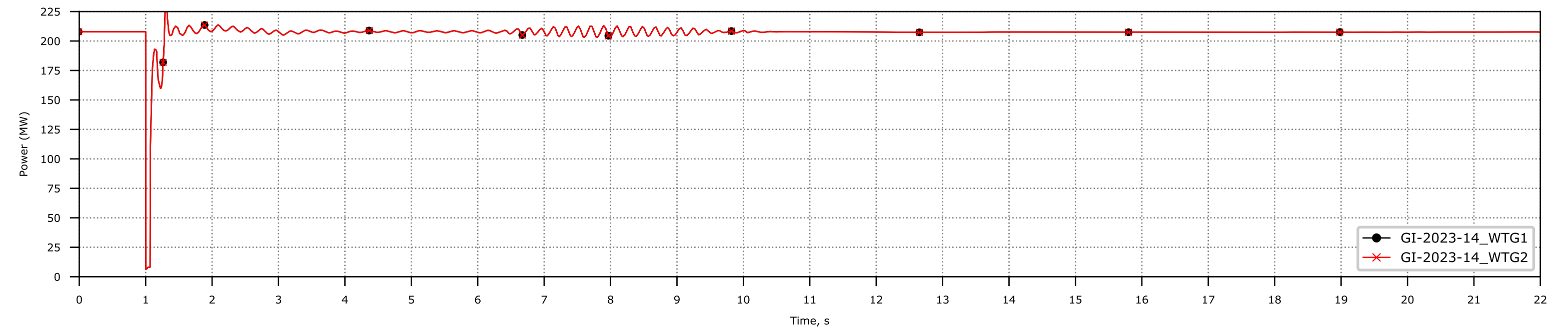


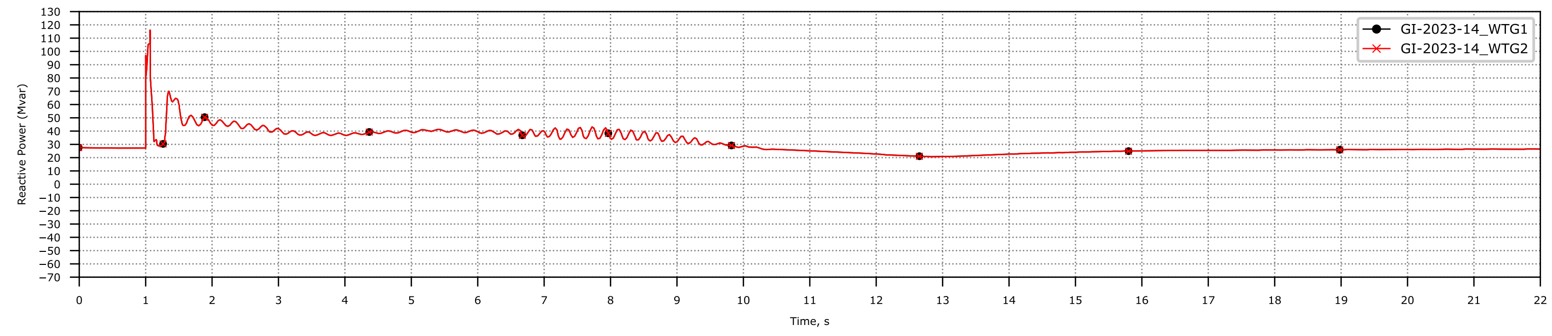
TC1_GI-2023-14_Study_East_Pawnee_Xfmr

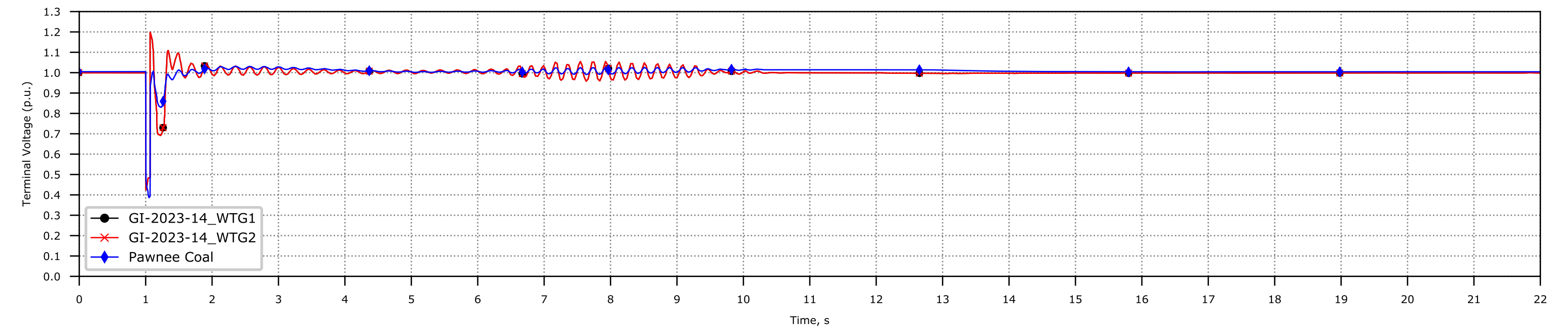


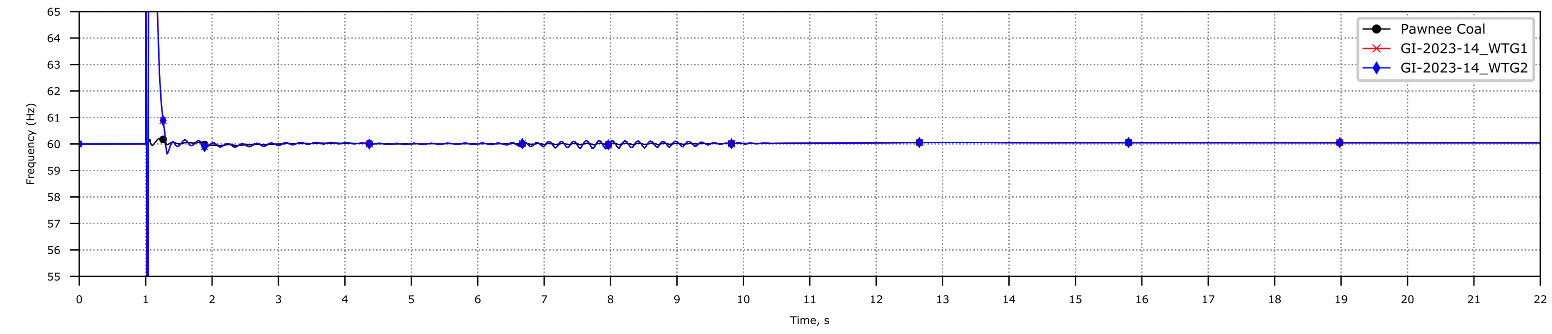


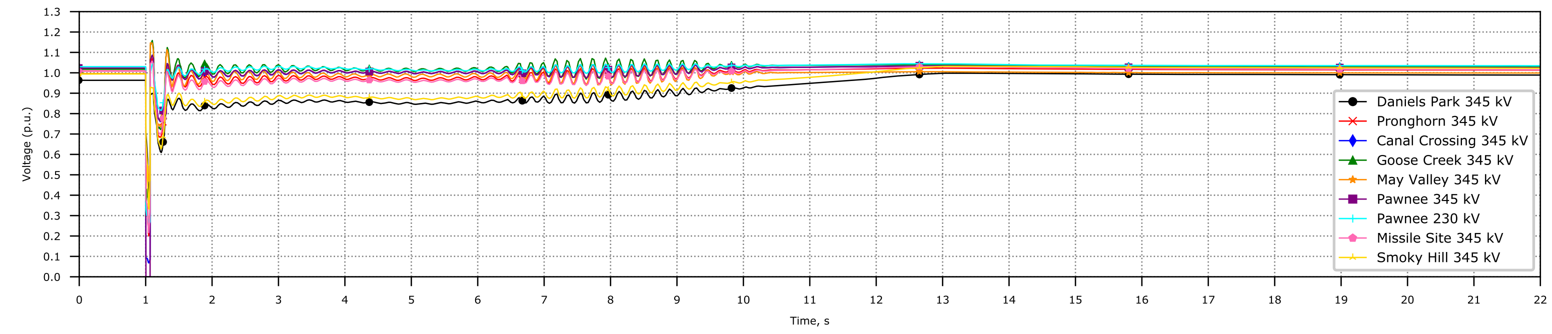




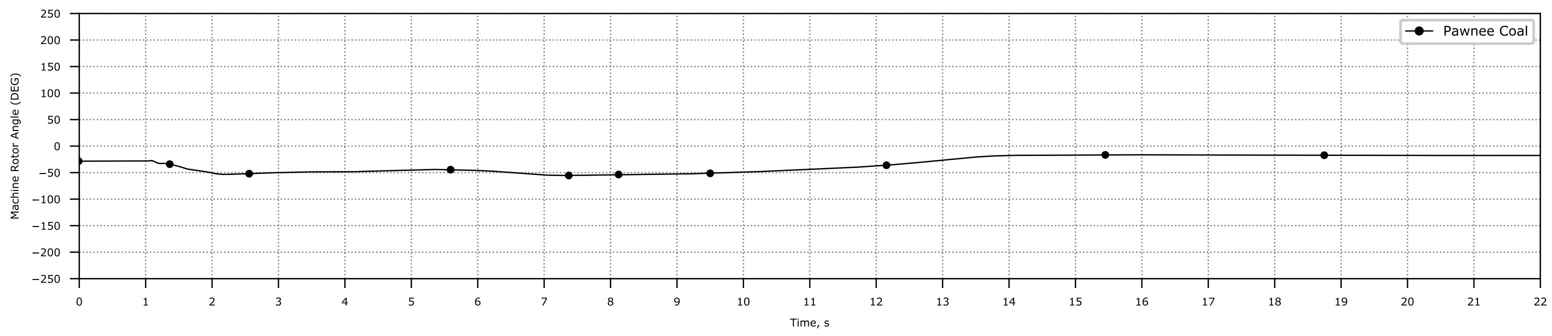


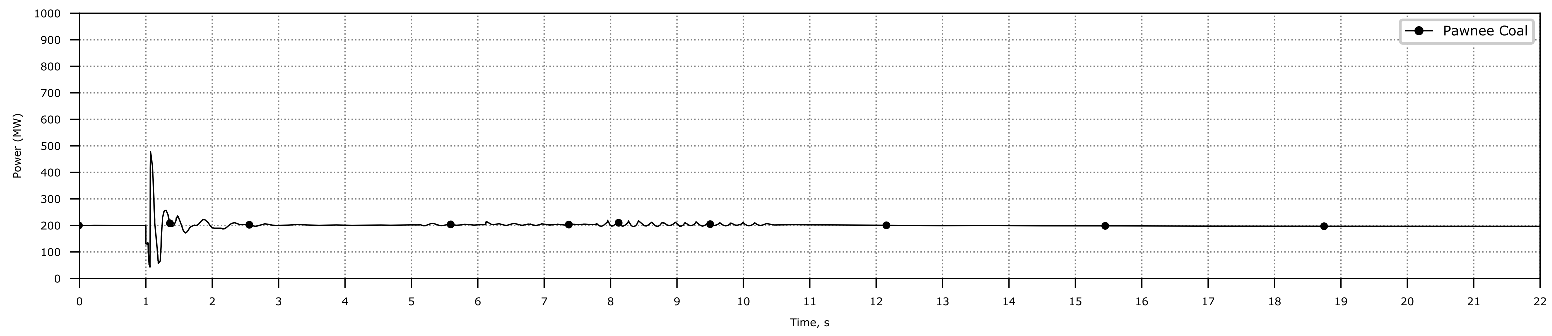


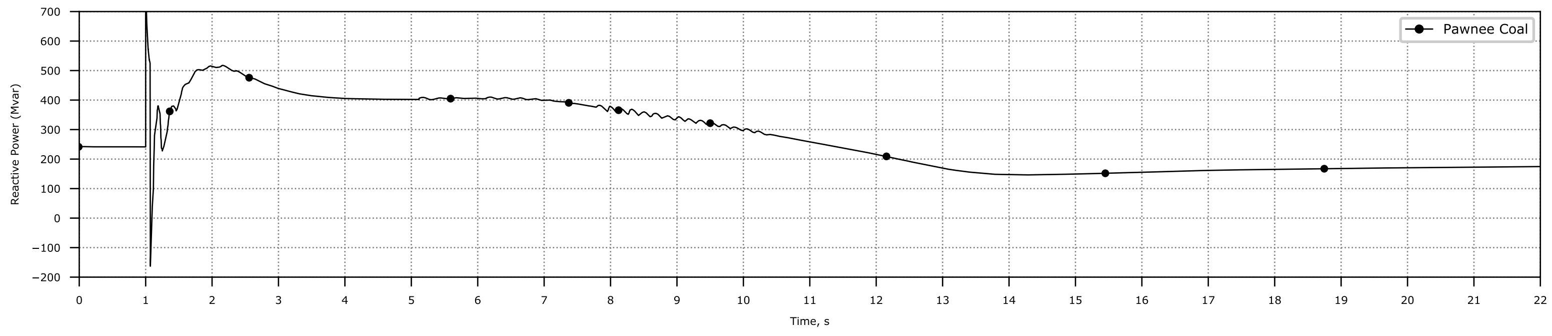


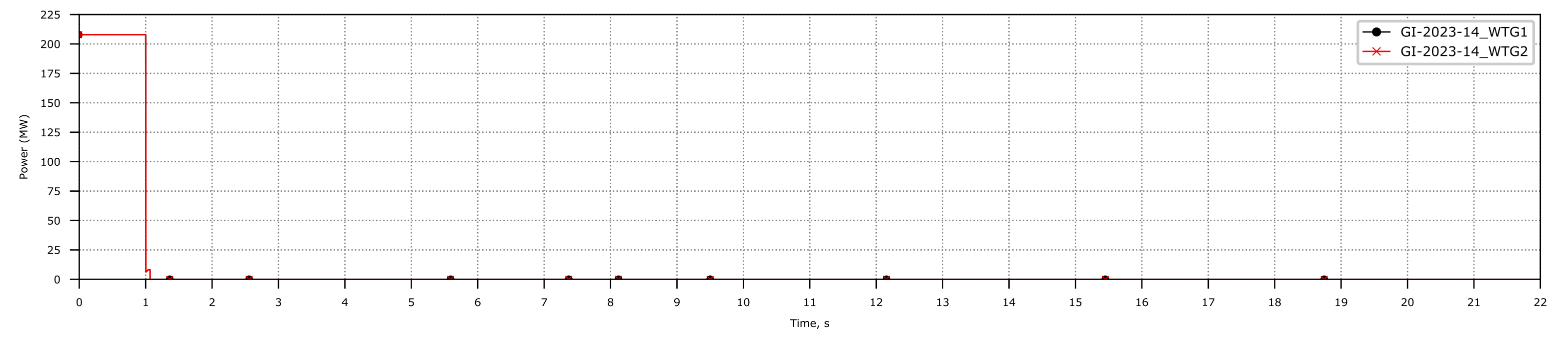


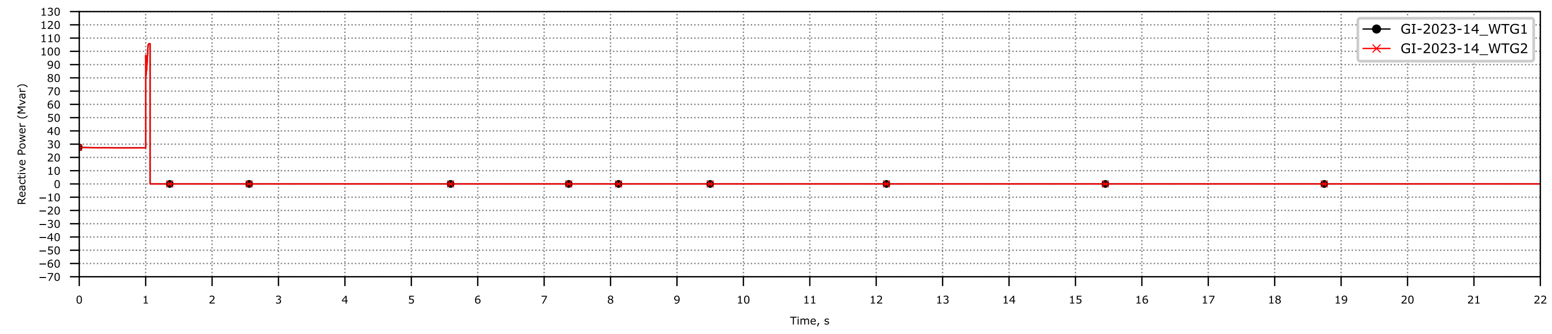
TC1_GI-2023-14_Study_East_GI-2023-14_Gen

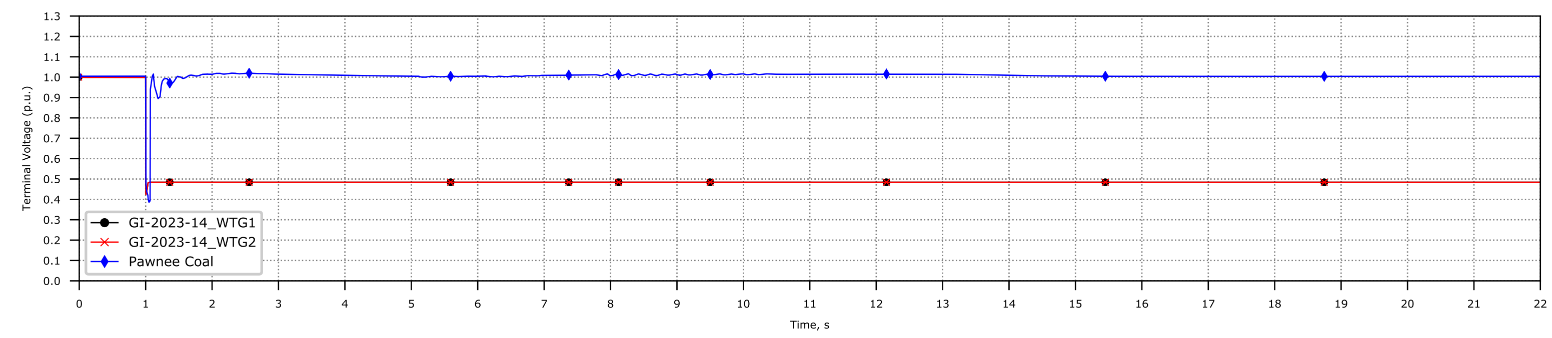


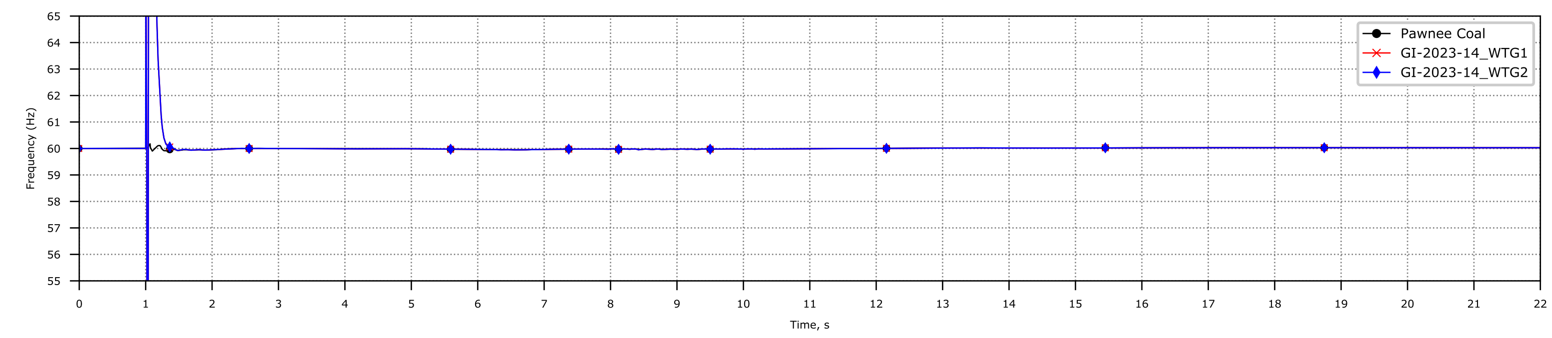


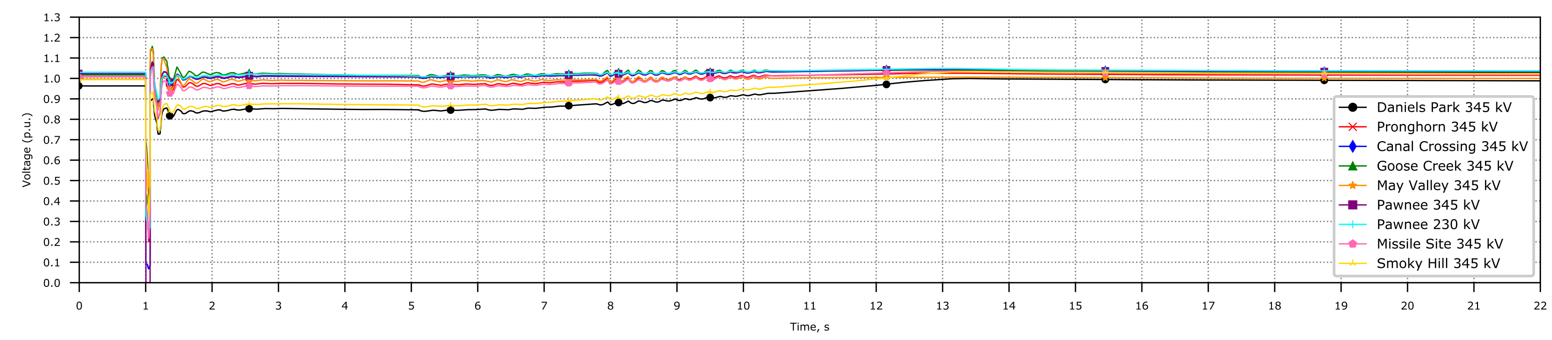




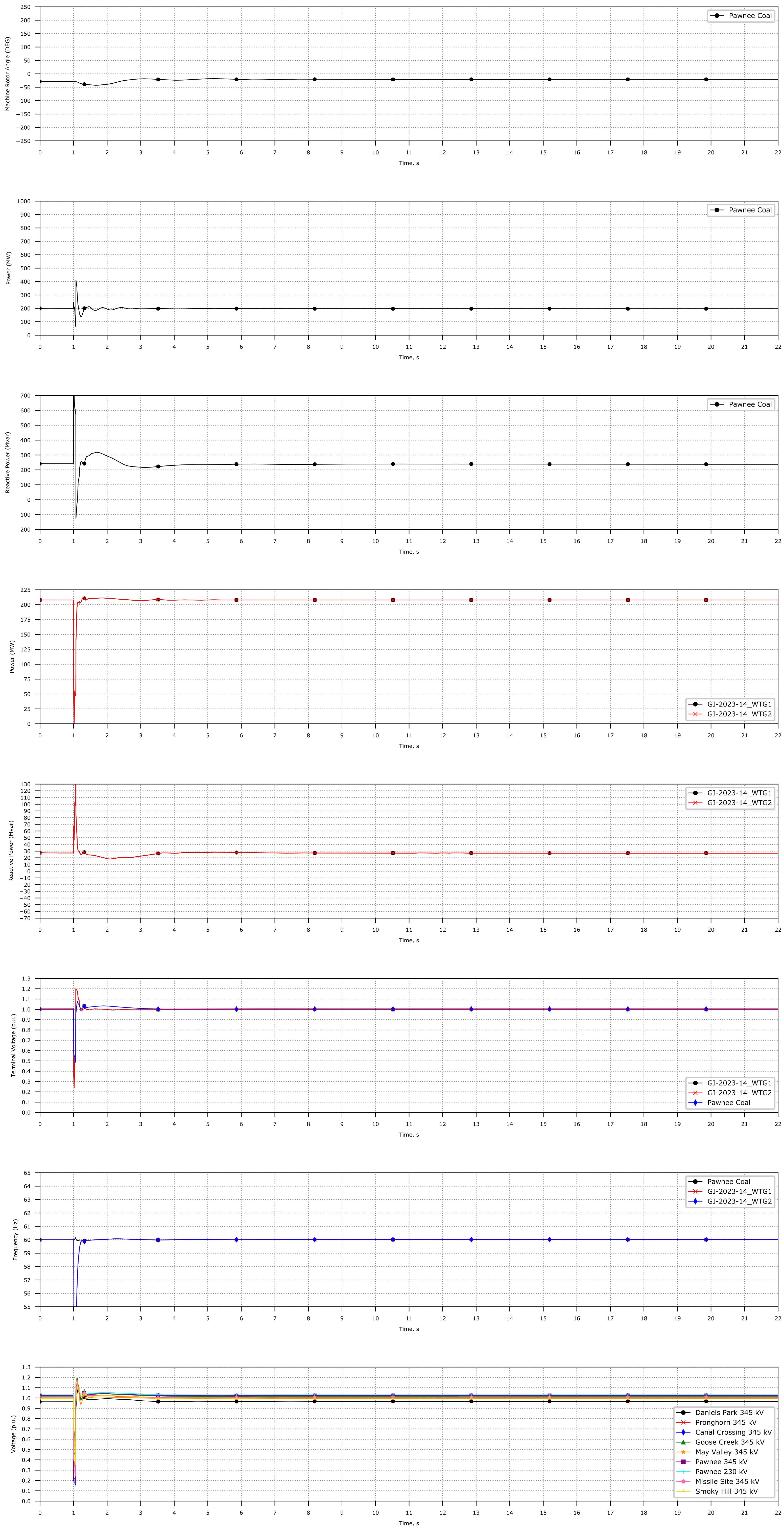




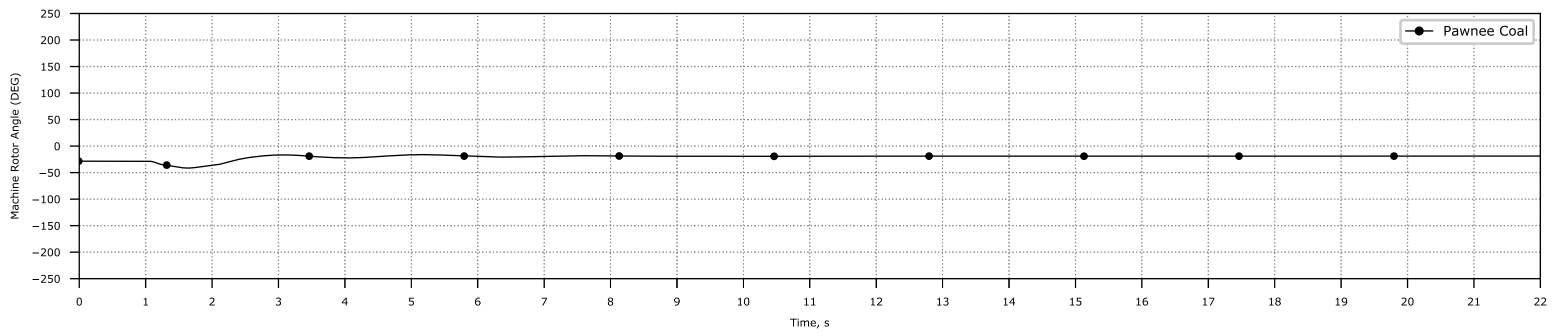


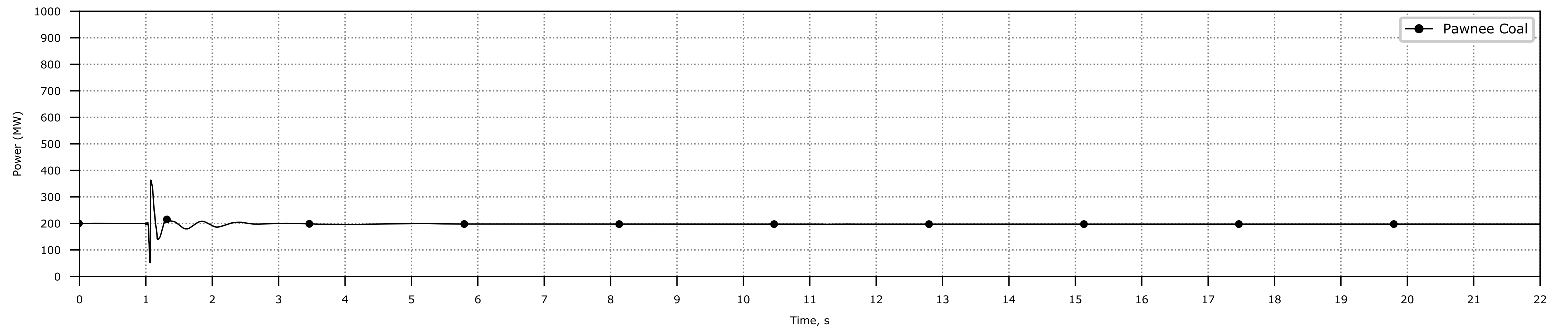


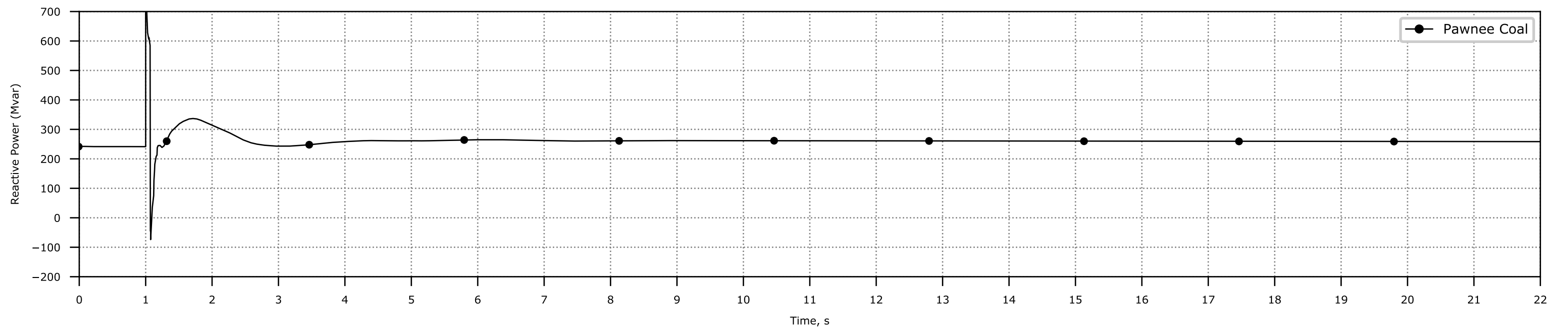
TC1_GI-2023-14_Study_East_MS-CanalXing_345kV

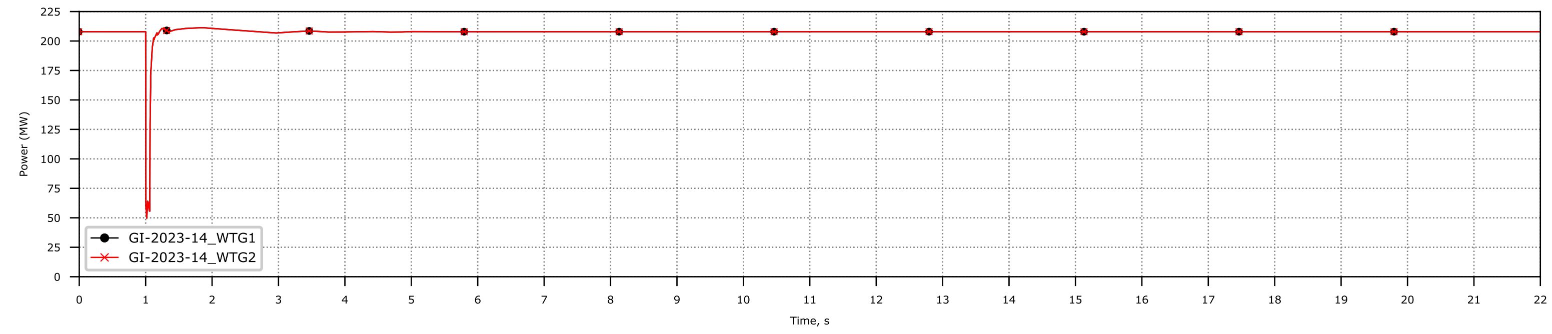


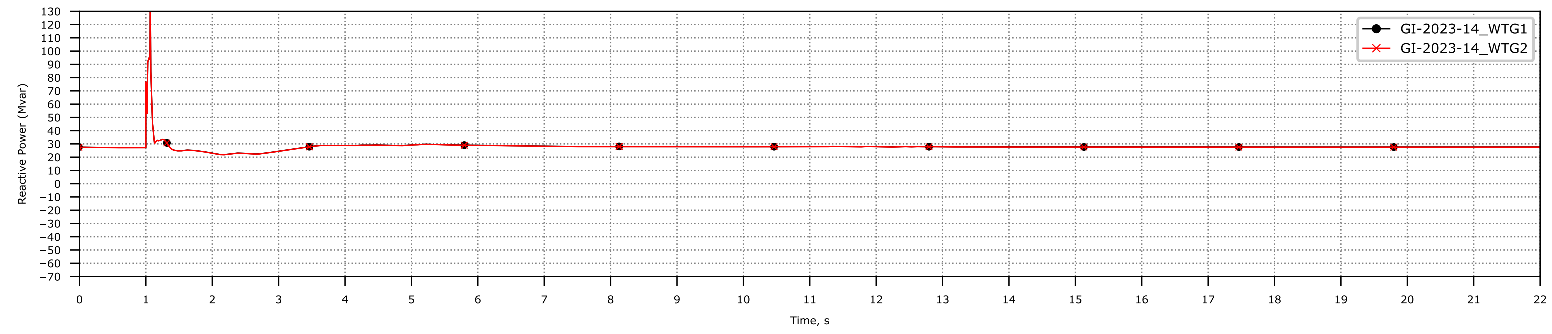
TC1_GI-2023-14_Study_East_FSV-CanalXing_345kV

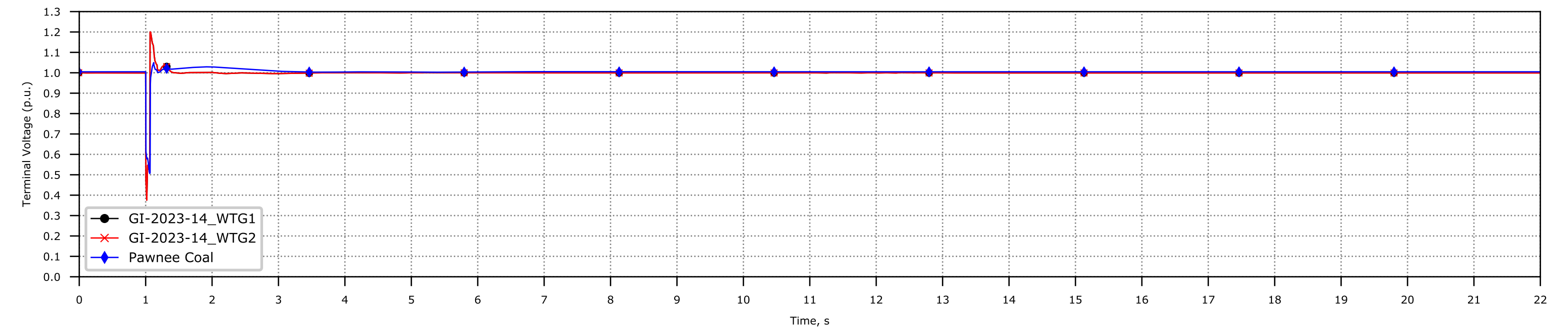


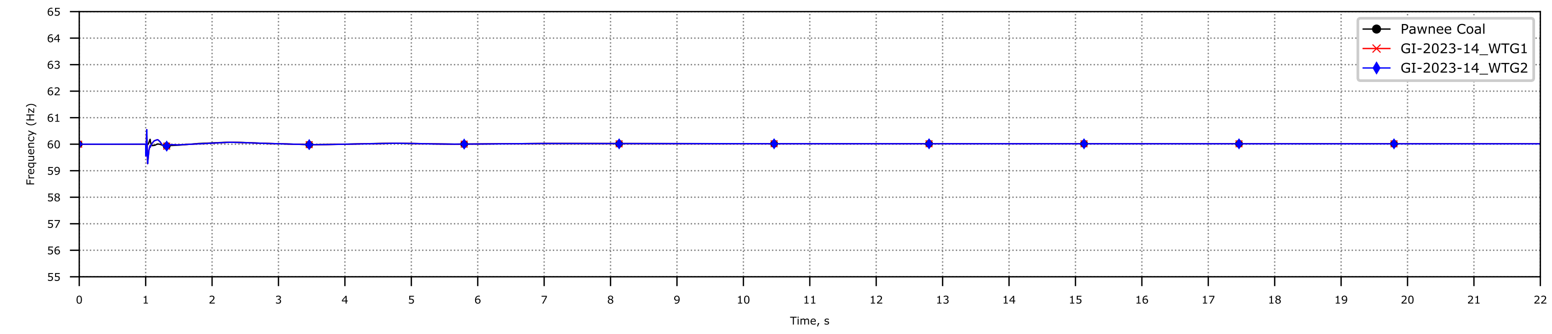


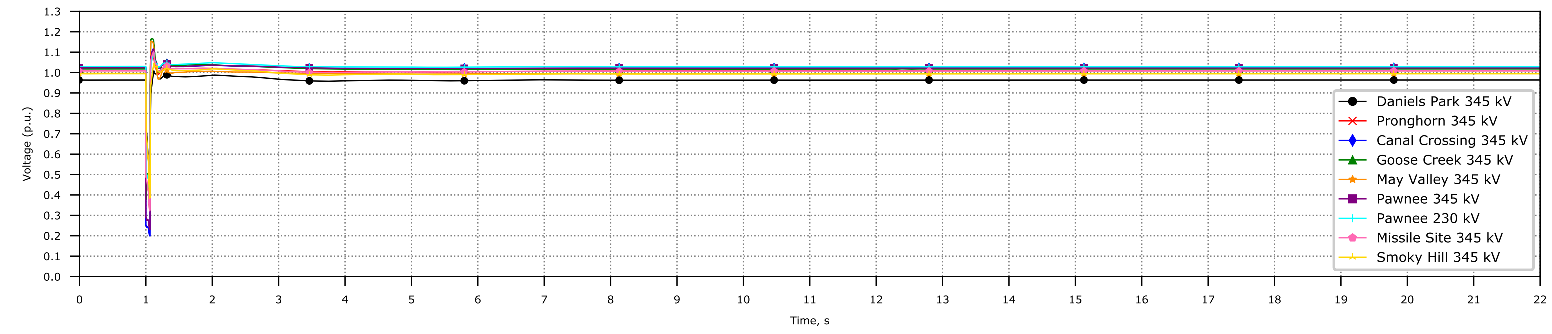




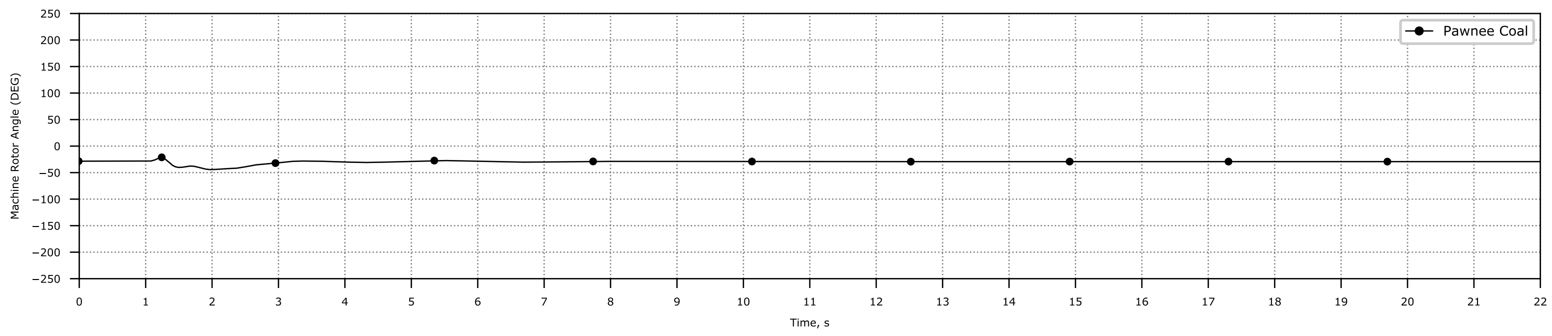


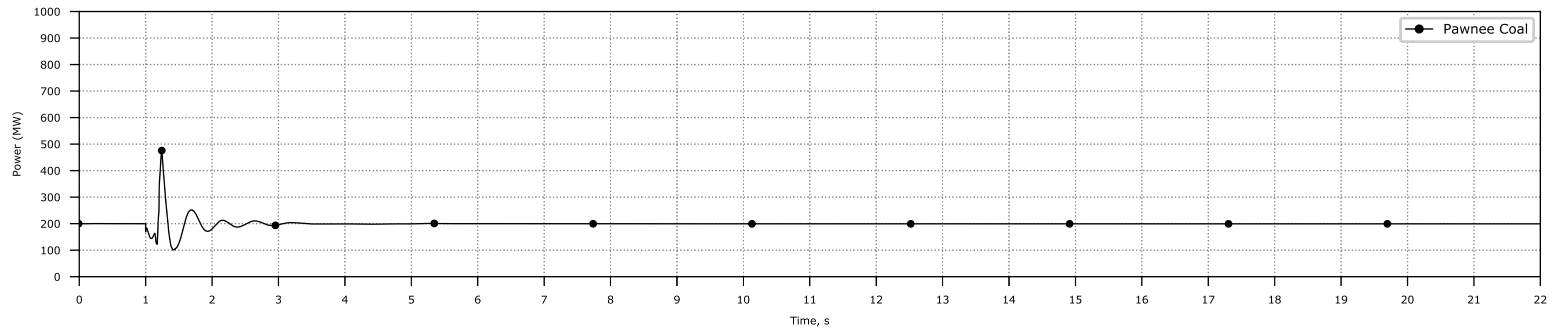


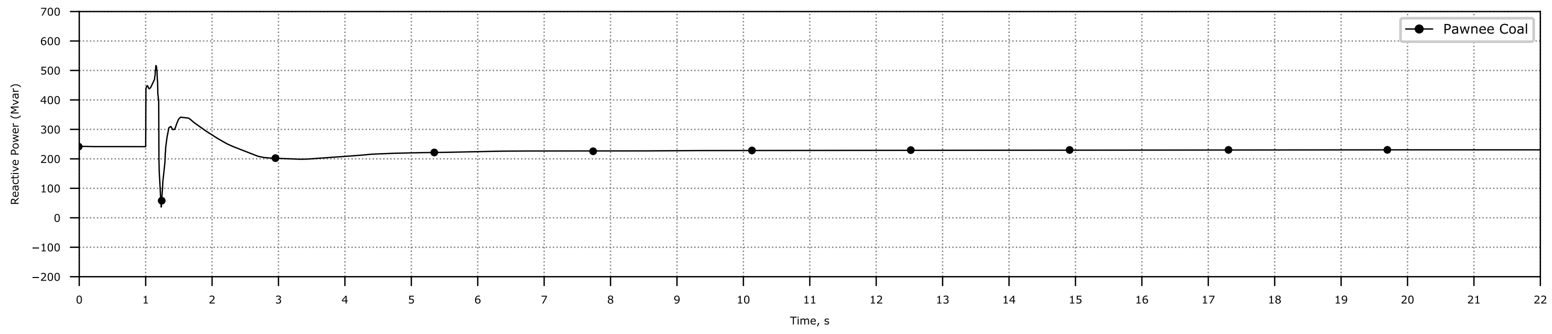


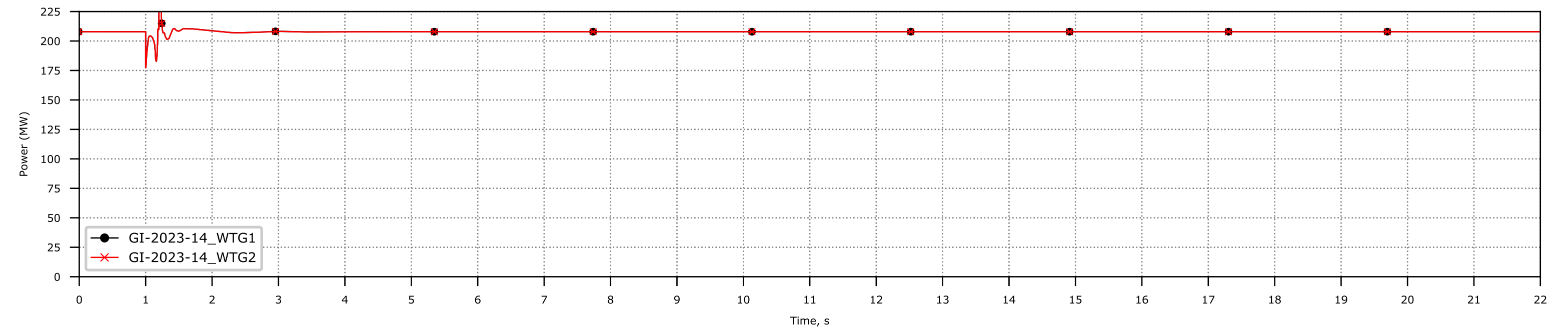


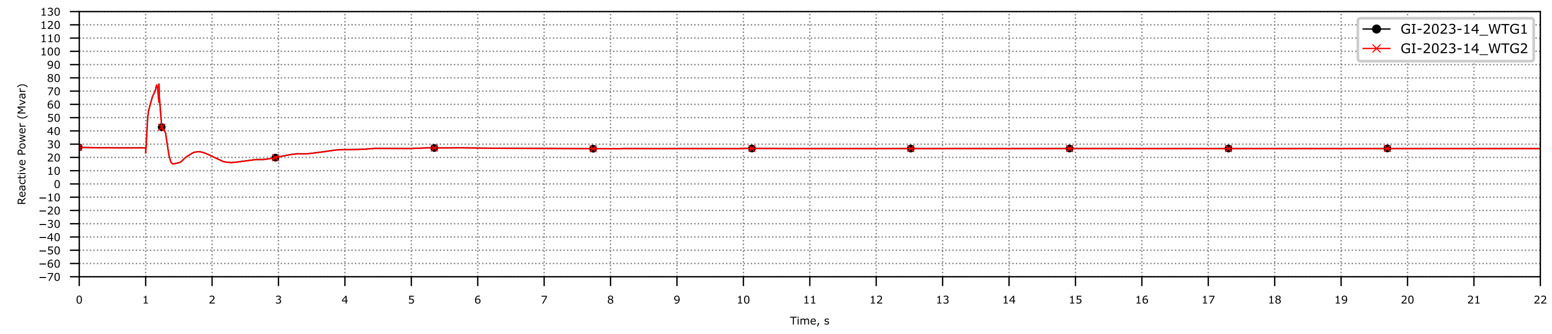
TC1_GI-2023-14_Study_East_line_324

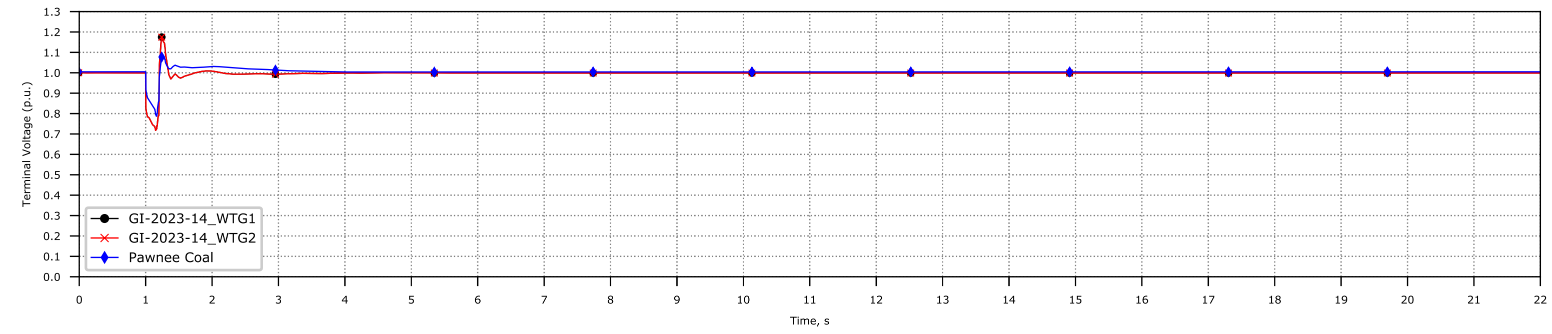


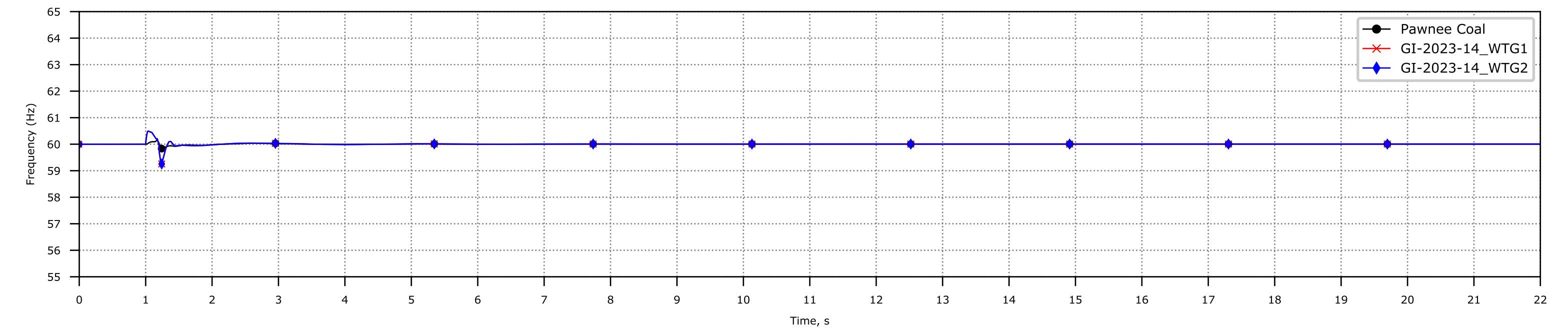


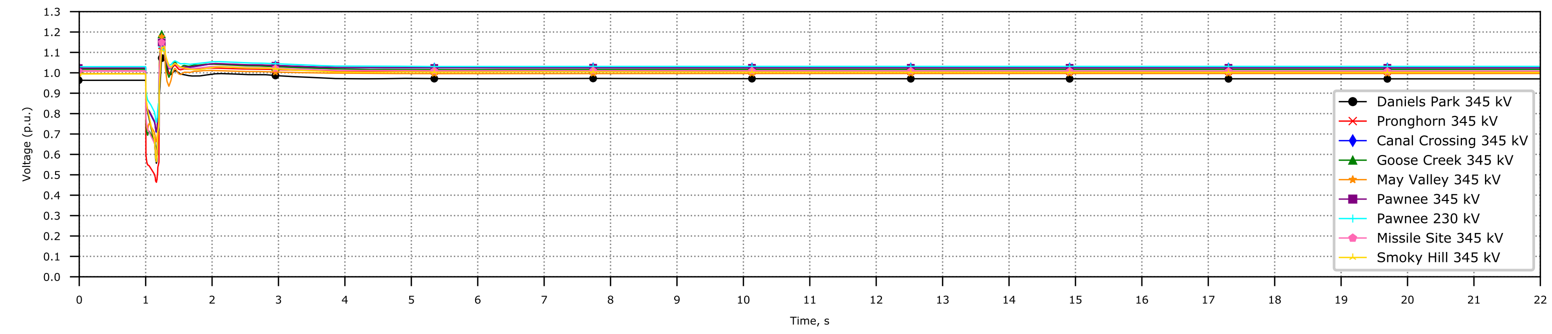












TC1_GI-2023-14_Study_East_line_402