DISIS-2020-001

Phase 2 Report

8/19/2021

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1.0 Summary

The Phase 2 of DISIS-2020-001 Definitive Interconnection Study Cluster includes seven (7) Generation Interconnection Request (GIR)s: GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-5, GI-2020-6, GI-2020-7 and GI-2020-10.

GI-2020-1 is a 199MW$_{ac}$ net rated Solar Photovoltaic (PV) Generating Facility requesting Energy Resource Interconnection Service (ERIS). The Point of Interconnection (POI) is Mirasol 230kV Station.

GI-2020-3 is a 199MW$_{ac}$ net rated Solar PV Generating Facility requesting ERIS. The POI is a tap on the Boone - Comanche 230kV line, at approximately 5 miles from the Boone Substation.

GI-2020-4 is a 100MW$_{ac}$ net rated Solar PV Generating Facility requesting ERIS. The POI is at Mirasol 230kV Station.

GI-2020-5 is a 24MW (18MW in Summer) expansion of the Existing Fort Saint Vrain#4 generator requesting ERIS.

GI-2020-6 is a 199MW$_{ac}$ net rated Solar Photovoltaic (PV) Generating Facility requesting Network Resource Interconnection Service (NRIS). The Point of Interconnection (POI) is a tap on the Pawnee - Missile 230kV line, at approximately 9.93 miles from the Missile Site Substation.

GI-2020-7 is a net 1000MW$_{ac}$ hybrid (700MW Wind plus 300MW Solar) Generating Facility requesting ERIS. The Point of Interconnection (POI) is at Mirasol 345kV Station.

GI-2020-10 is a net 230MW$_{ac}$ AC-coupled Solar PV and Battery Energy Storage (BES) Generating Facility requesting NRIS. The Point of Interconnection (POI) is a tap on the Comanche - Midway 230kV, at approximately 6 miles from the Comanche Substation.

The GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-7 and GI-2020-10 are studied in the Southern Colorado study pocket analysis. The GI-2020-5 is studied under the Northern Colorado study pocket and GI-2020-6 is studied under the Eastern Colorado study pocket analysis.

The Generation Interconnection Service identified in this report in and of itself does not convey transmission service.

1.1 GI-2020-1 Results

The total estimated cost of the transmission system improvements for GI-2020-1: $17.014 Million (Tables 18, 23 and 24).

The maximum output of GI-2020-1 before Network Upgrades is 175MW

Energy Resource Interconnection Service of GI-2020-1 is: 199MW (after required transmission system improvements in Tables 18, 23 and 24)

1.2 GI-2020-3 Results

The total cost of the required Upgrades for GI-2020-3 to interconnect at the GI-2020-3 230kV Switching Station is $26.568 Million (Tables 20, 23 and 25).

The maximum output of GI-2020-3 before Network Upgrades is 175MW

Energy Resource Interconnection Service of GI-2020-3 is: 199MW (after required transmission system improvements in Tables 20, 23 and 25).

1.3 GI-2020-4 Results

The total cost of the required Upgrades for GI-2020-4 to interconnect at the Mirasol 230kV Station is $16.0375 Million (Tables 18, 23 and 26).

The maximum output of GI-2020-4 before Network Upgrades is 85MW

Energy Resource Interconnection Service of GI-2020-4 is: 100MW (after required transmission system improvements in Tables 18, 23 and 26).

1.4 GI-2020-5 Results

The total estimated cost of the transmission system improvements for GI-2020-5 are: $0.05 Million (Table 27).

The maximum output of GI-2020-4 before Network Upgrades is 24MW

Energy Resource Interconnection Service of GI-2020-5 is: 24MW (after required transmission system improvements in Tables 27).

1.5 GI-2020-6 Results

The total estimated cost of the transmission system improvements for GI-2020-6 are: $22.569 Million (Tables 21, 23 and 28).

Network Resource Interconnection Service of GI-2020-6 is: 199MW (after required transmission system improvements in Tables 21, 23 and 28).

1.6 GI-2020-7 Results

The total estimated cost of the transmission system improvements for GI-2020-7 are: $38.475 Million (Tables 19, 23 and 29).

The maximum output of GI-2020-7 before Network Upgrades is 1000MW

Energy Resource Interconnection Service of GI-2020-7 is: 1000MW (after required transmission system improvements in Tables 19, 23 and 29).

1.7 GI-2020-10 Results

The total estimated cost of the transmission system improvements for GI-2020-10 are: $5.009 Million (Tables 22, 23 and 30).

Network Resource Interconnection Service of GI-2020-10 is: 230MW (after required transmission system improvements in Tables 22, 23 and 30).

2.0 Introduction

Public Service Company of Colorado (PSCo) received seven (7) Generation Interconnection Request (GIR)s in the DISIS-2020-001 Phase 1, all of which moved to Phase 2. The total Interconnection Service requested in the DISIS-2020-001 cluster is 1951MW. Out of the seven (7) GIRs, GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-5 and GI-2020-7 requested ERIS[1] and, GI-2020-6 and GI-2020-10 requested NRIS[2]. A summary of the requests is given in Table 1.

[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

[2] 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.

Table 1 – Summary of GIRs in the DISIS-2020-001

Status of PSCo's Interconnection Requests and Studies as of: 6/1/2020

Generation Interconnection Number	Current Cluster	Date of Valid Request	Capacity (MW)	Maximum MW Output Summer	Maximum MW Output Winter	Location (County/State)	Station or Transmission Line POI	Projected In-Service Date	Service Type	Generating Facility Type	Status of Request
DEFINITIVE INTERCONNECTION SYSTEM IMPACT STUDY CLUSTER # 1 - WINDOW OPENED FEBRUARY 1, 2020 - CLOSED MARCH 16, 2020 (DISIS-2020-001)											
GI-2020-01	DISIS-2020-001	3/9/2020	199	199	199	Pueblo County, CO	Mirasol 230 kV Substation	12/1/2023	ERIS	Solar	DISIS Studies In-Progress
GI-2020-02	DISIS-2020-001	3/9/2020	199	199	199	Kit Carson County, CO	Missile Site 345 kV Substation	12/1/2022	ERIS	Wind	Withdrawn 4/15/2020
GI-2020-03	DISIS-2020-001	3/9/2020	199	199	199	Pueblo County, CO	Boone-Comanche 230kV Line	12/1/2023	ERIS	Solar	DISIS Studies In-Progress
GI-2020-04	DISIS-2020-001	3/9/2020	100	100	100	Pueblo County, CO	Mirasol 230 kV Substation	12/1/2023	ERIS	Solar	DISIS Studies In-Progress
GI-2020-05	DISIS-2020-001	3/9/2020	24	18	24	Weld County, CO	Ft. St. Vrain	11/1/2020	ERIS	Combustion Turbine	DISIS Studies In-Progress
GI-2020-06	DISIS-2020-001	3/26/2020	199	199	199	Adams County, CO	Pawnee-Missile Site 230 kV Line	11/15/2022	NRIS	Solar	DISIS Studies In-Progress
GI-2020-07	DISIS-2020-001	3/26/2020	1000	1000	1000	Pueblo County, CO	Mirasol 345 kV Substation	12/1/2023	ERIS	Wind+Solar	DISIS Studies In-Progress
GI-2020-08	DISIS-2020-001	3/30/2020	199	199	199	Weld County, CO	Ft. Lupton - Pawnee 230kV Line	12/15/2022	NRIS	Battery+Solar	Withdrawn 5/29/2020
GI-2020-09	DISIS-2020-001	4/6/2020	230	230	230	Washington County, CO	Smoky Hill-Pawnee 345kV Line	11/1/2022	ERIS	Wind	Withdrawn 5/22/2020
GI-2020-10	DISIS-2020-001	4/7/2020	230	230	230	Pueblo County, CO	Comanche - Midway 230kV Line	12/1/2023	NRIS	Battery+Solar	DISIS Studies In-Progress
GI-2020-11	DISIS-2020-001	4/15/2020	1500	1500	1500	Baca County, CO	Mirasol 345 kV Substation	12/1/2023	ERIS	Wind+Solar	Withdrawn 5/22/2020

3.0 Description of the GIRs

There were no changes to the GIR descriptions from the Phase 1 study.

3.1 Description of GI-2020-1

GI-2020-1 is a 199MW$_{ac}$ net rated Solar Photovoltaic (PV) Generating Facility located in Pueblo County, Colorado. The Solar PV Generating Facility will consist of sixty-eight (68) FS3350M 3.35MVA, ±0.90PF inverters, each with its own 0.66/34.5kV, 3.51MVA, wye-delta, Z=8.5% and X/R=10 pad-mounted step-up transformer. The 34.5kV collector system will connect to one (1) 135/180/225MVA, 34.5/13.8/230kV wye-gnd/delta/wye-gnd, Z=8.5% and X/R = 35 main step-up transformer which will connect to the PSCo transmission system via a 0.5 mile 230kV generation tie-line. The POI is Mirasol 230kV Station which is a new Substation in Pueblo County, approximately 10 miles from the existing Comanche Substation. GI-2020-1 and GI-2020-4 share the same POI.

The proposed Commercial Operation Date (COD) of GI-2020-1 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

3.2 Description of GI-2020-3

GI-2020-3 is a 199MW$_{ac}$ net rated Solar PV Generating Facility that will be located in Pueblo County, Colorado. The Solar PV Generating Facility will consist of sixty-eight (68) FS3350M 3.35MVA, ±0.90PF inverters, each with its own 0.66/34.5kV, wye-delta 3.51MVA, Z=8.5% and X/R=10.5 pad-mounted step-up transformer. The 34.5kV collector system will connect to one (1) 135/180/225MVA, 34.5/13.8/230kV wye-gnd/delta/wye-gnd, Z=8.5% and X/R=35 main step-up transformer which will connect to the PSCo transmission system via a 0.5mile 230kV generation tie-line. The POI is a tap on PSCo's Boone – Comanche 230kV line at approximately 5.1 miles from the Boone Substation. The interconnection at the tap point will require building a new 230kV switching station which will be referred to as "GI-2020-3 Switching Station" in this report.

The proposed COD of GI-2020-3 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

3.3 Description of GI-2020-4

GI-2020-4 is a 100MW$_{ac}$ net rated Solar PV Generating Facility that will be located in Pueblo County, Colorado. The Solar PV Generating Facility will consist of thirty-six (36) FS3350M 3.35MWA, ±0.90PF inverters, each with its own 0.66/34.5kV, 3.51MVA, Z=8.5% and X/R=10.5 pad-mounted step-up transformer. The 34.5kV collector system will connect to one (1) 69/92/115MVA, 34.5/13.8/230kV wye-gnd/delta/wye-gnd, Z=8.5% and X/R=35 main step-up

transformer which will connect to the PSCo transmission system via a 0.5 mile, 230kV generation tie-line. The POI is Mirasol 230kV Station, which is a new Substation in Pueblo County, approximately 10 miles from the existing Comanche Substation. GI-2020-1 and GI-2020-4 share the same POI.

The proposed COD of GI-2020-4 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

3.4 Description of GI-2020-5

GI-2020-5 is an 18MW (Summer)/24MW(Winter) incremental capacity in the output of the existing Fort Saint Vrain#4 Combustion Turbine generator located in Weld County, Colorado. The incremental output is driven by turbine prime mover changes being performed as part of maintenance and modernizing the equipment and no changes to the electrical generator set are anticipated. The net generating capacity of Fort Saint Vrain#4 after the Provisional Interconnection will be 167MW(Summer)/173MW(Winter).

The POI of the incremental capacity is the existing Fort Saint Vrain Substation where Fort Saint Vrain#4 currently interconnects.

The proposed Commercial Operation Date (COD) of the incremental capacity is November 1, 2020. Since the POI is existing and operational, a backfeed date is not applicable to GI-2020-5.

3.5 Description of GI-2020-6

GI-2020-6 is a 199MW_{ac} net rated Solar PV Generating Facility that will be located in Adams County, Colorado. The Solar PV Generating Facility will consist of sixty-two (62) SMA SC-4000 UP-US 3.75MVA, ±0.80PF inverters, each with its own 0.6/34.5kV, 4.00MVA, wye-delta, Z=6% and X/R=15 pad-mounted step-up transformer. The 34.5kV collector system will connect to four (4) 48/64/80MVA, 34.5/13.8/230kV wye-gnd/delta/wye-gnd, Z=9% and X/R=35 main step-up transformers which will connect to the PSCo transmission system via a 0.5 mile 230kV generation tie-line. The POI is a tap on the PSCo's Pawnee – Missile 230kV line at approximately 9.93 miles from the Missile Substation. The interconnection at the tap point will require building a new 230kV switching station which will be referred to as "GI-2020-6 Switching Station" in this report. The output of GI-2020-6 NRIS request is assumed to be serving PSCo native load.

The proposed COD of GI-2020-6 is November 15, 2022. For the study purpose, the back-feed date is assumed to be May 15, 2022, approximately six (6) months before the COD.

3.6 Description of GI-2020-7

GI-2020-7 is a 1000MW$_{ac}$ net rated Solar PV and Wind hybrid Generating Facility that will be located in Pueblo County, Colorado. The wind Generating Facility will consist of three hundred fifty-four (354) GE 2.5MW, ±0.90PF wind turbines each with its own 0.69/34.5kV, 2.9MVA, Z=6.06% and X/R=7.5 wye-gnd/delta pad-mounted step-up transformer. The solar PV Generating Facility will consist of one-hundred-ten (110) FS3430M 3.43MVA, ±0.90PF inverters, each with its own 0.66/34.5kV, 3.51MVA, Z=8.5% and X/R=7.5 wye-gnd/delta pad-mounted step-up transformer. The 34.5kV collector system of the PV and the wind Generating Facilities will connect to three (3) 168/224/280MVA, 34.5/13.8/345kV wye-gnd/delta/wye-gnd, Z=8.5% and X/R=40 main step-up transformers for Wind and one (1) 201/268/335MVA, Z=8.5% and X/R=40 main step-up transformer for Solar PV which will connect to the PSCo transmission system via a 150 mile 345kV generation tie-line. The POI is Mirasol 345kV Station, which is a new Substation in Pueblo County, approximately 10 miles from the existing Comanche Substation. The output of the hybrid Generating Facility will be limited to 1000MW at the POI using centralized power plant controller.

The proposed COD of GI-2020-7 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

3.7 Description of GI-2020-10

GI-2020-10 is a 230MW$_{ac}$ net rated AC-Coupled Solar PV plus BES hybrid Generating Facility that will be located in Pueblo County, Colorado. The Solar PV Generating Facility will consist of seventy-three (73) HEM FS3350M 3.35MVA, ±0.90PF inverters and the BES Generating Facility will consist of seventy (70) HEM FS3350M 3.35MVA, ±0.985PF inverters. The inverters are medium voltage inverters with embedded padmount transformers. The 34.5kV collector system of the Solar PV and BES generating facilities will connect to one (1) 154/206/256MVA, 34.5/230kV wye-gnd/delta/wye-gnd, Z=7.5% and X/R=42.4 main step-up transformer which will connect to the PSCo transmission system via a 0.1 mile 230kV generation tie-line. The POI is a tap on the PSCo's Comanche – Midway 230kV line, at approximately 6 miles from the Comanche Substation. Since the tap position of the higher-queued request GI-2014-9 is at the same location, the study assumed GI-2020-10 interconnects at the same switching station as GI-2014-9 (GI-2014-9 230kV Switching Station).

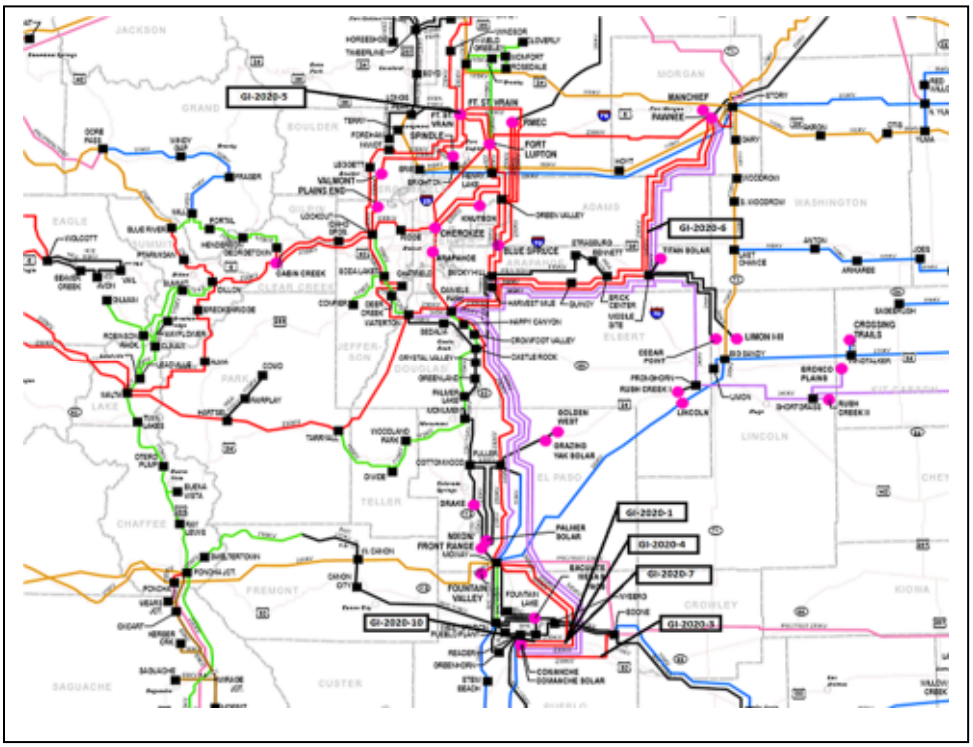
The BES facility has a charge rate and discharge rate of 230MW for 4hrs. The output of the hybrid Generating Facility will be limited to 230MW at the POI using centralized power plant controller.

The PV and BES generators will be operated together to meet the FERC 827 reactive power capability requirements. The BES generator is capable of a primary frequency response operating range of +/-0.036Hz. The BES generator will only charge from the PV.

The output of GI-2020-10 NRIS request is assumed to be serving PSCo native load.

The proposed COD of GI-2020-10 is December 1, 2023. For the study purpose, the back-feed date is assumed to be June 1, 2023, approximately six (6) months before the COD.

Figure 1 – Approximate Locations of the POIs of the GIRs in the DISIS-2020-001



4.0 Study Scope

The purpose of the study is to determine the system impact of interconnecting all seven (7) GIRs in the DISIS-2020-001 for Interconnection Service. The scope of the study which is Phase 2 of the Definitive Interconnection System Impact Study (DISIS) consists of:

a) An updated power flow/voltage analysis (if necessary),
b) stability analysis and short circuit analysis,
c) Non-binding cost estimates for the Transmission Provider's Interconnection Facilities, Station Network Upgrades and Network Upgrades required to reliability interconnect the GIR.

d) The report identifies total costs and each Interconnection Customer's estimated allocated costs.

e) The report also identifies the Contingent Facilities applicable to each GIR.

Since the completion of the Phase 1 study report on 10/16/2020, PSCo's study methodology for identifying the maximum allowable output of ERIS before Network Upgrades has changed. Also, GI-2014-8 and GI-2014-12 have withdrawn and expected to impact the Southern Colorado study analysis performed in Phase 1.

The Phase 1 Northern Colorado study only included GI-2020-5, which was allotted the maximum permissible output of 24MW before Network Upgrades; the Phase 1 results are not impacted by the new ERIS study methodology or withdrawal of GI-2014-8 and GI-2014-12. The Phase 1 Eastern Colorado analysis included GI-2020-06 which is an NRIS request. The Phase 1 Eastern Colorado analysis is not impacted by the new study methodology or GI-2014-8 and GI-2014-12 withdrawal. So, the Phase 2 study included a refresh of the Southern Colorado analysis, which included GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-7 and GI-2020-10 requests.

4.1 Study Pocket Determination

As shown in Figure 1, GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-7, and GI-2020-10, are in Southern Colorado and fall under the "Southern Colorado" study pocket. GI-2020-5 falls under the "Northern Colorado" study pocket and GI-2020-6 falls under the "Eastern Colorado" study pocket. Each study pocket analysis modeled the cluster GIRs that fall under the study pocket.

4.2 Study Criteria

The following Criteria is used for the reliability analysis of the PSCo system and Affected Systems. The Steady-State analysis Criteria are as follows:

P0 - System Intact conditions:

Thermal Loading: <=100% of the normal facility rating

Voltage range: 0.95 to 1.05 per unit

P1 & P2-1 – Single Contingencies:

Thermal Loading: <=100% Normal facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: <=8% of pre-contingency voltage

P2 (except P2-1), P4, P5 & P7 – Multiple Contingencies:

Thermal Loading: <=100% Emergency facility rating

Voltage range: 0.90 to 1.10 per unit

Voltage deviation: <=8% of pre-contingency voltage

The following transient stability criteria are as follows.

Transient Voltage Stability Performance Criteria:

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.

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

The steady state assessment is performed using PSSE V33 and the ACCC tool. The generation redispatch for ERIS is identified using GE's OPF 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 voltage has a further variation of 0.1p.u.

DFAX criteria for identifying contribution to thermal overloads is ≥1%.

DFAX criteria for identifying contribution to the voltage violations is 0.005p.u.

When the study pocket has a mix of NRIS and ERIS requests, it is studied by first modeling the NRIS GIRs at their full requested amount and modeling the ERIS GIRs offline. Network Upgrades required to mitigate the thermal and/or voltage violations per the criteria mentioned above are identified for the NRIS with the ERIS offline. These upgrades are only allocated to NRIS requests because other GIR's output is modeled at zero.

The NRIS GIRs and their associated Network Upgrades are then modeled in the NRIS Study Case, and ERIS GIRs are dispatched at 100% to study the system impact. Violations are identified and the study evaluates if a generation redispatch combination eliminates the violation by using the Optimum Power Flow (OPF) software tool. If generation redispatch is unable to eliminate the violation, upgrades will be required to provide the requested ERIS.

The resources included in the 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

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 select single and multiple contingencies in the Study Pocket.

PSCo can only perform breaker duty analysis on the PSCo system. Before the GIR goes in-service the Affected Systems may choose to perform a breaker duty analysis to identify breaker duty violations on their system

4.4 Study Area

The study area selected for the Southern Colorado study pocket includes WECC designated zones 121, 700, 703, 704, 710, 712, 752 and 757. The Affected System included in the analysis include Tri-State Generation and Transmission Inc. (TSGT), Black Hills Energy (BHE), Colorado Spring Utilities (CSU), Intermountain Rural Electric Association (IREA) and Western Area Power Administration (WAPA) transmission systems in the study area.

The study area selected for the Northern study pocket includes WECC designates zones 700, 703 and 706. The neighbouring utilities included in the analysis include TSGT transmission system in the study area.

The study area selected for the Eastern Colorado study pocket includes WECC designates zones 700, 703 and 706. The neighbouring utilities included in the analysis include TSGT, IREA and WAPA systems in the study area.

5.0 Base Case Modeling Assumptions

The Phase 2 studies were performed using the same Study Case modeling assumptions as the Phase 1 study.

The Southern Colorado and Eastern Colorado analysis was performed using the 2023HS case.

The Northern Colorado Study Pocket analysis was performed using the 2020HW WECC approved base case released on February 28, 2020, consistent with the COD of the GIR.

The Southern Colorado power flow restudy was performed using the PSSE cases created for Phase 1. The stability analysis is performed using GE PSLF case, so a replica model of the corresponding Phase 1 PSSE Study Pocket Study Case is created using the same modeling assumptions as the Phase 1 report.

See the DISIS-2020-001 Phase 1 report posted here for modeling details:
https://www.rmao.com/public/wtpp/Final_Studies/DISIS-2020-001_Phase%201%20Report.pdf

6.0 Generation Interconnection Service Analysis

6.1 Southern Colorado Study Pocket Analysis

The Benchmark Case and the Study Case created for the Phase 1 study was updated to remove GI-2014-8 and GI-2014-12. Also, the Daniels Park – Prairie1 230kV line & Daniels Park – Prairie3 230kV line are modeled at 756MVA.

As stated in the Phase 1 report, the multiple contingency analysis is done for informational purpose only and overloads are mitigated using system adjustments, including generation redispatch (existing and GIRs under study) and/or operator actions. So, the restudy of the power flow analysis only included single contingency analysis.

NRIS Steady-State Analysis:

The NRIS Study Case is created from the Benchmark Case by modeling GI-2020-10 at the same POI as GI-2014-9 and dispatched at its full requested amount of 230MW. The GI-2020-10 output is balanced by reducing the Pawnee generation.

The addition of GI-2020-10 did not result in any single contingency overloads.

ERIS Steady-State Analysis:

Following the evaluation of GI-2020-10 NRIS GIR, the ERIS Study Case is developed from the NRIS study Case by making the following modifications:

- GI-2020-3 is modeled tapping the Boone – Comanche 230kV line and dispatched at 100%
- GI-2020-1 and GI-2020-4 are modeled at the new Mirasol 230kV Station, tapping the GI-2014-9 POI – Midway 230kV line, and dispatched at 100%
- GI-2020-7 is modeled at the new Mirasol 345kV Station, tapping the Comanche – Tundra 345kV line, and dispatched at 100%.
- The ERIS output of GI-2020-1, GI-2020-3, GI-2020-4 and GI-2020-7 is balanced by reducing all PSCo and non-PSCo generation outside the study pocket on a pro-rata basis.

The results of the single contingency analysis (P1 and P2-1) for the ERIS Study case are given in Table 2 below. Additionally, the following contingencies resulted in a solution divergence, but OPF identified generation redispatch scenario that solved the contingencies without violations:

- Contingency of Comanche – GI-2014-9 230kV line
- Contingency of Mirasol – GI-2014-9 230kV line
- Contingency of Daniels park – Tundra 345kV line
- Contingency of Daniels Park – Comanche 345kV line
- Contingency of Mirasol – Tundra 345kV line

Xcel Energy

Table 2 Southern Colorado Study Pocket ERIS study results – Overloads identified in Single Contingency Analysis

Overloaded Facility	Type	Owner	Facility Normal Rating (MVA)	Facility Loading in NRIS Study Case		Facility Loading in ERIS Study Case		% Change due to Study Pocket GIRs	Single Contingency Definition	OPF Identified
				MVA Flow	% Line Loading	MVA Flow	% Line Loading			
Boone – MidwayPS 230kV	Line	PSCo / TSGT	478	280.6	58.7%	494.2	103.4%	44.7%	System Intact	Yes
Daniels Park – Fuller 230kV	Line	PSCo	478	361.4	75.6%	568.8	119.0%	43.4%	System Intact	Yes
MidwayPS 230/115kV #1	Xfmr	PSCo	150	105.6	70.4%	159.8	106.5%	36.1%	System Intact	Yes
Midway 230kV bus tie	Line	PSCo / WAPA	576	355.4	61.7%	595.6	103.4%	41.7%	System Intact	Yes
Blende – Erie Ave 69kV	Line	BHE	42	29.8	71%	42.9	102.1%	31.1%	Fountain Lake – Baculite 115kV	Yes
Boone – MidwayPS 230kV #1	Line	PSCo / TSGT	318.7	249.9	78.4%	431.2	135.3%	56.9%	Midway – Mirasol 230kV	Yes
Canyon City – Skala 115kV	Line	BHE	119	92.7	77.9%	122.2	102.7%	24.8%	West Canyon – MidwayBR 230kV	Yes
Comanche – MidwayPS 230kV	Line	PSCo	478	291.6	61%	489	102.3%	41.3%	Midway – Mirasol 230kV	Yes
Daniels Park 345/230kV #T3	Xfmr	PSCo	560	496.2	88.6%	636.7	113.7%	25.7%	Daniels Park 345/230kV #T5 or T4	Yes
Daniels Park 345/230kV #T4	Xfmr	PSCo	560	496.2	88.6%	636.7	113.7%	25.7%	Daniels Park 345/230kV #T5 or T3	Yes
Daniels Park 345/230kV #T5	Xfmr	PSCo	560	496.2	88.6%	636.7	113.7%	25.7%	Daniels Park 345/230kV #T3 or T4	Yes
Daniels Park – Fuller 230kV	Line	PSCo	560	495.7	88.5%	784.4	140.0%	51.5%	Waterton – Midway 345kV	Yes
Federal Ht – Semper 115kV	Line	PSCo	159	154.4	97.1%	161.5	101.6%	4.5%	Cherokee S – FederalHt 23 115kV	Yes
Greenwood – Prairie3 230kV	Line	PSCo	576	558.1	96.9%	789.7	137.1%	40.2%	Daniels Park – Prairie1 230kV	Yes
Greenwood – Prairie1 230kV	Line	PSCo	576	544.9	94.6%	777.6	135.0%	40.4%	Daniels Park – Prairie3 230kV	Yes

Greenwood – Monaco 230kV	Line	PSCo	560	476	85%	570.1	101.8%	16.8%	Buckley12 – Smokyhill 230kV	Yes
HydePark – Pueblo plant 115kV	Line	BHE	160	109.3	68.3%	175.8	109.9%	41.6%	Greenhorn – Reader 115kV	Yes
MidwayPS 230/115kV	Xfmr	PSCo	150	134.8	89.9%	204.8	136.5%	46.6%	Mirasol – Midway 230kV	Yes
Comanche – GI-2014-9	Line	PSCo	478	NA	NA	740.9	155%	NA	Mirasol – Midway 230kV	No
Mirasol – Midway 230kV	Line	PSCo	478	370.5	77.5%	575.5	120.4%	42.9%	Comanche – MidwayPS 230kV	No
Midway 230kV bus tie	Line	PSCo / WAPA	576	570.2	99%	894.5	155.3%	56.3%	MidwayPS – Fuller 230kV	Yes
Midway 345/230kV	Xfmr	PSCo	560	498.4	89%	767.2	137%	48%	Daniels Park – Fuller 230kV	Yes
Palmer Lake – Monument 115kV	Line	PSCo / CSU	151	121.1	80.2%	204.9	135.7%	55.5%	Daniels Park – Fuller 230kV	Yes
Portland – Skala 115kV	Line	BHE	120	98.6	82.2%	128.5	107.1%	24.8%	MidwayBR – West Canyon 230kV	Yes
Pueblo Plant – Reader 115kV	Line	BHE	160	126.7	79.2%	193.6	121%	41.8%	Greenhorn – Reader 115kV	Yes
Waterton 345/230kV	Xfmr	PSCo	560	498.4	89%	767.2	137%	48%	Daniels Park – Fuller 230kV	Yes
West canyon 230/115kV	Xfmr	BHE	100	94.9	94.9%	139.5	139.5%	44.6%	MidwayBR – West Canyon 230kV	Yes
Daniels Park – Tundra 345kV	Line	PSCo	1195	719.4	60.2%	1309.7	109.6%	49.4%	Daniels Park – Fuller 230kV	Yes
Daniels Park – Comanche 345kV	Line	PSCo	1195	730.1	61.1%	1242.8	104%	42.9%	Daniels Park – Fuller 230kV	Yes
Vollmer – Black Squirrel MV 115kV	Line	TSGT	173	166.9	96.5%	238.9	138.1%	41.6%	Daniels Park – Fuller 230kV	Yes
Vollmer – Fuller 1151kV	Line	TSGT	173	166.9	96.5%	238.9	138.1%	41.6%	Daniels Park – Fuller 230kV	Yes
Kelker - Templeton 115kV	Line	CSU	131	118.0	90.1%	139.9	106.8%	16.7%	Kelker W – Rock Island 115kV	Yes
MidwayBR – RD_Nixon 230kV	Line	CSU	531	336.6	63.4%	533.6	100.5%	37.1%	Midway – Fuller 230kV	Yes
Monument – Gresham 115kV	Line	TSGT	145	129.3	89.2%	200.2	138.1%	48.9%	Daniels Park – Fuller 230kV	Yes

Gresham – Black Forest Tap 115kV	Line	TSGT	173	132.9	76.8%	204.1	118%	41.2%	Daniels Park – Fuller 230kV	Yes
Black Forest Tap – Black Squirrel MV 115kV	Line	TSGT	143	138.1	96.6%	209.5	146.5%	49.9%	Daniels Park – Fuller 230kV	Yes
Fuller 230/115kV # 1	Xfmr	TSGT	100	81.9	81.9%	106.8	106.8%	24.9%	Daniels Park – Fuller 230kV	Yes
Fuller 230/115kV # 2	Xfmr	TSGT	100	81.9	81.9%	106.8	106.8%	24.9%	Daniels Park – Fuller 230kV	Yes
Boone – GI-2020-3 POI	Line	PSCo	318.7	NA	NA	331.8	104.1%	NA	Mirasol – Midway 230kV	Yes

Except the two overloads shown below, the OPF identified redispatch scenarios that mitigated the overloads, so the mitigated overloads are not assigned to the ERIS GIRs.

- Comanche – GI-2014-9 230kV line for the loss of Mirasol – Midway 230kV line
- Mirasol – Midway 230kV line for the loss of Comanche – Midway 230kV line

The following alternatives were considered to mitigate the overloads

Alternative 1 – Tap the Comanche – MidwayPS 230kV line at the Mirasol 230kV Station. This alternative mitigated the two overloads and did not cause any new overloads. This is the preferred alternative.

Alternative 2 – Add a 230/345kV, 560MVA transformer at the Mirasol station connecting the 230kV and 345kV stations. This alternative did not resolve the overloads and also caused several new overloads. Hence it is considered ineffective.

The maximum output of the ERIS GIRs that can be accommodated before the identified Network Upgrade is as follows:

- ERIS of GI-2020-1 is 170MW
- ERIS of GI-2020-3 is 170MW
- ERIS of GI-2020-4 is 85MW
- ERIS of GI-2020-7 is 1000MW

The Alternative 1 Network Upgrade is modeled in the NRIS Study Case to perform transient stability analysis. The transient stability analysis was performed for the faults shown in Table 3, for the NRIS Study Case. The NRIS Study Case is modified to implement the OPF for the ERIS Study Case. The following results were obtained for the disturbances analysed:

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

Table 3 - Transient Stability Analysis – NRIS Study Case and ERIS Study Case - Southern Colorado Study Pocket

#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
NRIS						
1	Boone 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Stable	Stable
2	Boone 230kV	3ph	Boone – Comanche 230kV	5.0	Stable	Stable
3	Boone 230kV	3ph	Boone – Midway 230kV	5.0	Stable	Stable
4	Comanche 345 kV	3ph	Comanche#3 generator	4.0	Stable	Stable
5	Lamar 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Stable	Stable
6	MidwayPS 230kV	3ph	All Fountain Valley gas units	5.0	Stable	Stable
7	MidwayPS 230kV	3ph	Lose MidwayPS-Fuller breaker	5.0	Stable	Stable
8	MidwayPS 345kV	3ph	MidwayPS – Waterton 345kV line & Midway 230/345kV xfmr	4.0	Stable	Stable
ERIS						
1	Boone 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Stable	Stable

2	Boone 230kV	3ph	Boone – GI-2020-3 230kV	5.0	Stable	Stable
2	Boone 230kV	3ph	Comanche – GI-2020-3 230kV	5.0	Stable	Stable

6.1.1 Affected Systems

There are no impacts to Affected System identified in the Southern Colorado study pocket analysis.

6.1.2 Short Circuit Analysis

The short-circuit fault current values and Thevenin equivalent impedances at the POI are shown in Tables 3.

Table 3 – Short Circuit Parameters at Mirasol 230kV POI (p.u. values on 100MVA Base)

	Before the Southern Colorado GIR additions	After Southern Colorado GIR additions
Three Phase		
Three Phase Current	11796A	19068 A
Positive Sequence Impedance	0.00238+j0.02125 p.u.	0.00108+j0.01422 p.u.
Negative Sequence Impedance	0.00240+j0.02127 p.u.	0.00110+j0.01424 p.u.
Zero Sequence Impedance	0.01101+j0.04003 p.u.	0.00147+j0.01278 p.u.
Phase-to-Ground		
Single Line to Ground Current	9003A	19626A
Positive Sequence Impedance	0.00238+j0.02125 p.u.	0.00134+j0.01407 p.u.
Negative Sequence Impedance	0.00240+j0.02127 p.u.	0.00135+j0.01409 p.u.
Zero Sequence Impedance	0.01101+j0.04003 p.u.	0.00147+j0.01284 p.u.

Table 4 – Short Circuit Parameters at Mirasol 345kV POI (p.u. values on 100MVA Base)

	Before the Southern Colorado GIR additions	After Southern Colorado GIR additions
Three Phase		
Three Phase Current	11375A	15872 A
Positive Sequence Impedance	0.00116+j0.01493 p.u.	0.00098+j0.01291 p.u.
Negative Sequence Impedance	0.00118+j0.01495 p.u.	0.00100+j0.01292 p.u.
Zero Sequence Impedance	0.3679+j0.3380 p.u.	0.0015+j0.01918 p.u.
Phase-to-Ground		

Single Line to Ground Current	1055A	13130A
Positive Sequence Impedance	0.00177+j0.01462 p.u.	0.00113+j0.01037 p.u.
Negative Sequence Impedance	0.00179+j0.01464 p.u.	0.00115+j0.01038 p.u.
Zero Sequence Impedance	0.3679+j0.3380 p.u.	0.0015+j0.01918 p.u.

Table 5 – Short Circuit Parameters at GI-2020-3 POI (p.u. values on 100MVA Base)

	Before the Southern Colorado GIR additions	**After Southern Colorado GIR additions**
Three Phase		
Three Phase Current	10413 A	10822 A
Positive Sequence Impedance	0.00262+j0.02407 p.u.	0.00256+j0.02364 p.u.
Negative Sequence Impedance	0.00266+j0.02408 p.u.	0.00260+j0.02365 p.u.
Zero Sequence Impedance	0.00762+j0.03808 p.u.	0.00312+j0.02333 p.u.
Phase-to-Ground		
Single Line to Ground Current	8673A	11157A
Positive Sequence Impedance	0.00262+j0.02407 p.u.	0.00256+j0.02364 p.u.
Negative Sequence Impedance	0.00266+j0.02408 p.u.	0.00260+j0.02365 p.u.
Zero Sequence Impedance	0.00762+j0.03808 p.u.	0.00312+j0.02333 p.u.

Table 6 – Short Circuit Parameters for GI-2020-10, at GI-2014-9 POI (p.u. values on 100MVA Base)

	Before the Southern Colorado GIR additions	**After Southern Colorado GIR additions**
Three Phase		
Three Phase Current	16260 A	20378 A
Positive Sequence Impedance	0.00148+j0.01546 p.u.	0.00121+j0.01304 p.u.
Negative Sequence Impedance	0.00151+j0.01549 p.u.	0.00123+j0.01306 p.u.
Zero Sequence Impedance	0.0062+j0.02350 p.u.	0.00212+j0.01198 p.u.
Phase-to-Ground		
Single Line to Ground Current	13771A	21355A
Positive Sequence Impedance	0.00170+j0.01531 p.u.	0.00138+j0.01292 p.u.
Negative Sequence Impedance	0.00172+j0.01533 p.u.	0.00140+j0.01294 p.u.
Zero Sequence Impedance	0.0062+j0.02350 p.u.	0.00212+j0.01198 p.u.

A breaker duty study for all seven (7) GIRs in the Cluster identified several circuit breakers that became over-dutied"[3]. The over-dutied circuit breakers and the cost allocation to each GIR is as shown in Table 7. Since GI-2020-05 is an incremental capacity increase in the output of the existing Fort Saint Vrain #4 generator with no anticipated changes to the electrical generator set, there is no fault current contribution from this GIR over the base case, so there is no cost allocated to this GI-2020-05.

Table 7 - Cost Allocation of Overstressed Breakers

SUBSTATION	BASE KV	BREAKER NAME	GI-2020-1	GI-2020-3	GI-2020-4	GI-2020-6	GI-2020-7	GI-2020-10
COMANCHE (PSCO)	230	5400	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5401	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5402	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5403	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5405	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5406	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5407	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5409	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5410	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5411	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5415	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5417	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5419	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5418	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
COMANCHE (PSCO)	230	5404	10.0%	11.5%	5.3%	0.2%	56.3%	16.7%
DANIELS PARK (PSCO)	230	5100	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5103	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5107	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5110	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%

[3] "Over-dutied" circuit breaker: A circuit breaker whose short circuit current (SCC) rating is less than the available SCC at the bus.

SUBSTATION	BASE KV	BREAKER NAME	GI-2020-1	GI-2020-3	GI-2020-4	GI-2020-6	GI-2020-7	GI-2020-10
DANIELS PARK (PSCO)	230	5111	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5112	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5115	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5113	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5707	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5104	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%
DANIELS PARK (PSCO)	230	5116	7.0%	7.6%	3.9%	25.7%	52.9%	2.9%

6.1.3 Summary of Southern Study Pocket Analysis

The maximum output of GI-2020-1 before Network Upgrades is 175MW

ERIS identified for GI-2020-1 is 199MW.

The maximum output of GI-2020-3 before Network Upgrades is 175MW

ERIS identified for GI-2020-3 is 199MW.

The maximum output of GI-2020-4 before Network Upgrades is 85MW

ERIS identified for GI-2020-4 is 100MW.

The maximum output of GI-2020-7 before Network Upgrades is 1000MW

ERIS identified for GI-2020-7 is 1000MW.

The NRIS identified for GI-2020-10 is 230MW

There are no Affected System impacts.

6.2 Eastern Study Pocket Analysis

The Phase 1 steady state analysis did not identify any overloads attributable to GI-2020-6. The transient stability analysis was performed for the faults shown in Table 8, for the NRIS Study Case. The following results were obtained for the disturbances analyzed:

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

Table 8- Transient Stability Analysis – NRIS Study Case - Eastern Colorado Study Pocket

#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Pawnee 345kV	3ph	Pawnee – Missile 345kV #1	4.0	Stable	Stable
2	Missile345kV	3ph	Missile – Smoky Hill 345kV #1	4.0	Stable	Stable
3	Missile345kV	3ph	Missile – Daniels park 345kV #1	4.0	Stable	Stable
4	Missile345kV	3ph	Missile 345/230kV Transformer	4.0	Stable	Stable
5	Pawnee 230kV	3ph	Loss of Pawnee generation	4.0	Stable	Stable
6	Pawnee 345kV	3ph	Pawnee – Missile # 1 & # 2 345kV	4.0	Stable	Stable
7	Missile345kV	3ph	Missile – Smoky and Missile – Daniels Park 345kV	4.0	Stable	Stable

6.2.1 Short Circuit Analysis

The short-circuit fault current values and Thevenin equivalent impedances at the GI-2020-06 POI are shown in Tables 9.

Table 9 – Short Circuit Parameters at GI-2020-06 POI (p.u. values on 100MVA Base)

	Before the Eastern Colorado GIR addition	After Eastern Colorado GIR addition
Three Phase		
Three Phase Current	12381A	12387 A
Positive Sequence Impedance	0.00184+j0.02047 p.u.	0.00202+j0.01626 p.u.
Negative Sequence Impedance	0.00190+j0.02047 p.u.	0.00189+j0.02043 p.u.
Zero Sequence Impedance	0.01022+j0.04256 p.u.	0.00183+j0.02043 p.u.
Phase-to-Ground		
Single Line to Ground Current	9062A	13892A
Positive Sequence Impedance	0.00184+j0.02047 p.u.	0.00202+j0.01626 p.u.
Negative Sequence Impedance	0.00190+j0.02047 p.u.	0.00189+j0.02043 p.u.
Zero Sequence Impedance	0.01022+j0.04255 p.u.	0.00183+j0.02043 p.u.

A breaker duty study for all seven (7) GIRs in the Cluster identified several circuit breakers that became over-dutied"[4]. The over-dutied circuit breakers and the cost allocation to each GIR is as shown in Table 7.

6.2.2 Affected Systems

There are no Affected System impacts identified in the Eastern study pocket analysis.

6.2.3 Summary of Eastern Study Pocket Analysis

The NRIS identified for GI-2020-6 is 199MW.

6.3 Northern Study Pocket Analysis

The Phase 1 steady state analysis did not identify any overloads attributable to GI-2020-6 and the maximum allowable output of GI-2020-6 is the 24MW, the ERIS requested.

The transient stability analysis was performed for the faults shown in Table 10. The following results were obtained for the disturbances analyzed:

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

Table 10- Transient Stability Analysis – ERIS Study Case Northern Colorado Study Pocket

#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Fort Saint Vrain #2 gen	3ph	Fort Saint Vrain #2 and half of Fort Saint Vrain#1	5.0	Stable	Stable
2	Fort Saint Vrain #3 gen	3ph	Fort Saint Vrain #3 and half of Fort Saint Vrain#1	5.0	Stable	Stable
3	Fort Saint Vrain 230kV Bus	3ph	Fort Lupton – Fort Saint Vrain #1 & #2	5.0	Stable	Stable
4	RMEC 230kV	3ph	All RMEC generators	5.0	Stable	Stable

[4] "Over-dutied" circuit breaker: A circuit breaker whose short circuit current (SCC) rating is less than the available SCC at the bus.

6.3.1 Short Circuit Analysis

Since the GI-2020-05 is an incremental capacity increase in the output of the existing Fort Saint Vrain#4 generator with no anticipated changes to the electrical generator set. There is no fault current contribution from this GI over the base case.

6.3.2 Affected Systems

There are no Affected System impacts identified in the Northern study pocket analysis.

6.3.3 Summary of Northern Study Pocket Analysis

The maximum allowable output of GI-2020-5 before Network Upgrades is 24MW

ERIS identified for GI-2020-5 is 24MW.

7.0 Generation Interconnection Service Cost Estimates and Assumptions

There are three types of costs identified in the study

- Transmission Provider's Interconnection Facilities 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 other Network Upgrades which are allocated by the proportional impact per Section 4.2.4(b) of the LGIP.

The total costs of Network Upgrades assigned under Sections 4.2.4(a) and 4.2.4(b) are given below

7.1 Total Costs of Network Upgrades

The estimated total cost of the station equipment Network Upgrades for Interconnection, by each POI are shown in Table 11.

Table 11 – Total cost of Station Network Upgrades by POI

POI	Total Cost	GIRs Sharing the POI
Mirasol 230kV Station	$42.848 Million	GI-2020-1 and GI-2020-4
Mirasol 345kV Station	$42.848 Million	GI-2020-7
GI-2020-3 230kV Switching Station	$17.182 Million	GI-2020-3
GI-2020-6 230kV Switching Station	$16.977 Million	GI-2020-6
Existing Fort Saint Vrain4	0	GI-2020-5

Breaker addition at GI-2014-9 230kV Switching Station	$2.229 Million	GI-2020-10

The estimated total cost and details of the station Network Upgrades required for the Mirasol 230kV Station POI are shown in Table 12. These Station Network Upgrade costs are shared by GI-2020-1 and GI-2020-4 on a per-capita basis, as shown in Table 18.

Table 12 –Station Network Upgrades - Mirasol 230kV Station

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 230kV Station	Install a new 230kV station on the 230kV Comanche - GI-2014-9 - Midway line. The new equipment includes: • (3) 230kV 3000A circuit breakers • (8) 230kV 3000A disconnect switches • (6) 230kV Surge Arresters • (10) 230kV Deadends • (2) Electrical Equipment Enclosure • (4) Line Traps • Station controls and wiring • Associated foundations and structures	$18.185
PSCo's Mirasol 230kV Station	Install required communication in the EEE's at the Mirasol switching station	$0.559
PSCo's Midway 230kVSubstation	Update primary and secondary line relaying and associated breaker fail on two 230kV lines to Mirasol	$0.608
PSCo's Comanche 230kV Bus	Update primary and secondary line relaying and associated breaker fail on two 230kV lines at Comanche	$0.761
PSCo's Mirasol 230kV Station	Reterminate the transmission line into the new switching station	$0.225
PSCo's Mirasol 230kV Station	Sighting & Land Rights support for substation construction	$0.225
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$20.563**
Time Frame	**Site, design, procure and construct**	**36 Months***

*Construction of the Mirasol 230kV Station requires a CPCN from the Colorado Public Utilities Commission. It is expected that the CPCN proceedings may take up to 18 months. The construction timeframe following the CPCN approval is estimated to take up to 18 months, so the total time required to site, design, procure and construct the Mirasol 230kV Station is expected to take up to 36 months.

The estimated total cost and details of the station Network Upgrades required for the Mirasol 345kV Station POI are shown in Table 13. These Station Network Upgrade costs are 100% assigned to GI-2020-7, as shown in Table 19.

Table 13 –Station Network Upgrades - Mirasol 345kV Station

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 345kV Station	Install a new 345kV Station on the 345 kV Comanche – Tundra line. The new equipment includes: • (3) 345kV 3000A circuit breakers • (8) 345kV 3000A disconnect switches • (6) 345kV Surge Arresters • (3) 345kV Deadends • (2) Electrical Equipment Enclosure • (4) Line Traps • Station controls and wiring • Associated foundations and structures	$21.834
PSCo's Mirasol 345kV Station	Install required communication in the EEE's at the Mirasol switching station	$0.481
PSCo's Comanche 345kV Substation	Update primary and secondary line relaying and associated breaker fail on two 345kV lines at Comanche	$0.837
PSCo's Tundra 345kV Station	Update primary and secondary line relaying and associated breaker fail on two 345kV lines at Tundra	$0.568
PSCo's Mirasol 345kV Station	Reterminate the transmission line into the new switching station	$0.225
PSCo's Mirasol 345kV Station	Sighting & Land Rights support for substation construction	$0.279
	Total Cost Estimate for PSCo-Funded, PSCo-Owned Interconnection Facilities	**$24.224**
Time Frame	**Site, design, procure and construct**	**36 Months***

*Construction of the Mirasol 345kV Station requires a CPCN from the Colorado Public Utilities Commission. It is expected that the CPCN proceedings may take up to 18 months. The construction timeframe following the CPCN approval is estimated to take up to 18 months, so the total time required to site, design, procure and construct the Mirasol 345kV Station is expected to take up to 36 months

The estimated total cost and details of the station Network Upgrades required at the GI-2020-3 230kV Switching Station are shown in Table 14. These Station Network Upgrade costs are 100% assigned to GI-2020-3, as shown in Table 20.

Table 14 –Station Network Upgrades – GI-2020-3 230kV Switching Station

Element	Description	Cost Est. (Millions)

PSCo's New GI-2020-3 230kV Switching Station	Install a new 230kV substation on the Boone-Comanche line. The new equipment includes: • (3) 230kV 3000A circuit breakers • (8) 230kV 3000A disconnect switches • (6) 230kV CCVTs • (6) 230kV Surge Arresters • (1) 230kV Deadends • (1) Electrical Equipment Enclosure • (2) Line Traps • Station controls and wiring • Associated foundations and structures	$16.015
PSCo's New GI-2020-3 230kV Switching Station	Install required communication in the EEE's at the switching station	$0.449
PSCo's New GI-2020-3 230kV Switching Station	Land acquisition & permitting	$0.163
PSCo's New GI-2020-3 230kV Switching Station	T-line taps into substation	$0.801
PSC0's Boone Substation	Boone-230kV 5415 Line Terminal Upgrade	$0.970
PSCo's Comanche Substation	Comanche-230kV 5415 Line Terminal Upgrade	$1.018
	Total Cost Estimate for PSCo-Funded Network Upgrades for Delivery	**$19.416**
Time Frame	**Site, design, procure and construct**	**36 Months****

**Construction of the GI-2020-3 230kV Switching Station requires a CPCN from the Colorado Public Utilities Commission. It is expected that the CPCN proceedings may take up to 18 months. The construction timeframe following CPCN approval is estimated to be 18 months, so the total time required to site, design, procure and construct the GI-2020-3 230kV Switching Station is expected to take up to 36 months

The estimated total cost and details of the station Network Upgrades required at the GI-2020-6 230kV Switching Station are shown in Table 15. These Station Network Upgrade costs 100% assigned to GI-2020-6, as shown in Table 21.

Table 15 –Station Network Upgrades – GI-2020-6 230kV Switching Station

Element	**Description**	**Cost Est. (Millions)**

PSCo's New GI-2020-6 230kV Switching Station	Install a new 230kV switching station on the Pawnee-Missile line. The new equipment includes: • (3) 230kV 3000A circuit breakers • (8) 230kV 3000A disconnect switches • (6) 230kV CCVTs • (6) 230kV Surge Arresters • (1) 230kV Deadends • (1) Electrical Equipment Enclosure • (2) Line Traps • Station controls and wiring • Associated foundations and structures	$17.151
PSCo's New GI-2020-6 230kV Switching Station	T-line taps into substation	$0.802
PSCo's New GI-2020-6 230kV Switching Station	Land acquisition & permitting	$0.163
PSC0's Pawnee Substation	Pawnee-230kV 5457 Line Terminal Upgrade	$0.352
PSCo's Missile Substation	Missile-230kV 5457 Line Terminal Upgrade	$0.326
	Total Cost Estimate for PSCo-Funded Network Upgrades for Delivery	**$18.794**
Time Frame	**Site, design, procure and construct**	**36 Months*** **

***Construction of the GI-2020-6 230kV Switching Station requires a CPCN from the Colorado Public Utilities Commission. It is expected that the CPCN proceedings may take up to 18 months. The construction timeframe following CPCN approval is estimated to be 18 months, so the total time required to site, design, procure and construct the GI-2020-6 230kV Switching Station is expected to take up to 36 months.

The estimated total cost and details of the station Network Upgrades required at the GI-2014-9 230kV Switching Station to accommodate interconnection of GI-2020-10 are shown in Table 16. These Station Network Upgrade costs are 100% assigned to GI-2020-10, as shown in Table 22.

Table 16 –Station Network Upgrades – Expansion of GI-2014-9 Switching Station

Element	Description	Cost Est. (Millions)
PSCo's GI-2014-9 New 230kV Substation	Expand GI-2014-9 POI to interconnect GI-2020-10. The new equipment includes: •One 230kV circuit breaker •Two 230kV gang switches •Associated communications, supervisory and SCADA equipment •Associated line relaying, station controls and testing •Associated bus, miscellaneous electrical equipment, cabling and wiring •Associated foundations and structures •Associated road and site development, fencing and grounding	$1.098

	Total Cost Estimate for PSCo-Funded Network Upgrades for Delivery	**$1.098**
Time Frame	**Site, design, procure and construct**	**36 Months**

The estimated total cost and details of the Network Upgrades and GIRs sharing the cost are shown in Table 17.

Table 17 – Total cost of Network Upgrades

Network Upgrade	Description	Total Cost	GIRs Sharing the Network Upgrade Cost
Tap Comanche – Midway 230kV line at Mirasol 230kV Station	Tap Comanche – Midway 230kV (L5413) at Mirasol 230kV Switching Station. Total time to site, design, procure and construct is 36 months	$8.360 Million	GI-2020-1, GI-2020-3 and GI-2020-4
Total cost of Daniels Park Breaker Upgrades (see Table 7)	Replace eleven (11) 230kV Circuit Breakers identified as Overstressed due to the Cluster addition. Total time to site, design, procure and construct is 36 months	$9.680 Million	GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-6, GI-2020-7 and GI-2020-10
Total cost of Comanche Breaker Upgrades (see Table 7)	Replace fifteen (15) 230kV Circuit Breakers identified as Overstressed due to the Cluster addition. Total time to site, design, procure and construct is 36 months	$13.2 Million	GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-6, GI-2020-7 and GI-2020-10

7.2 Cost Estimates of Station and Other Network Upgrades by GIR

Table 18 – Allocation of Mirasol 230 Switching Station Costs by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 12)
GI-2020-1	199MW	50%	$10.2815 Million
GI-2020-4	100MW	50%	$10.2815 Million

Table 19 – Allocation of Mirasol 345kV Switching Station Costs by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 13)
GI-2020-7	1000MW	100%	$24.224 Million

Table 20 – Allocation of GI-2020-3 230kV Switching Station Costs by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 14)
GI-2020-3	199MW	100%	$19.416 Million

Table 21 – Allocation of GI-2020-6 230kV Switching Station Costs by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 15)
GI-2020-6	199MW	100%	$18.794 Million

Table 32 – Allocation of GI-2020-10 breaker addition Costs by GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 16)
GI-2020-10	230MW	100%	$1.098 Million

Table 23 – Allocation of Cost of Other Network Upgrades

Network Upgrade	GIR	GIR MW	% Share per Section 4.2.4(b) of Attachment N	Costs allocated to GIR (% share x total costs from Table 17)
Tap Comanche – Midway 230kV at Mirasol 230kV Station	GI-2020-1	199MW	40%	$3.344 Million
	GI-2020-3	199MW	40%	$3.344 Million
	GI-2020-4	100MW	20%	$1.672 Million
Comanche 230kV Breaker Replacements	GI-2020-1	199MW	10%	$1.32 Million
	GI-2020-3	199MW	11.5%	$1.518 Million
	GI-2020-4	100MW	5.3%	$0.7 Million
	GI-2020-6	199MW	0.2%	$0.026 Million
	GI-2020-7	1000MW	56.3%	$7.432 Million
	GI-2020-10	230MW	16.7%	$2.204 Million
Daniels Park 230kV Breaker Replacements	GI-2020-1	199MW	7.0%	$0.677 Million
	GI-2020-3	199MW	7.6%	$0.736 Million
	GI-2020-4	100MW	3.9%	$0.377 Million
	GI-2020-6	199MW	25.7%	$2.488 Million
	GI-2020-7	1000MW	52.9%	$5.121 Million
	GI-2020-10	230MW	2.9%	$0.281 Million

7.2.1 Summary of Transmission Provider's Interconnection Facilities and Network Upgrades Costs assigned to GI-2020-1

The total cost of the required Upgrades to connect GI-2020-1 at the Mirasol 230kV Switching Station is **$17.014 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.391 Million (Table 24)**
- **The cost of Station Network Upgrades is $10.2815 Million (Table 18)**
- **The cost of other Network Upgrades is $5.341 Million (Table 23)**

Figure 2 is a conceptual one-line of the GI-2020-1 POI at the Mirasol 230kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-1, the Customer's 199MW Solar PV Generating Facility are given in Tables 18, 23 and 24. A CPCN will be required to build the Mirasol 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 24 – GI-2020-1 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 230kV Switching Station	Interconnection Customer to tap at the Mirasol 230kV Switching Station. The new equipment includes: • (1) 230kV deadend/girder • (3) 230kV Surge Arresters • (1) 230kV 3000A disconnect switch • (1) 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.	$1.316
PSCo's Mirasol 230kV Switching Station	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's Mirasol 230kV Switching Station	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.391**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.2 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-3

The total cost of the required Upgrades for GI-2020-3 to interconnect at the GI-2020-3 230kV Switching Station is **$26.568 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.554 Million (Table 25)**
- **The cost of Station Network Upgrades is $19.416 Million (Table 20)**
- **The cost of other Network Upgrades is $5.598 Million (Table 23)**

Figure 3 is a conceptual one-line of the GI-2020-3 230kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-3, the Customer's 199MW Solar PV Generating Facility are given in Tables 20, 23 and 25. A CPCN will be required to build the GI-2020-3 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 25 – GI-2020-3 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-3 230kV Switching Station	Interconnection Customer to tap at the Boone-Comanche 230kV line. The new equipment includes: • (1) 230kV deadend/girder • (3) 230kV Surge Arresters • (1) 230kV 3000A disconnect switch • (1) 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.	$1.479
PSCo's GI-2020-3 230kV Switching Station	Transmission line legs into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's GI-2020-3 230kV Switching Station	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.554**

Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.3 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-4

The total cost of the required Upgrades for GI-2020-4 to interconnect at the Mirasol 230kV Station is **$16.0375 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.335 Million (See Table 26)**
- **The cost of Station Network Upgrades is $10.2815 Million (Table 18)**
- **The cost of other Network Upgrades is $4.421 Million (Table 23)**

Figure 2 is a conceptual one-line of the GI-2020-4 POI at the Mirasol 230kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-4, the Customer's 100MW Solar PV Generating Facility are given in Tables 18, 23 and 26. A CPCN will be required to build the Mirasol 230kV Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 26 – GI-2020-4 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 230kV Switching Station	Interconnection Customer to tap at the Mirasol 230kV Switching Station. The new equipment includes: • (1) 230kV deadend/girder • (3) 230kV Surge Arresters • (1) 230kV 3000A disconnect switch • (1) 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.	$1.260
PSCo's Mirasol 230kV Switching Station	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's Mirasol 230kV Switching Station	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.335**

Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.4 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-5

The total cost of the upgrades required to accommodate the expansion of GI-2020-5 at the Fort Saint Vrain # 4 generator is **$50,000.**

- **The cost of Transmission Provider's Interconnection Facilities is $50,000 (Table 27)**

The list of improvements required to accommodate the GI-2020-5, the Customer's 24MW incremental output at Fort Saint Vrain#4 are given in Table 27.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 27 - GI-2020-05 Transmission Provider's Intrconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's FSV Unit #4	Confirmation testing of incremental increase in generation output due to an plant equipment upgrade	$0.050
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$0.050**
Time Frame	**Site, design, procure and construct**	**12 Months**

7.2.5 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-6

The total cost of the required Upgrades for GI-2020-6 to interconnect at the GI-2020-6 230kV switching station tapping the Pawnee – Missile 230kV line is **$22.569 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.261 Million (Table 28)**
- **The cost of Station Network Upgrades is $18.794 Million (Table 21)**
- **The cost of other Network Upgrades is $2.514 Million (Table 23)**

Figure 4 is a conceptual one-line of the GI-2020-6 230kV Switching Station.

The list of improvements required to accommodate the interconnection of GI-2020-6, the Customer's 199MW Solar PV Generating Facility are given in Tables 21, 23 and 28. A CPCN will be required to build the GI-2020-6 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and

construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 28 – GI-2020-6 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2020-6 New 230kV Switching Station	Interconnection Customer to tap at the Pawnee-Missile 230kV line. The new equipment includes: • (1) 230kV deadend/girder • (3) 230kV Surge Arresters • (1) 230kV 3000A disconnect switch • (1) 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.	$1.186
PSCo's GI-2020-6 New 230kV Switching Station	Transmission line legs into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's GI-2020-6 New 230kV Switching Station	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.261**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.6 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-7

The total cost of the required Upgrades for GI-2020-7 to interconnect at the Mirasol 230/345kV Substation is **$38.475 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.718 Million (Table 29)**
- **The cost of Station Network Upgrades is $24.224 Million (Table 19)**
- **The cost of other Network Upgrades is $12.533 Million (Table 23)**

The list of improvements required to accommodate the interconnection of GI-2020-7, the Customer's 1000MW Wind plus Solar PV hybrid Generating Facility are given in Tables 19, 23 and 29. A CPCN will be required to build the Mirasol 345kV Switching Station to accommodate

the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 29 – GI-2020-7 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Mirasol 345kV Switching Station	Interconnection Customer to tap at the Mirasol 345kV Switching Station.The new equipment includes: • (1) 345kV deadend/girder • (3) 345kV Surge Arresters • (1)345kV 3000A disconnect switch • (1) 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.	$1.643
PSCo's Mirasol 345kV Switching Station	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's Mirasol 345kV Switching Station	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.718**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.7 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2020-10

The total cost of the required Upgrades for GI-2020-10 to interconnect at the GI-2014-9 230kV Switching Station is **$5.009 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.426 Million (Table 30)**
- **The cost of Station Network Upgrades is $1.098 Million (Table 22)**
- **The cost of other Network Upgrades is $2.485 Million (Table 23)**

The list of improvements required to accommodate the interconnection of GI-2020-10, the Customer's 230MW Solar PV and BES Hybrid Generating Facility are given in Tables 22, 23 and 30.

System improvements are subject to revision as a more detailed and refined design is produced.

Table 30 – GI-2020-10 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's GI-2014-9 POI expansion	Expand GI-2014-9 POI to interconnect GI-2020-10. The new equipment includes: • (1) 230kV deadend/girder • (3) 230kV Surge Arresters • (1) 230kV 3000A disconnect switch • (1) 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.	$1.351
PSCo's GI-2014-9 POI expansion	Transmission line tap into substation. Three spans, structures, conductor insulators, hardware and labor.	$0.055
PSCo's GI-2014-9 POI expansion	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Interconnection Customer-Funded, PSCo-Owned Interconnection Facilities	**$1.426**
Time Frame	**Site, design, procure and construct**	**36 Months**

8.0 Summary of Generation Interconnection Service

This report only evaluated Interconnection Service of GIRs in DISIS-2020-001 and Interconnection Service in and itself does not convey transmission service.

8.1 Cost Estimate Assumptions

The PSCo Engineering has developed indicative level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the DISIS-2020-001 Cluster. The cost estimates are in 2021 dollars with escalation and contingencies applied. Allowances for Funds Used During Construction (AFUDC) is not included. These estimated costs include all applicable labor and overheads associated with the siting, engineering, design, and construction of these new PSCo facilities. This estimate does not include the cost for any Customer owned equipment and associated design and engineering.

- Labour is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- Except for GI-2020-05, it is expected that a CPCN will be required for the interconnection facilities.

- The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.
- Except for GI-2020-05, the Customer Generating Facilities are not located in PSCo's retail service territory. Therefore, no costs for retail load metering are included in these estimates.
- PSCo (or it's Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- Customer will install two (2) redundant fiber optics circuits into the Transmission provider's substation as part of its interconnection facilities construction scope.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.
- Line outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested backfeed date.
- 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 / Xcel will need indications, readings and data from the LFAGC RTU.

8.2 GI-2020-1

The total estimated cost of the transmission system improvements for GI-2020-1: $17.014 Million (Tables 18, 23 and 24).

The maximum output of GI-2020-1 before Network Upgrades is 175MW

Energy Resource Interconnection Service of GI-2020-1 is: 199MW (after required transmission system improvements in Tables 18, 23 and 24).

Note: A CPCN is needed for the construction of the Mirasol 230kV Station. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2020-1.

GI-2020-1 and GI-2020-4 share the same Mirasol 230kV Station POI.

8.3 GI-2020-3

The total cost of the required Upgrades for GI-2020-3 to interconnect at the GI-2020-3 230kV Switching Station is $26.568 Million (Tables 20, 23 and 25).

The maximum output of GI-2020-3 before Network Upgrades is 175MW

Energy Resource Interconnection Service of GI-2020-3 is: 199MW (after required transmission system improvements in Tables 20, 23 and 25).

Note: A CPCN is needed for the construction of the GI-2020-3 230kV Switching Station. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2020-3.

8.4 GI-2020-4

The total cost of the required Upgrades for GI-2020-4 to interconnect at the Mirasol 230kV Station is $16.0375 Million (Tables 18, 23 and 26).

The maximum output of GI-2020-4 before Network Upgrades is 85MW

Energy Resource Interconnection Service of GI-2020-4 is: 100MW (after required transmission system improvements in Tables 18, 23 and 26).

Note: A CPCN is needed for the construction of the Mirasol 230kV Station. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2020-4.

GI-2020-1 and GI-2020-4 share the same Mirasol 230kV Station POI.

8.5 GI-2020-5

The total estimated cost of the transmission system improvements for GI-2020-5 are: $0.05 Million (Table 27).

The maximum output of GI-2020-4 before Network Upgrades is 24MW

Energy Resource Interconnection Service of GI-2020-5 is: 24MW (after required transmission system improvements in Tables 27).

8.6 GI-2020-6

The total estimated cost of the transmission system improvements for GI-2020-6 are: $22.569 Million (Tables 21, 23 and 28).

Network Resource Interconnection Service of GI-2020-6 is: 199MW (after required transmission system improvements in Tables 21, 23 and 28).

Note: A CPCN will be required to build the GI-2020-6 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.

8.7 GI-2020-7

The total estimated cost of the transmission system improvements for GI-2020-7 are: $38.475 Million (Tables 19, 23 and 29).

The maximum output of GI-2020-7 before Network Upgrades is 1000MW

Energy Resource Interconnection Service of GI-2020-7 is: 1000MW (after required transmission system improvements in Tables 19, 23 and 29).

Note: A CPCN will be required to build the Mirasol 345kV Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained. The output of the hybrid Generating Facility will be limited to 1000MW at the POI using centralized power plant controller. The GIR output will also be monitored by PSCo operations. Additional monitoring and control requirements will be added to the LGIA to ensure the Interconnection Service amount is not exceeded.

8.8 GI-2020-10

The total estimated cost of the transmission system improvements for GI-2020-10 are: $5.009 Million (Tables 22 and 23).

Network Resource Interconnection Service of GI-2020-10 is: 230MW (after required transmission system improvements in Tables 22 and 23).

Note: The output of the hybrid Generating Facility will be limited to 230MW at the POI using centralized power plant controller. The GIR output will also be monitored by PSCo operations.

Additional monitoring and control requirements will be added to the LGIA to ensure the Interconnection Service amount is not exceeded. The construction of the GI-2014-9 230kV Switching Station will require a CPCN and the estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of GI-2020-10.

9.0 Contingent Facilities

GI-2020-5: There are no unbuilt facilities modeled in the Northern Colorado Study Pocket. Also, there are no Interconnection Facilities, Station Upgrades or Network Upgrades identified for GI-2020-5. So, there are no Contingent Facilities identified for GI-2020-5.

GI-2020-6: There are no unbuilt facilities modeled in the Eastern Colorado Study Pocket Interconnection Facilities and Upgrades identified in this report.

GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-7 and GI-2020-10: The Contingent Facilities identified for these GIRs are:

1. The following unbuilt transmission projects modeled in the Base Case are identified as Contingent Facilities to GI-2020-1, GI-2020-3, GI-2020-4, GI-2020-7 and GI-2020-10
    - Monument – Flying Horse 115kV Series Reactor – ISD 2022
    - Upgrade Daniels Park – Priarie1 230kV line to 756MVA – ISD under development
    - Upgrade Greenwood – Priarie1 230kV line to 756MVA – ISD 2021
    - Upgrade Daniels Park – Priarie3 230kV line to 576MVA – ISD under development
    - Upgrade Greenwood – Priarie3 230kV line to 576MVA – ISD 2021
    - Upgrade Midway 230kV bus tie to 576MVA – ISD 2023
    - Upgrade Leetsdale – Monaco 230kV line to 560MVA – ISD 2021
    - Upgrade Greenwood – Monaco 230kV line to 560MVA – ISD 2021
    - Fuller – Vollmer – Black Squirrel 115kV line modeled at 173MVA – ISD 2022
    - Fuller 230/115kV, 100MVA #2 transformer – ISD 2023
    - Burnt Mill – Greenhorn 115kV Rebuild (1/21/2021)
    - Desert Cove - Ftn Valley Rebuild (1/22/2021)
    - Nyberg - Airport Memorial Rebuild (1/22/2021)

- Pueblo West substation (4/13/2021)
- Pueblo Reservoir – Burnt Mill 115kV Rebuild (8/31/2021)
- Boone - South Fowler 115kV Project (10/1/2021)
- North Penrose Substation (January 2022)
- West Station – Pueblo Res 115kV Rebuild (1/31/2022)
- The Cottonwood – Tesla 34.5kV line is modeled open and Kettle Creek – Tesla 34.5kV line is modeled closed on the CSU system – ISD 2023
- Briargate S 115/230kV transformer project tapping the Cottonwood – Fuller 230kV line – ISD 2023

2. Station Network Upgrades identified for the respective GIRs in Section 7 & 8 of this report
3. Other Network Upgrades identified for the respective GIRs in Section 7 & 8 of this report

Figure 2 – Preliminary One-line of the Mirasol 230kV Station showing POIs of GI-2020-1 and GI-2020-4

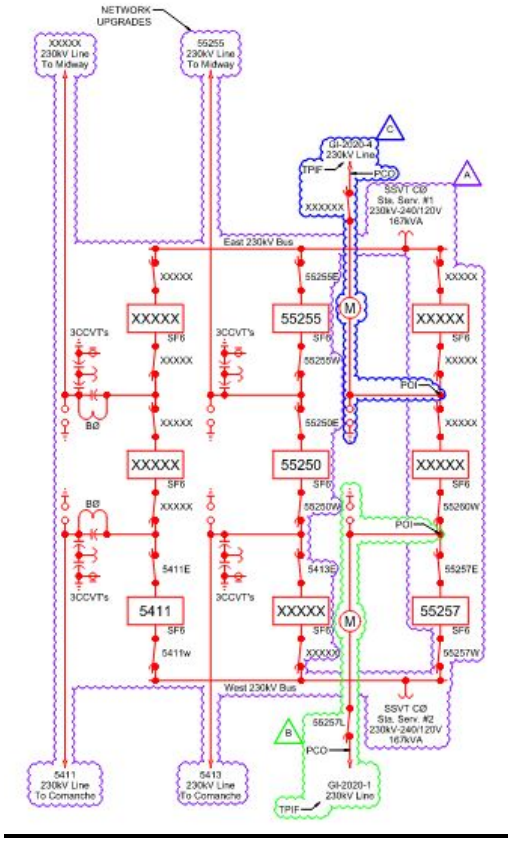


Figure 3 – Preliminary One-line of the Mirasol 345kV Station showing GI-2020-7 POI

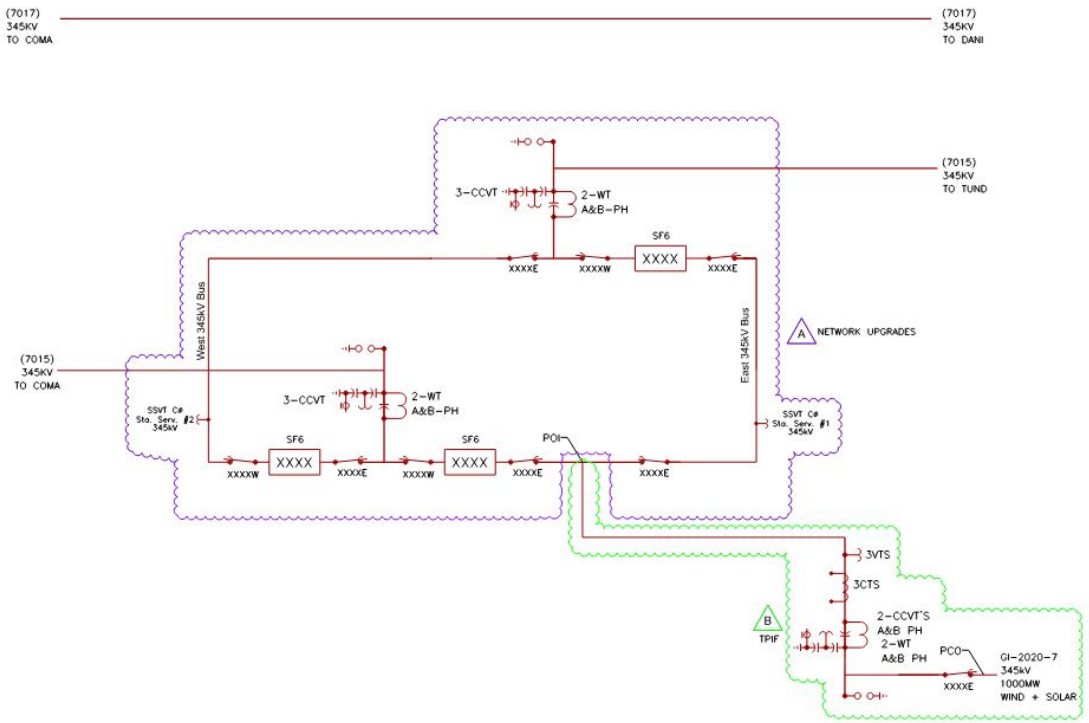


Figure 4 – Preliminary One-line of the GI-2020-3 230kV Switching Station showing GI-2020-3 POI

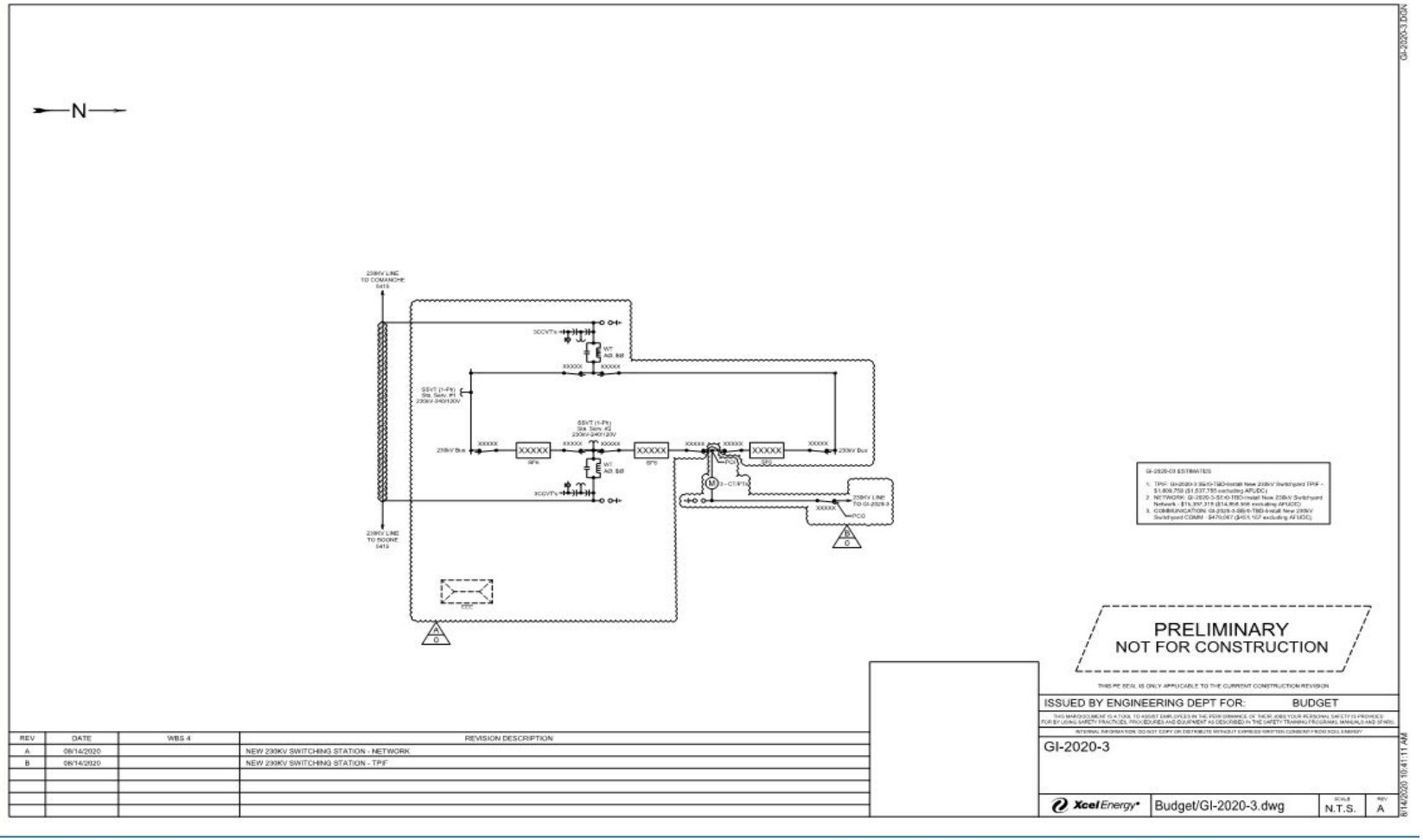


Figure 5 – Preliminary One-line of the GI-2020-6 230kV Switching Station showing GI-2020-6 POI

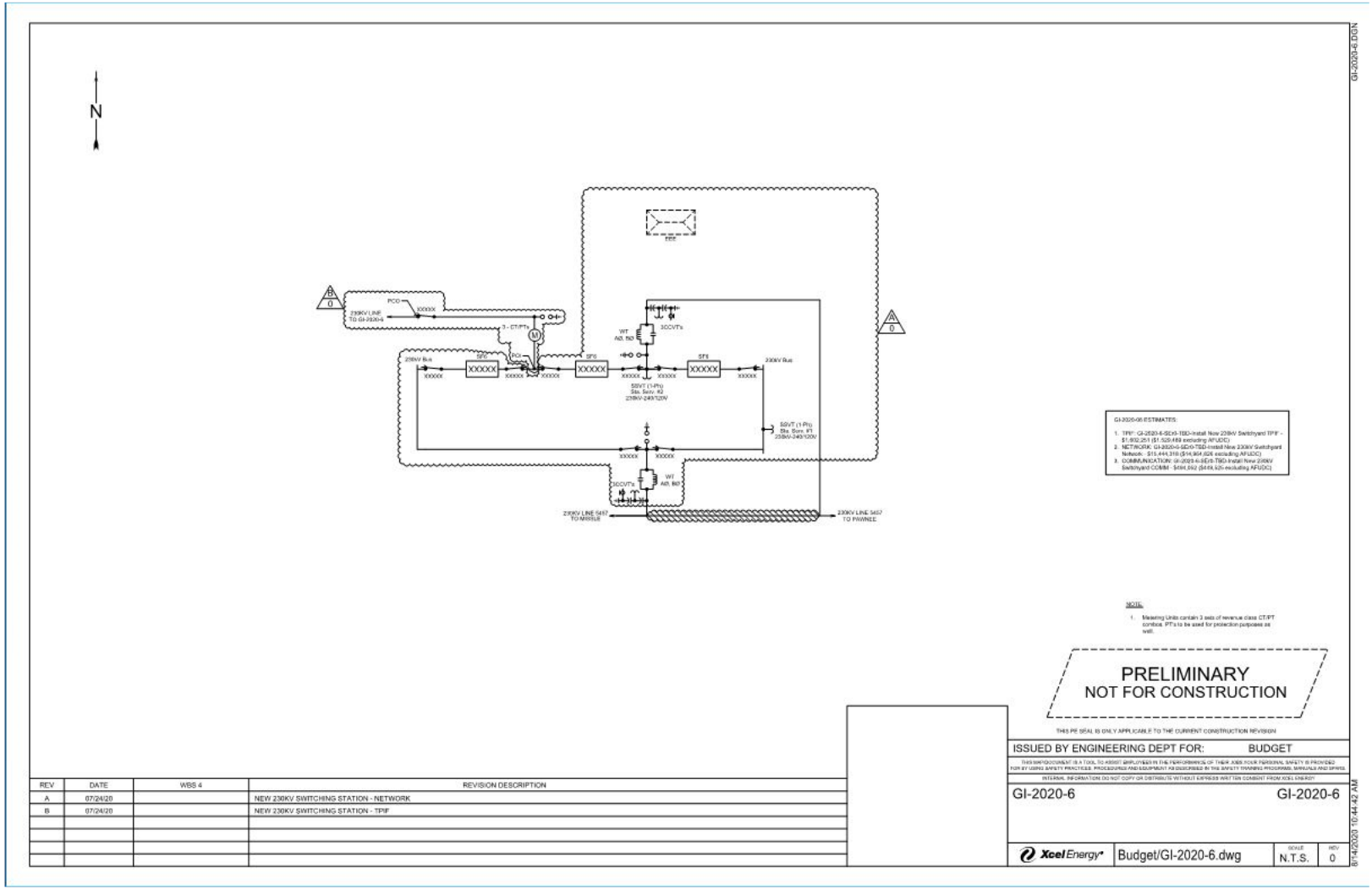
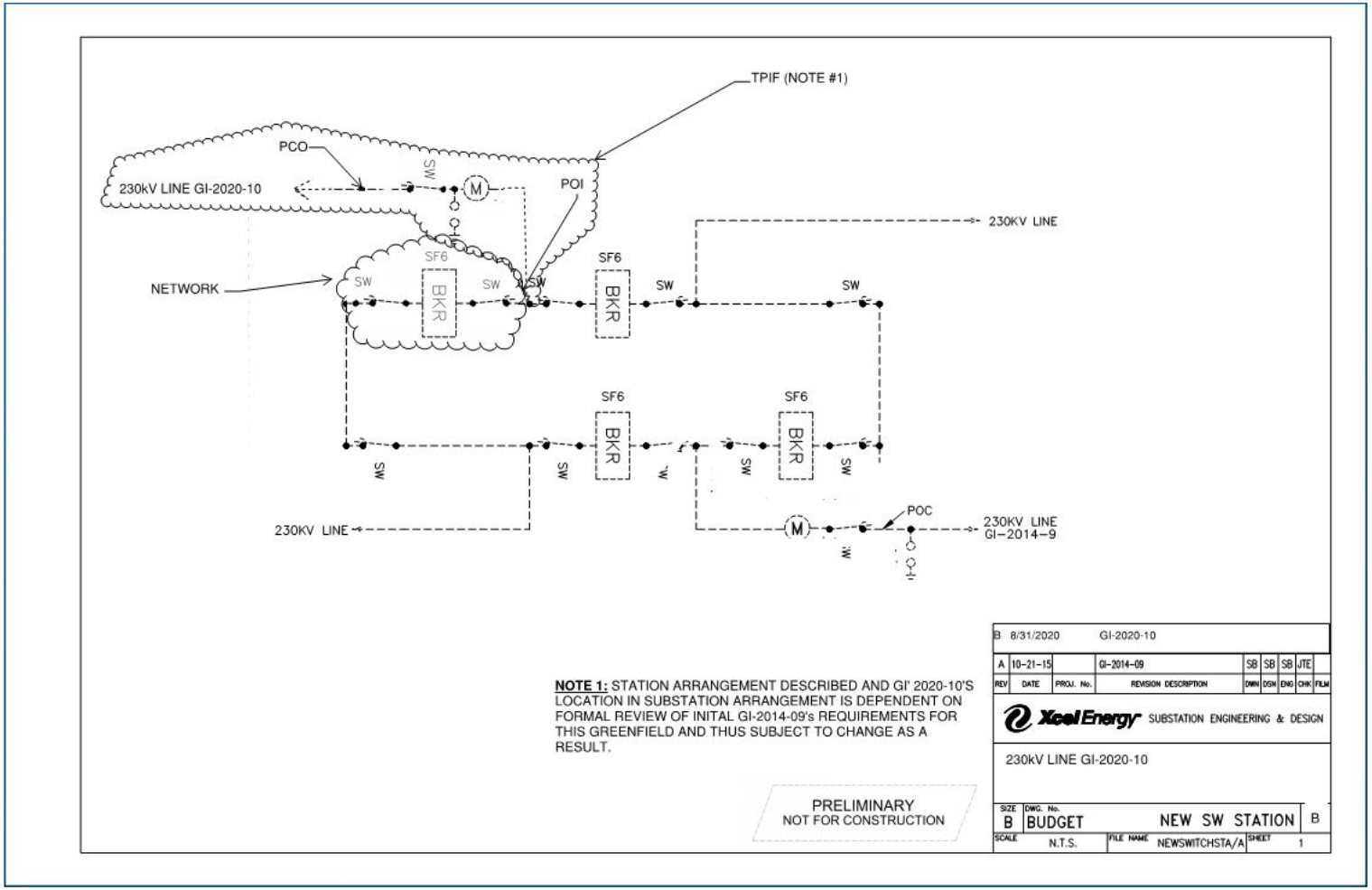


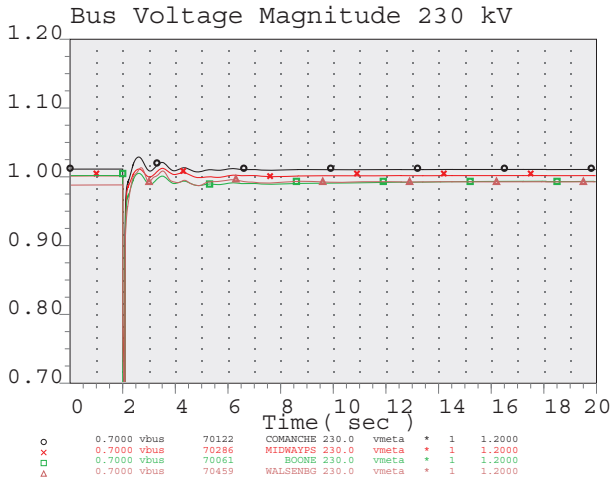
Figure 6 – Preliminary One-line of the GI-2014-9 230kV Switching Station showing GI-2020-10 POI

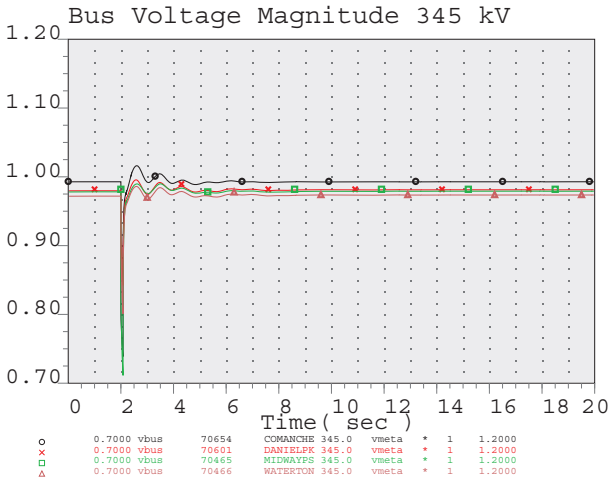


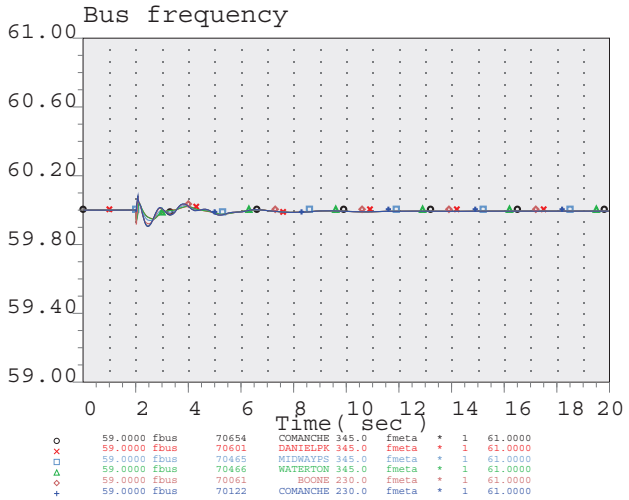
Appendix A-2

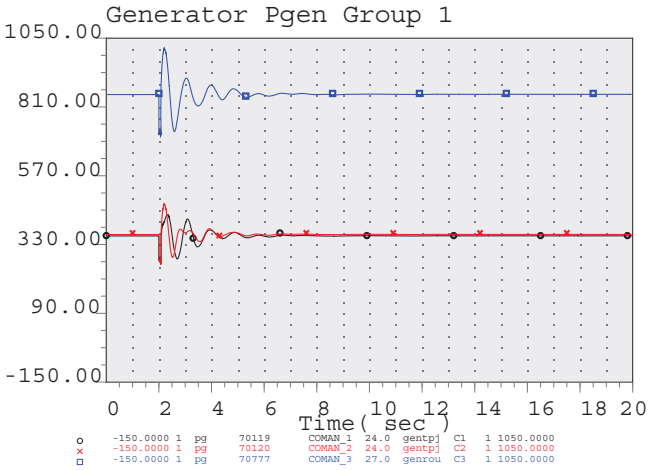
Transient Stability Plots – Southern Colorado

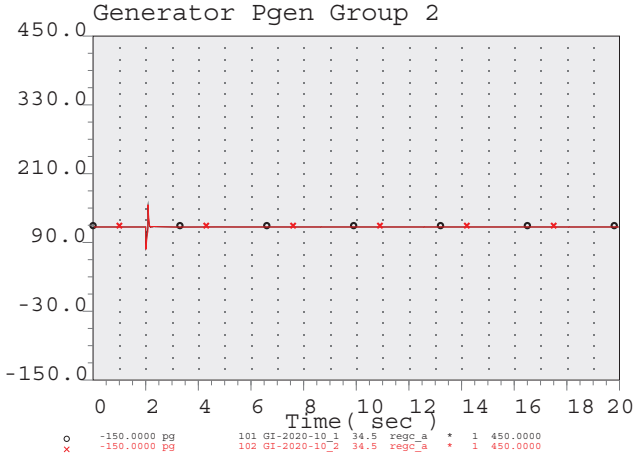
Study Pocket - NRIS

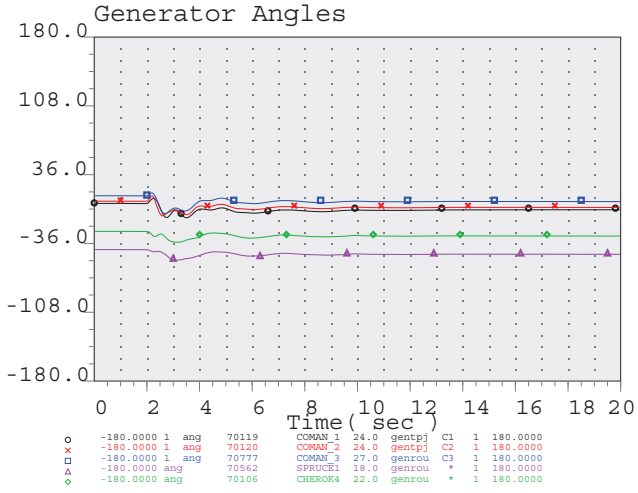




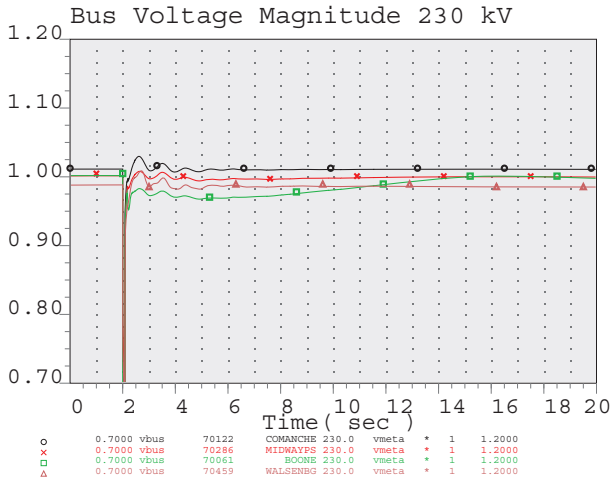


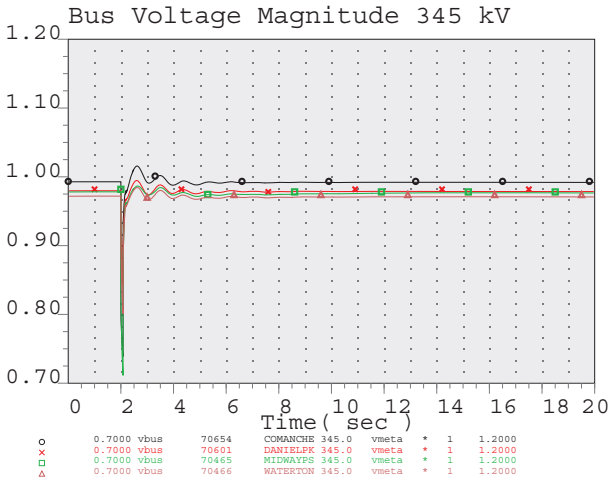


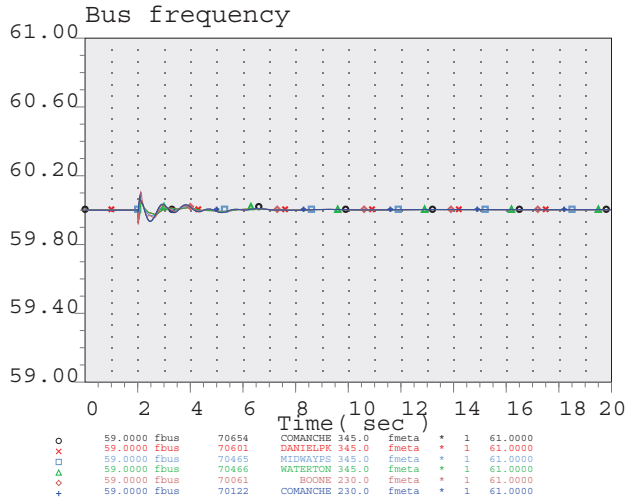


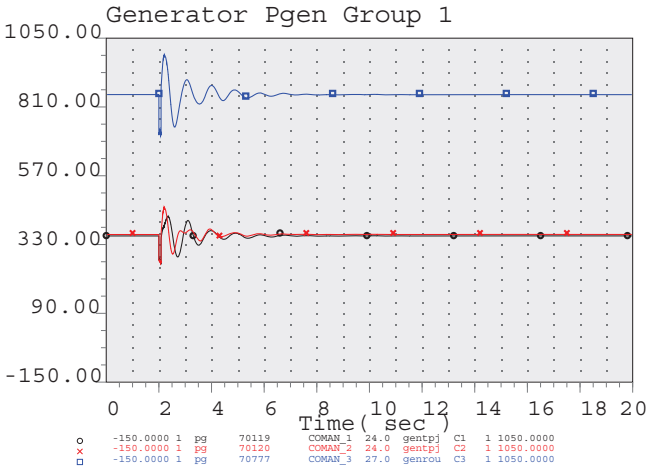


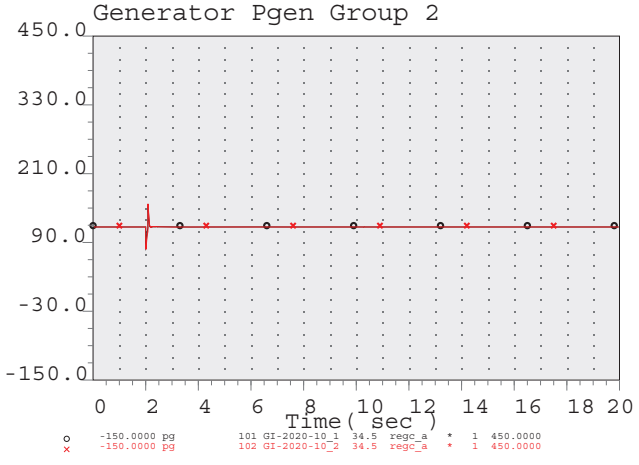
Fault:5-cycle bus fault at Boone 230kV
Outage:Lamar - Boone 230kV line and all generation at Lamar

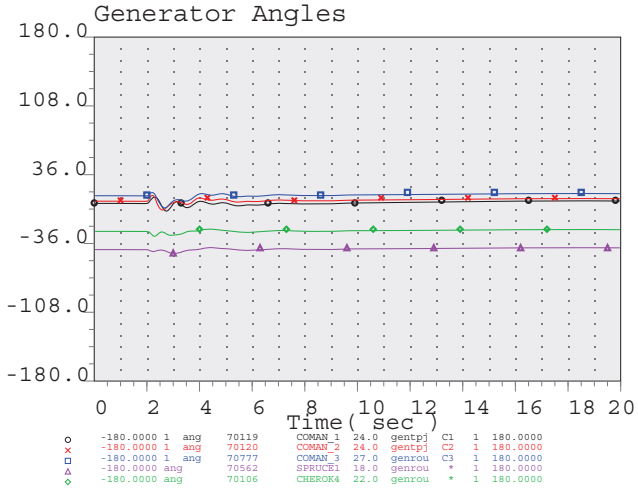




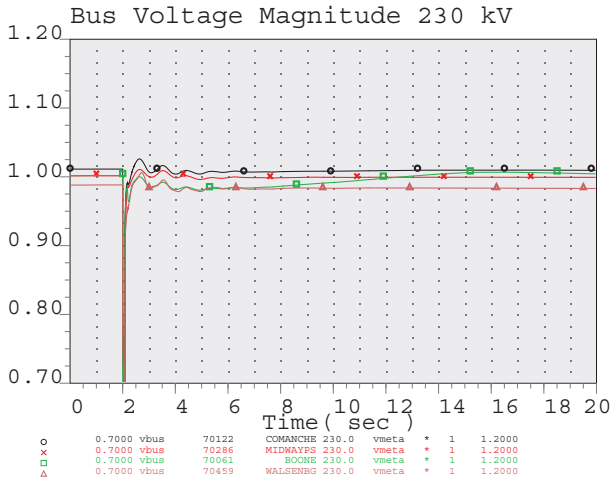


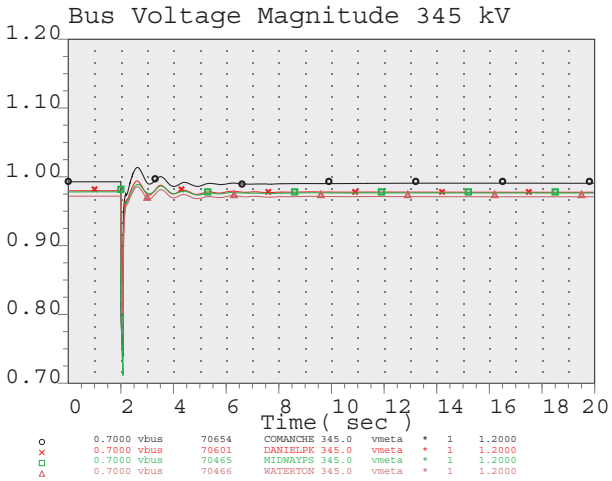


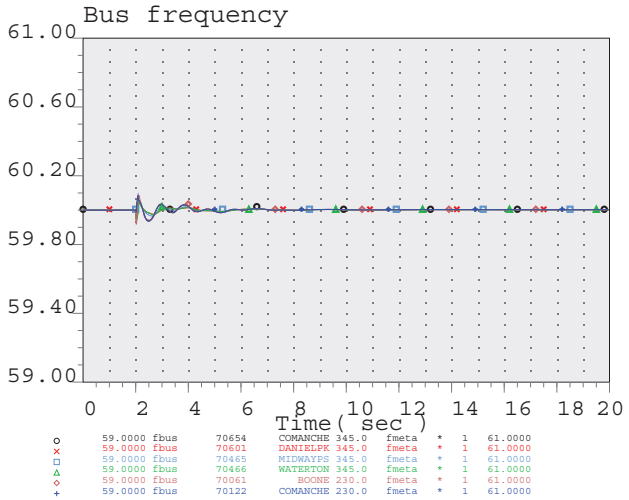


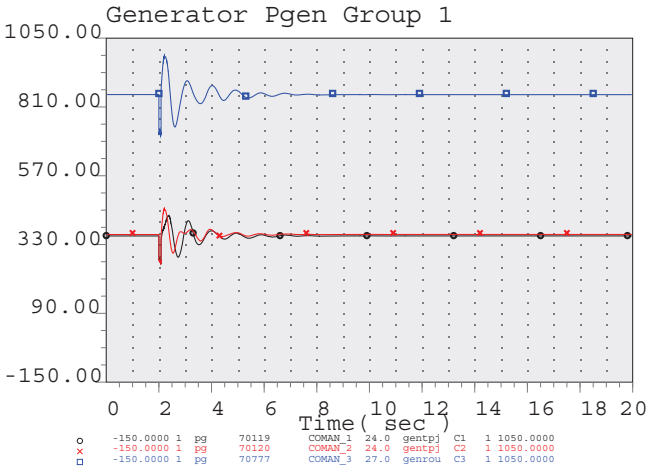


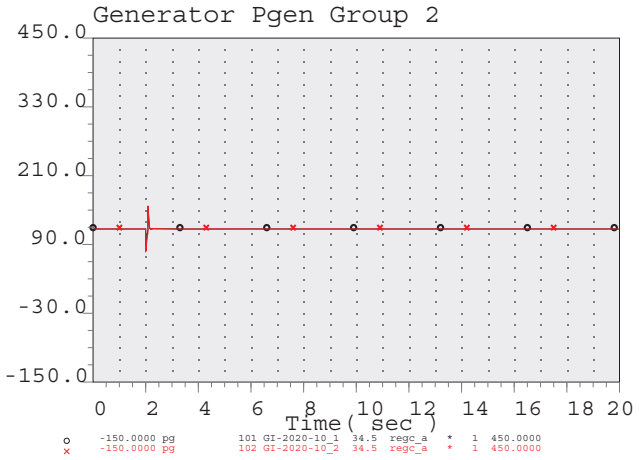
Fault:5-cycle bus fault at Boone 230kV
Outage:Boone - Comanche 230kV line

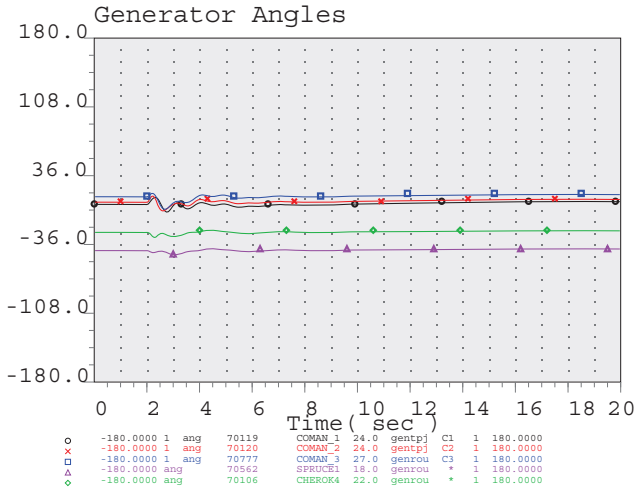




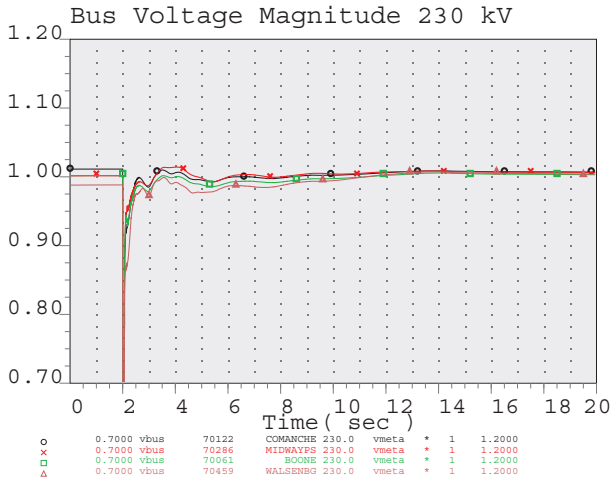


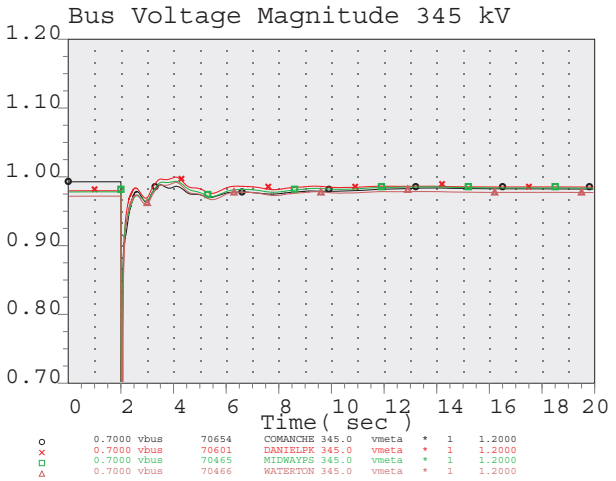


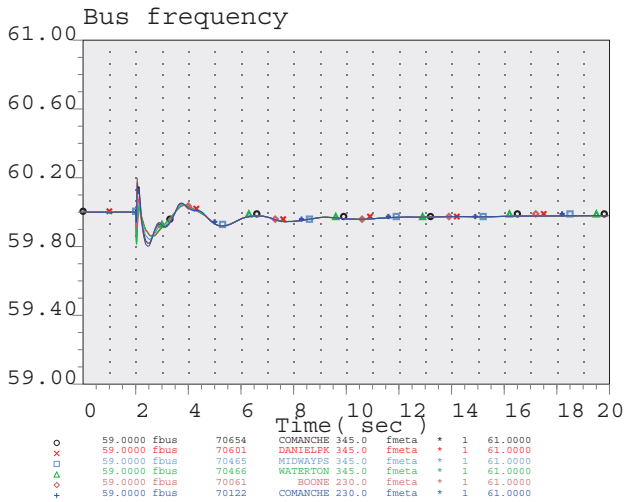


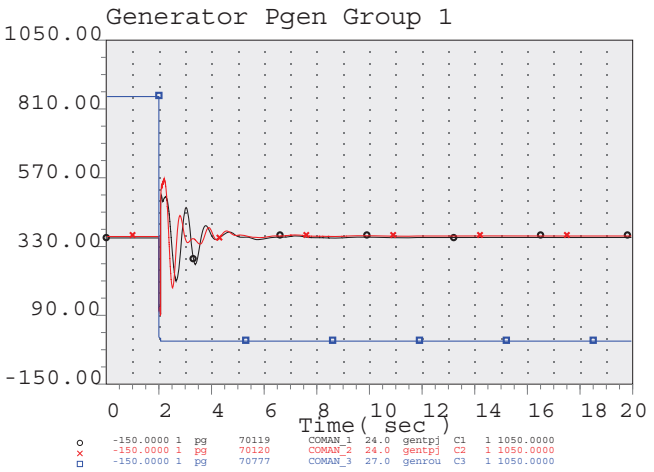


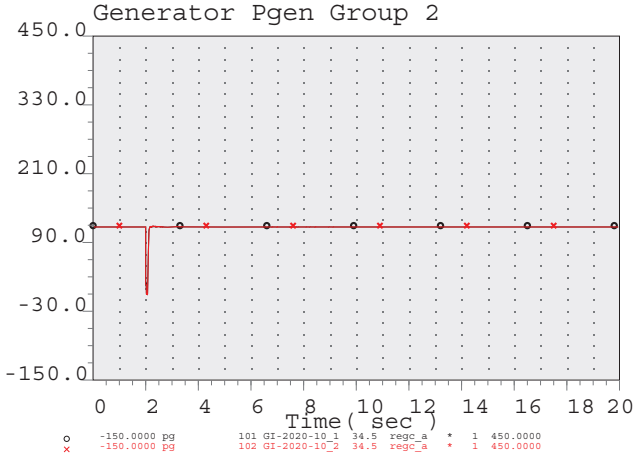
Fault:5-cycle bus fault at Boone 230kV
Outage:Boone - Midway 230kV line

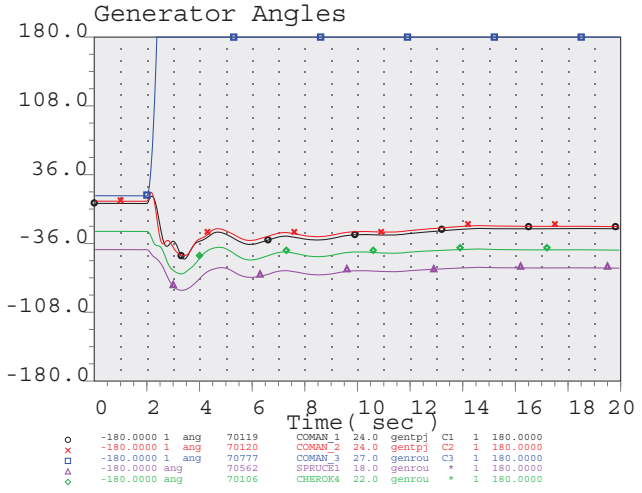




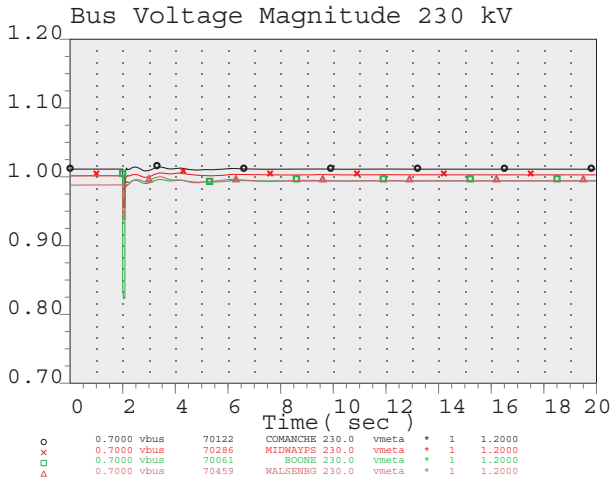


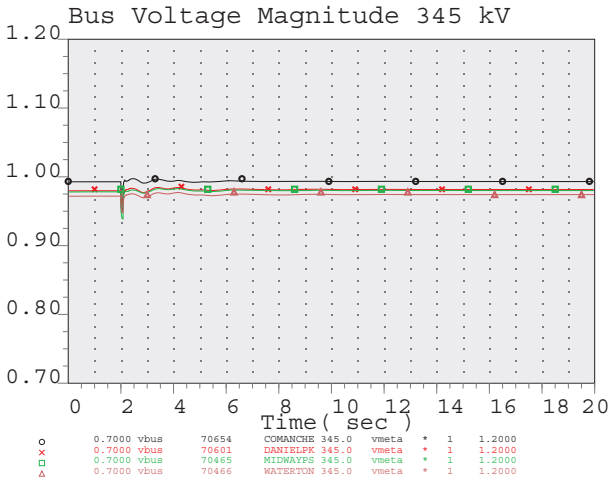


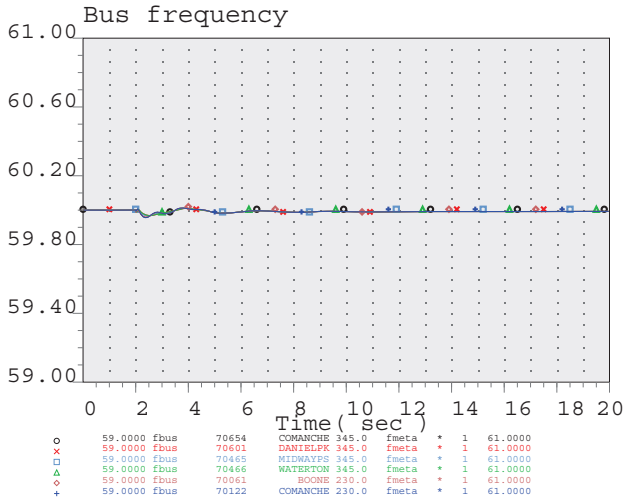


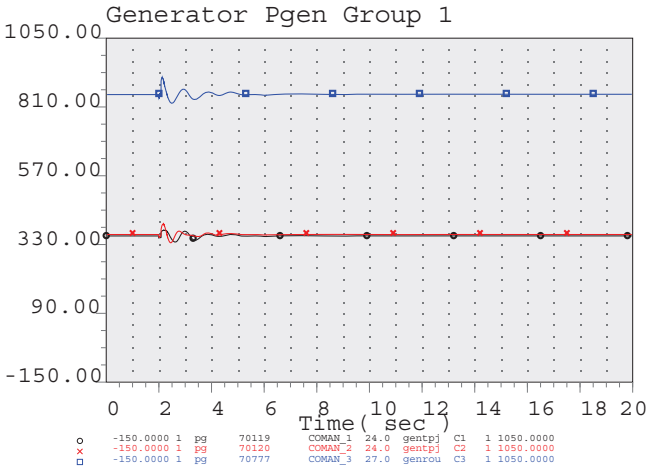


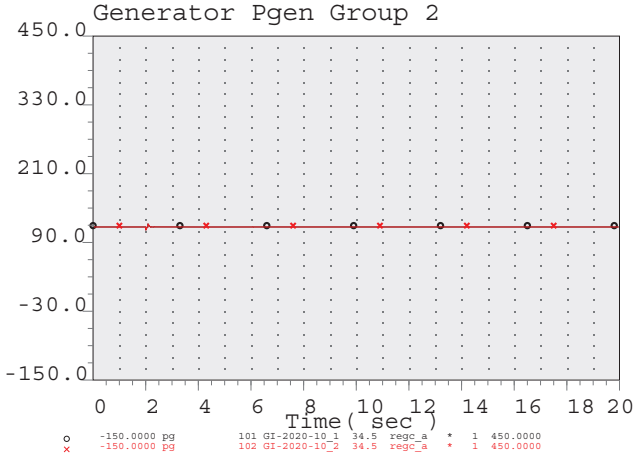
Fault:4-cycle bus fault at Comanche 345kV
Outage:Comanche#3 generator

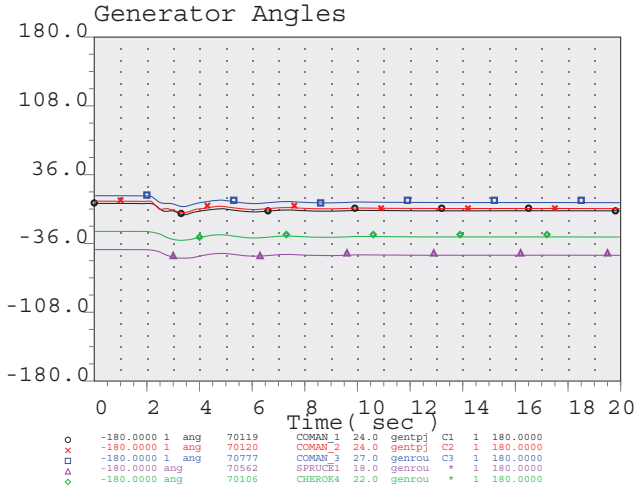




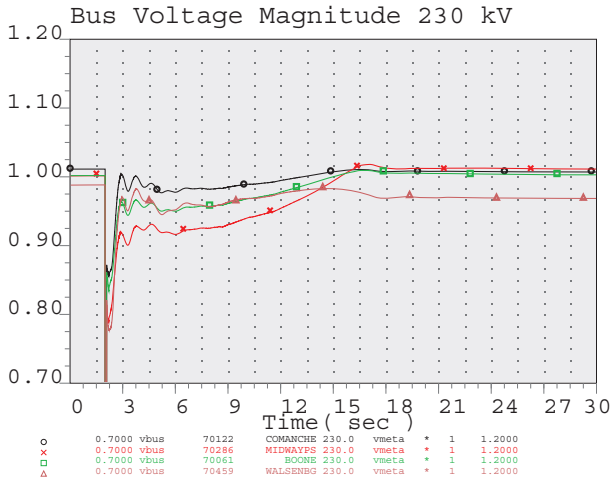


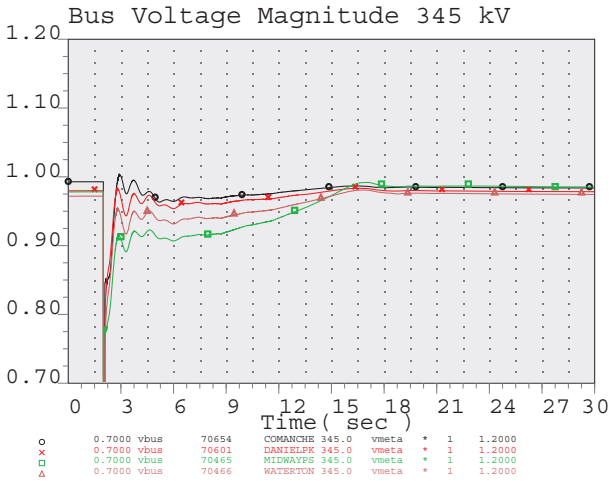


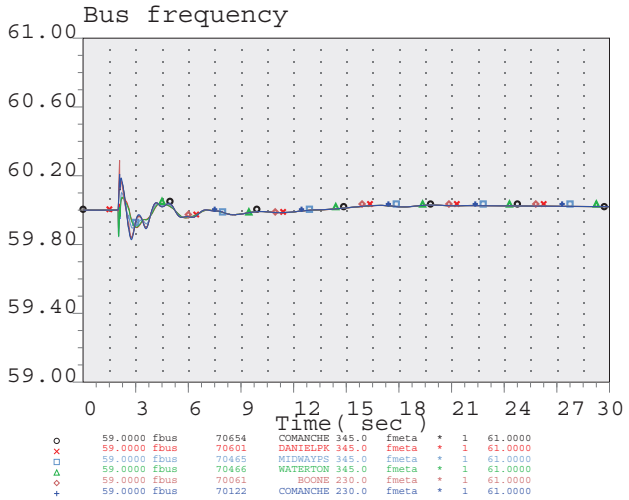


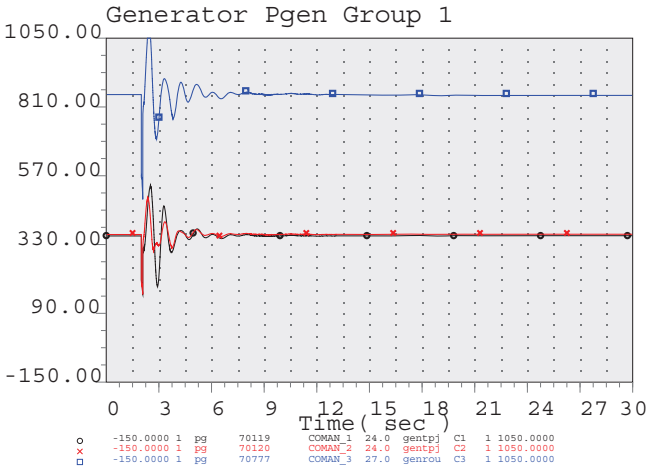


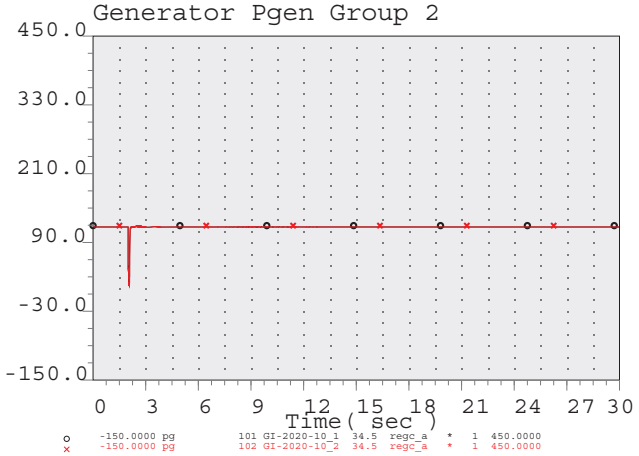
Fault:5-cycle bus fault at Lamar 230kV
Outage:Lamar - Boone 230kV line and all generation at Lamar

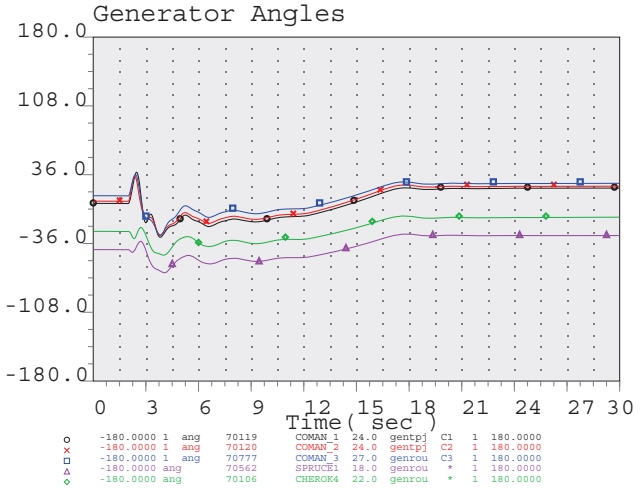




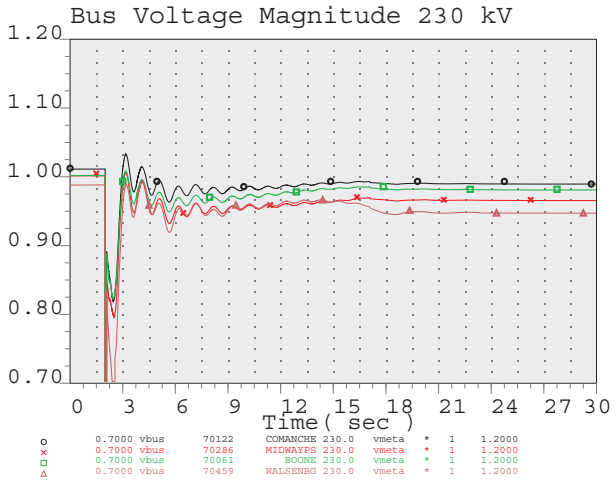


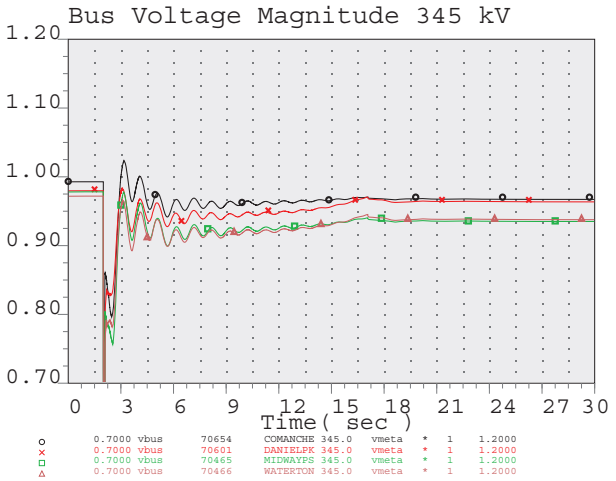


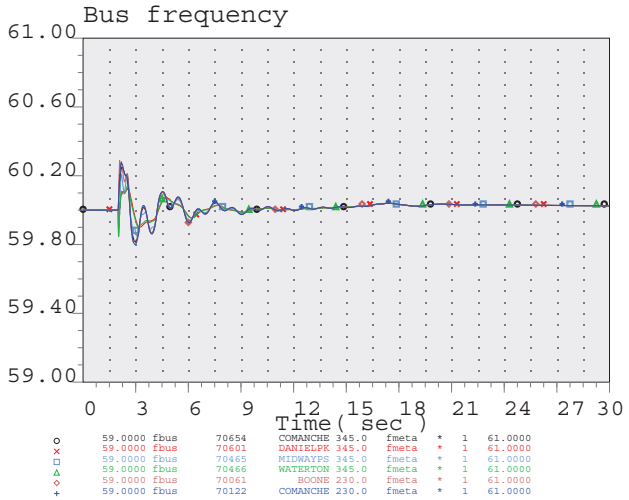


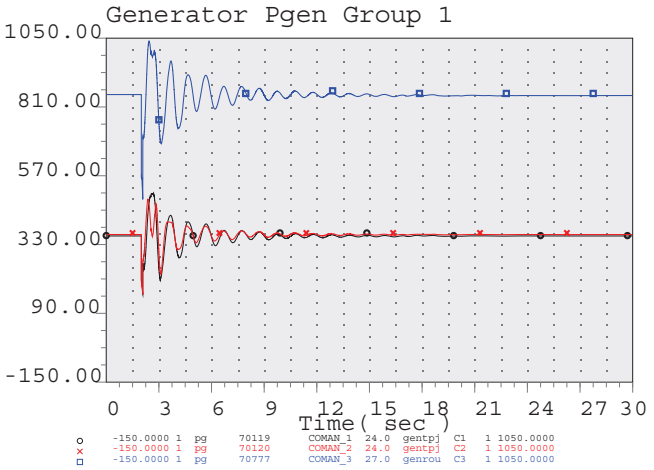


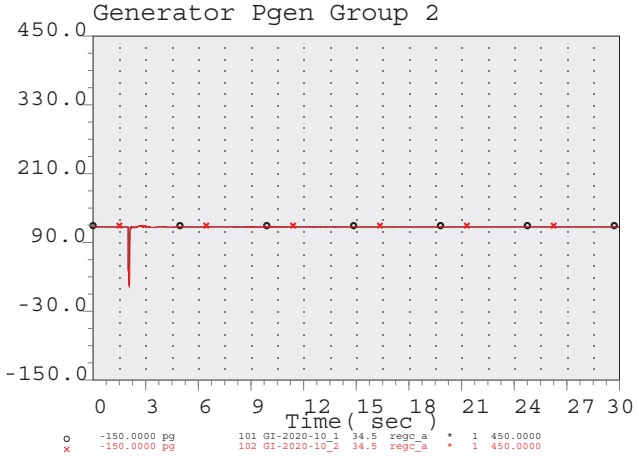
Fault:5-cycle bus fault at MidwayPS 230kV
Outage:All Fountain Valley gas units

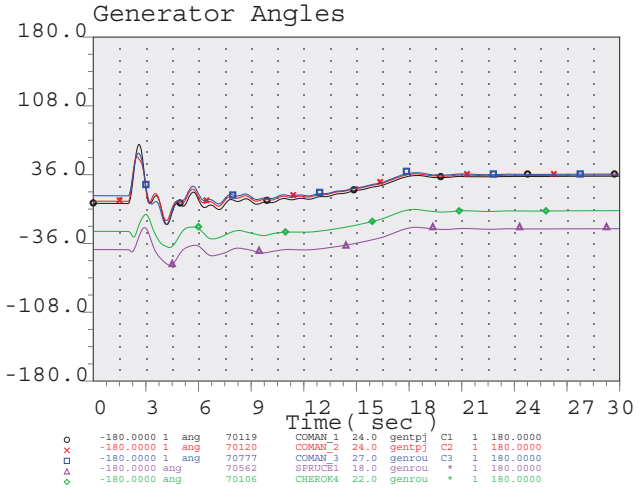




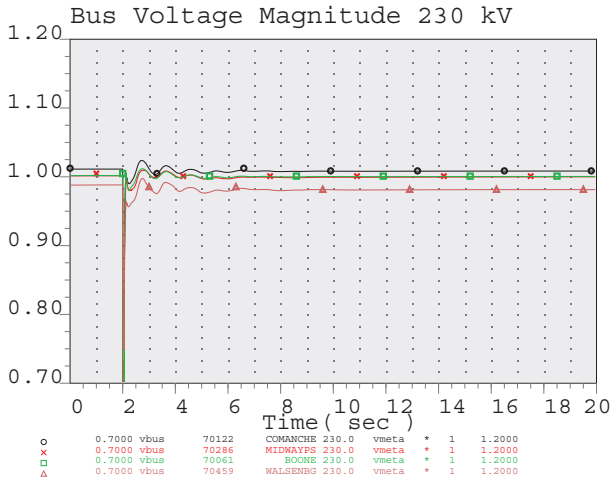


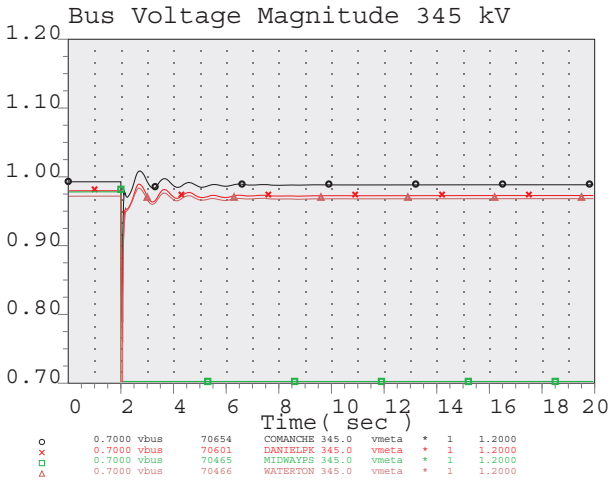


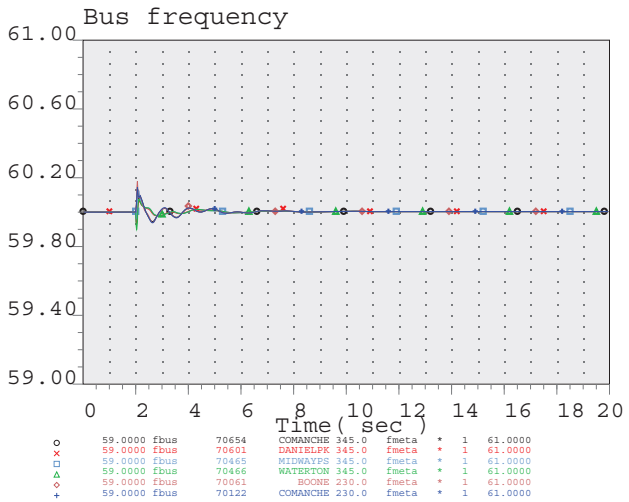


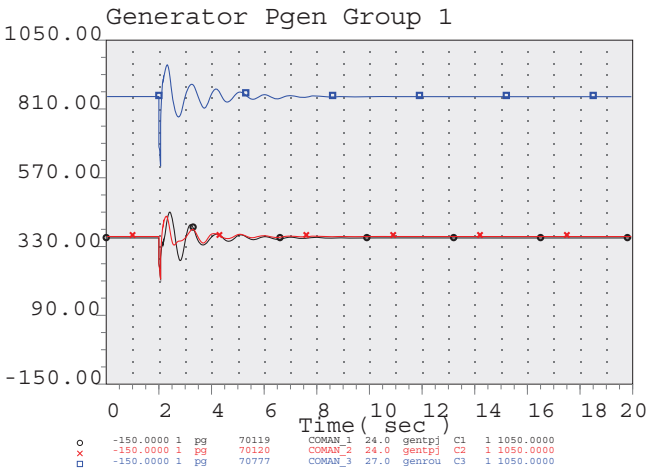


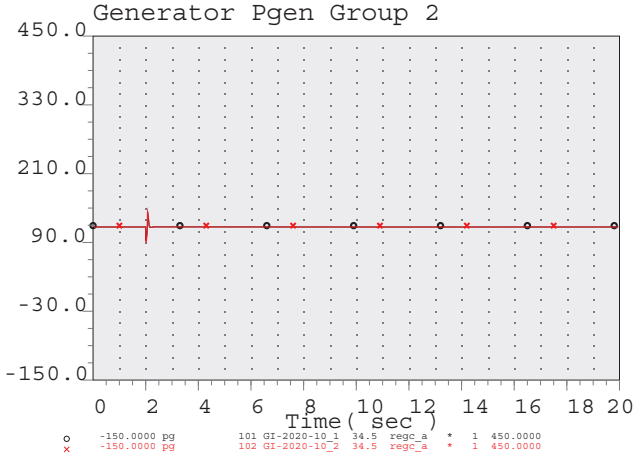
Fault:5-cycle bus fault at MidwayPS 230kV
Outage:Lose MidwayPS - Fuller 230kV and MidwayBR 115kV and 230kV lines

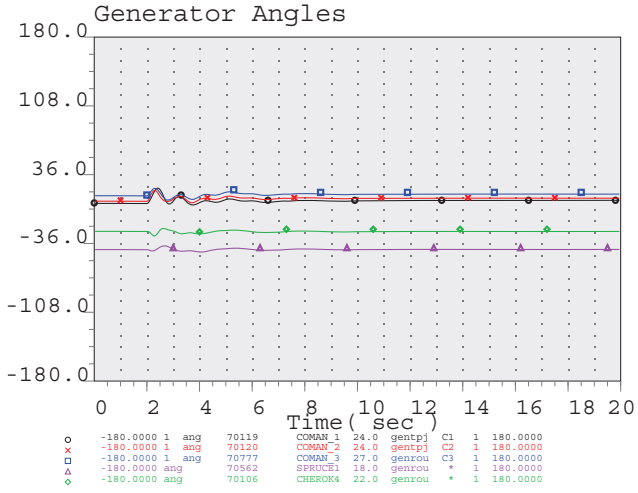










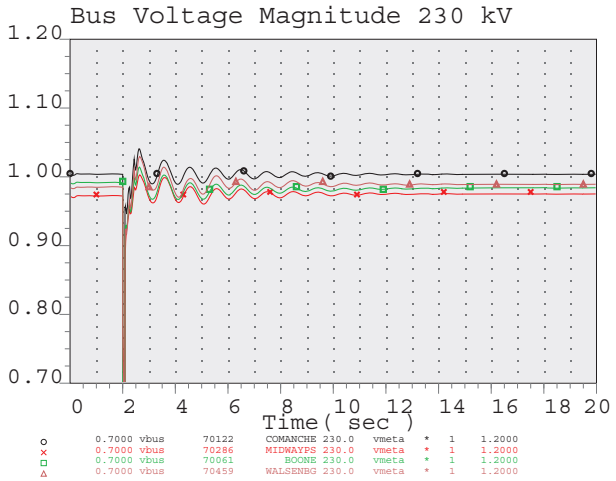


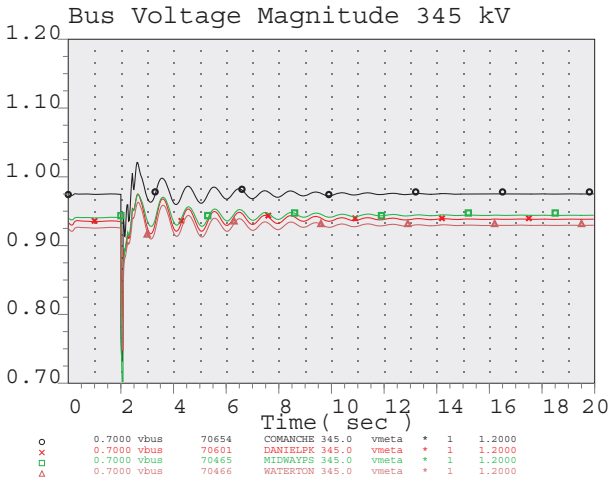
Fault:4-cycle bus fault at MidwayPS 345kV
Outage:Lose MidwayPS - Waterton 345kV line and Midway 230/345kV transformer

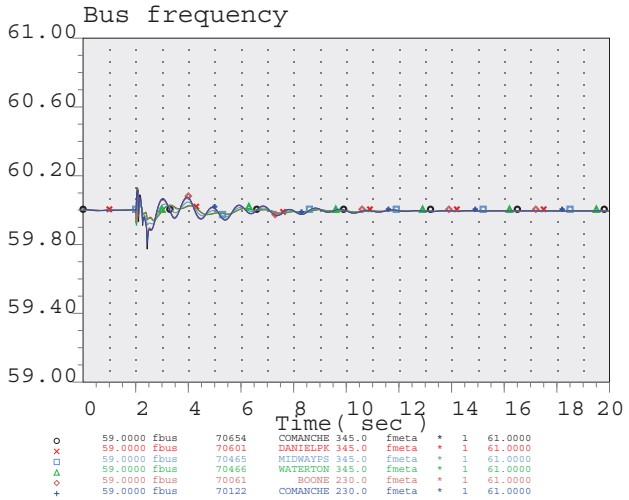
Appendix A-2

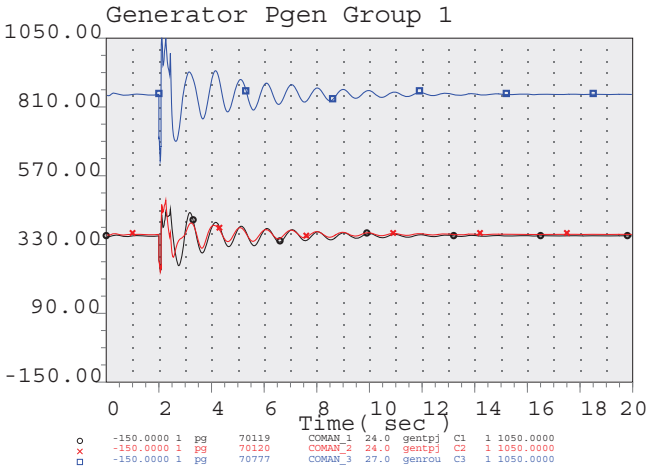
Transient Stability Plots – Southern Colorado

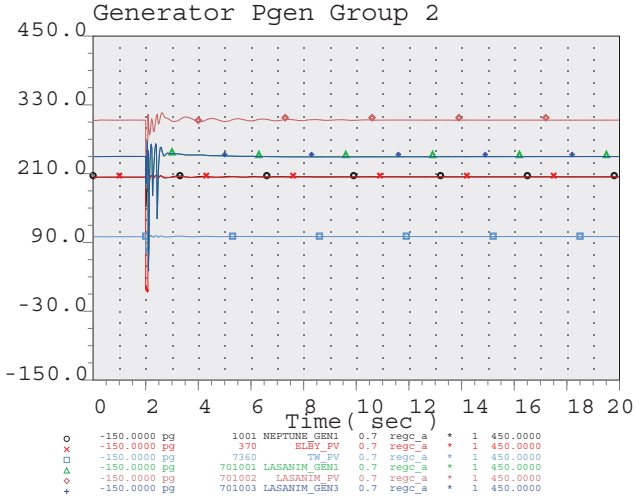
Study Pocket - ERIS

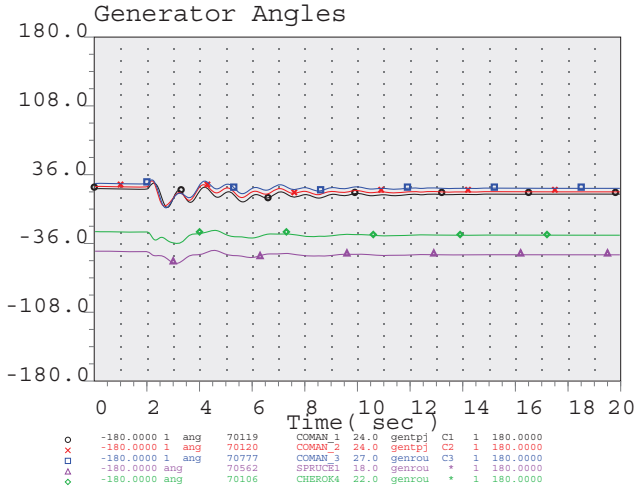






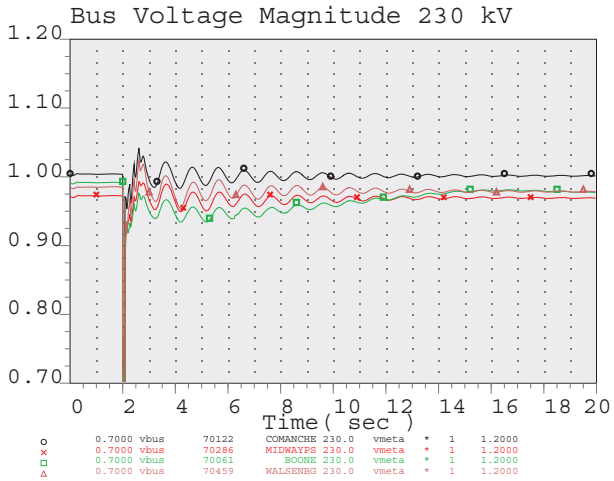


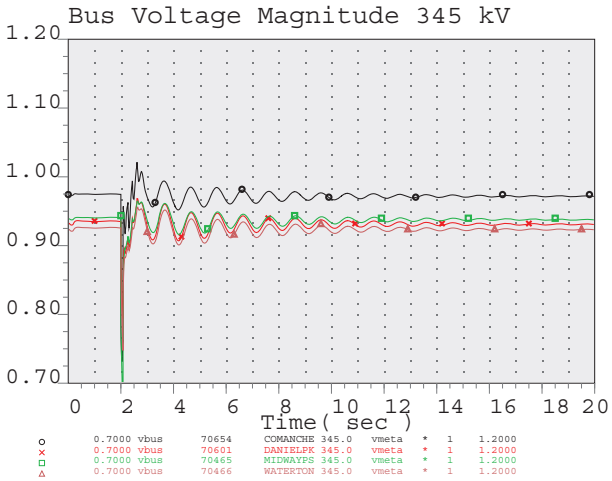


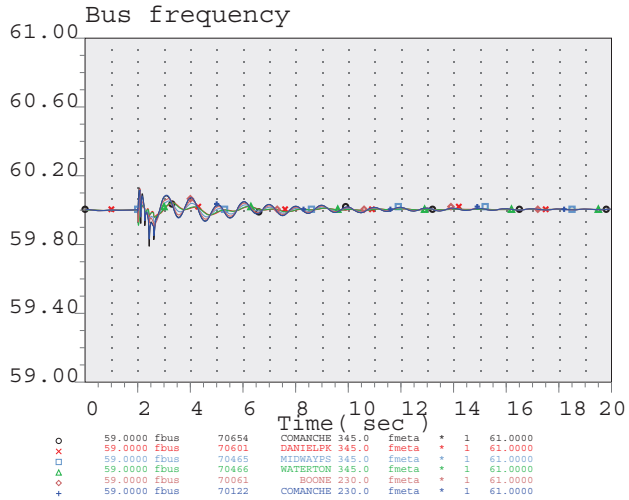


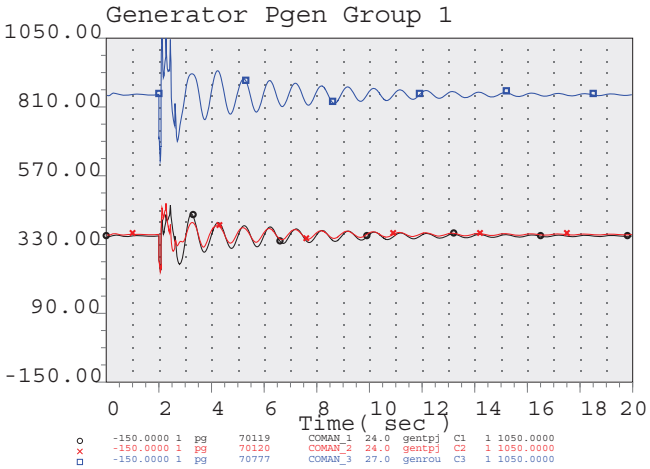
v2_Spring_DISIS_Phase2_South_Pocket_ERIS_#1 lose_Boone-Lamar_230kV_and_La

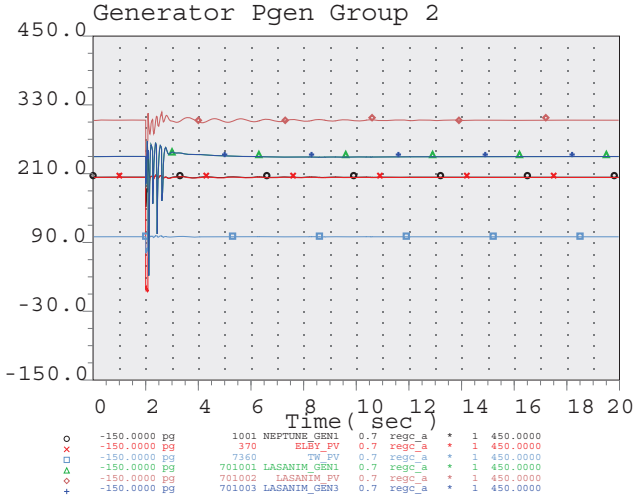
Fault:5-cycle bus fault at Boone 230kV
Outage:Lamar - Boone 230kV line and all generation at Lamar

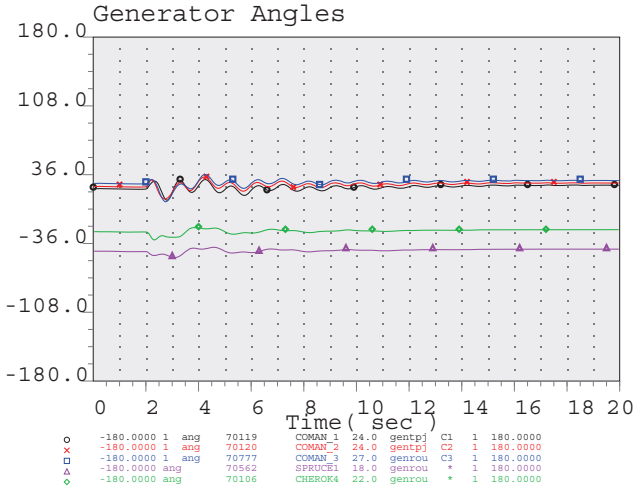






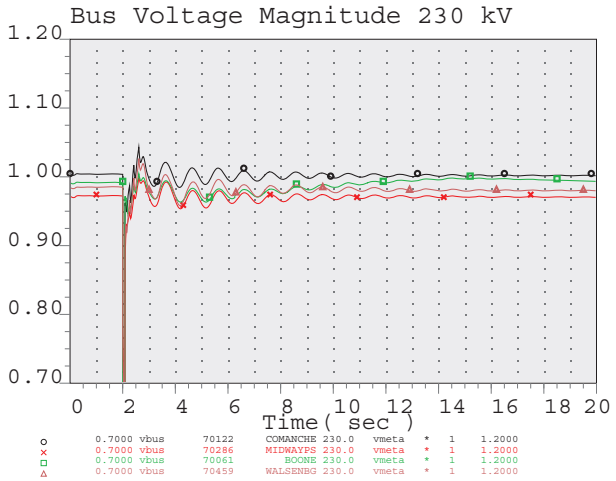


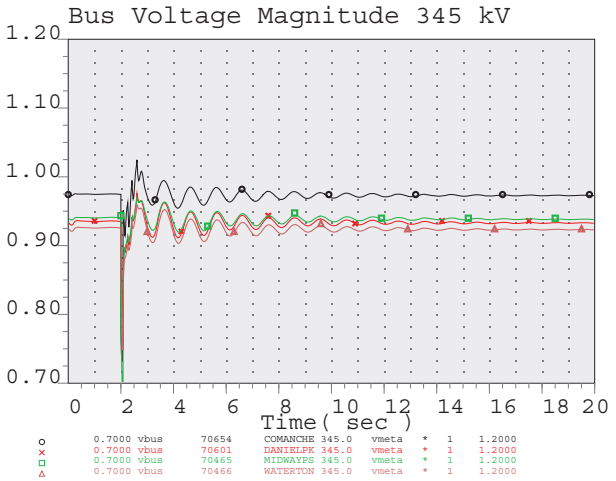


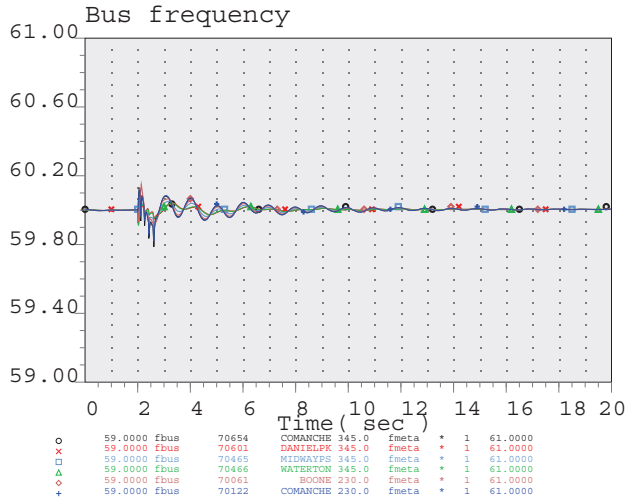


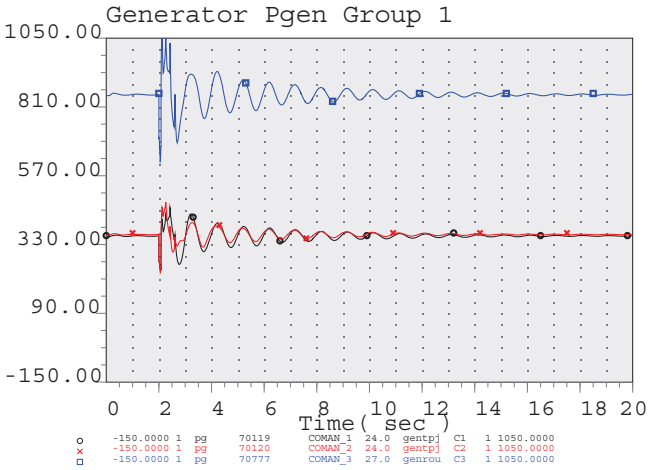
v2_Spring_DISIS_Phase2_South_Pocket_ERIS_#2a lose_Boone-GI-2020-3POI.chf

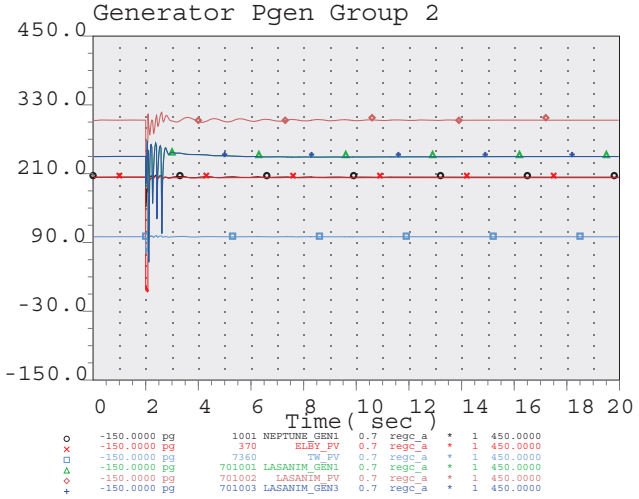
Fault:5-cycle bus fault at Boone 230kV
Outage:Boone - GI-2020-3 Switching Station 230kV line

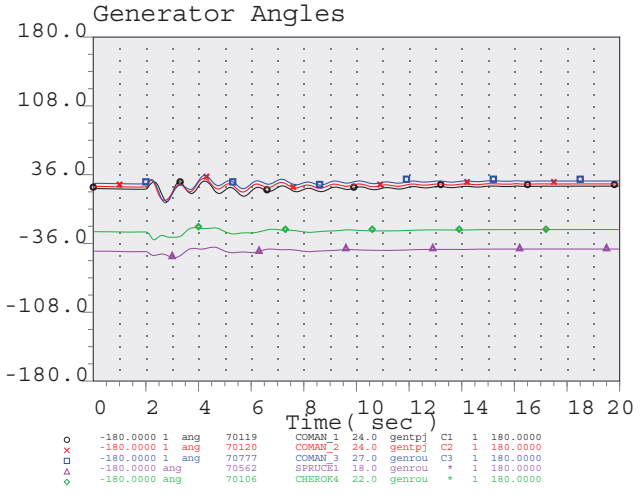












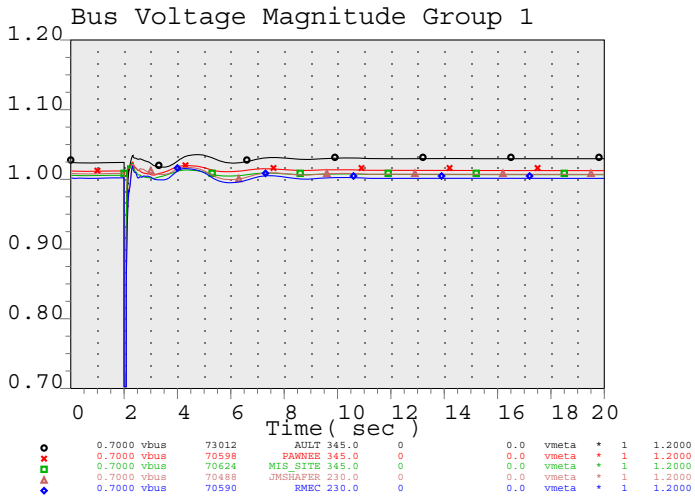
v2_Spring_DISIS_Phase2_South_Pocket_ERIS_#2b lose_GI-2020-3POI-Comanche_2

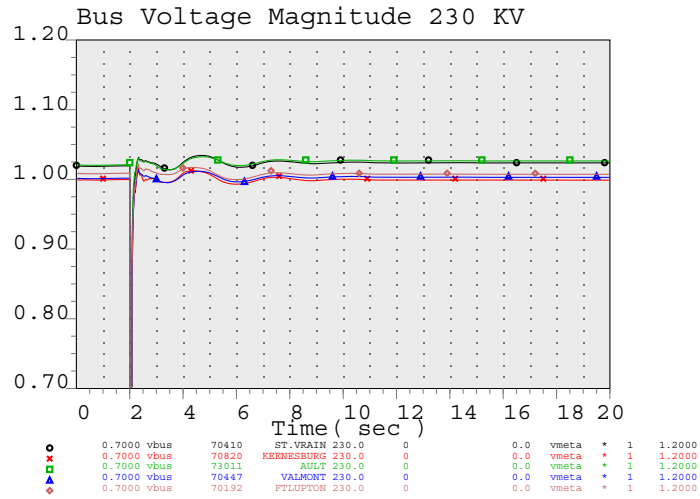
Fault:5-cycle bus fault at Boone 230kV
Outage:GI-2020-3 Switching Station - Comanche 230kV line

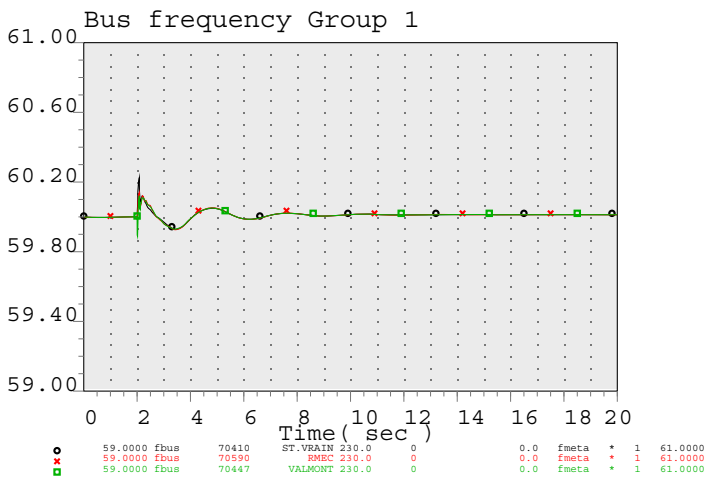
Appendix A-3

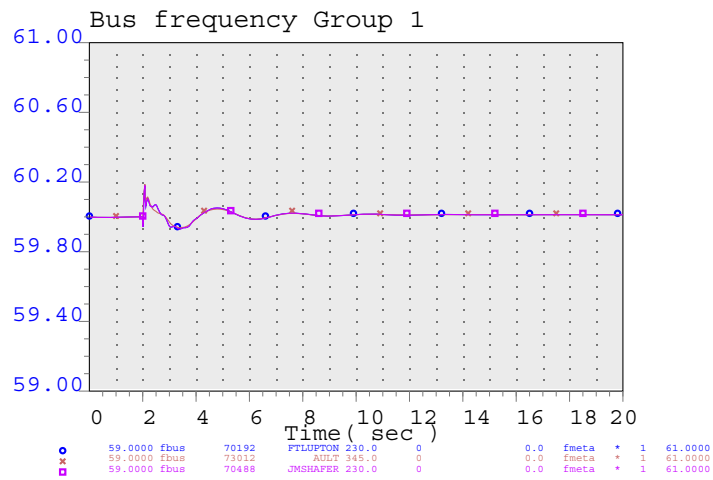
Transient Stability Plots – Northern Colorado

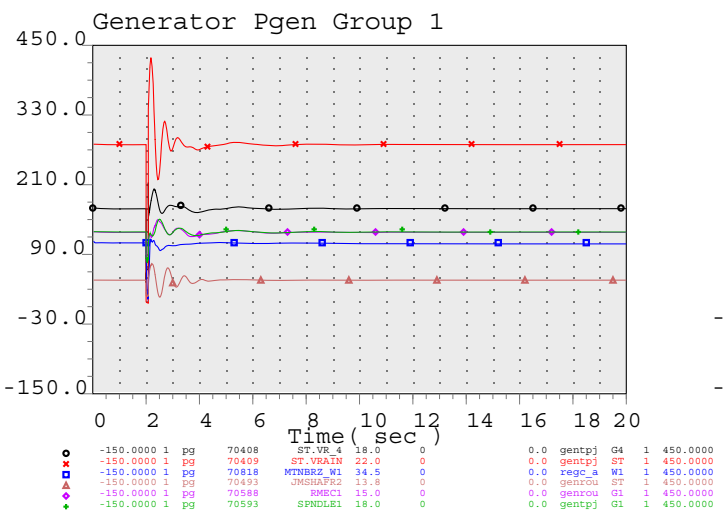
Study Pocket

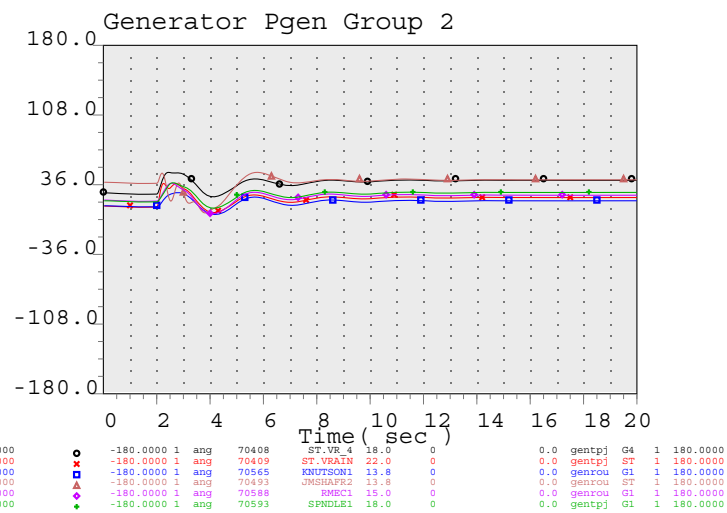




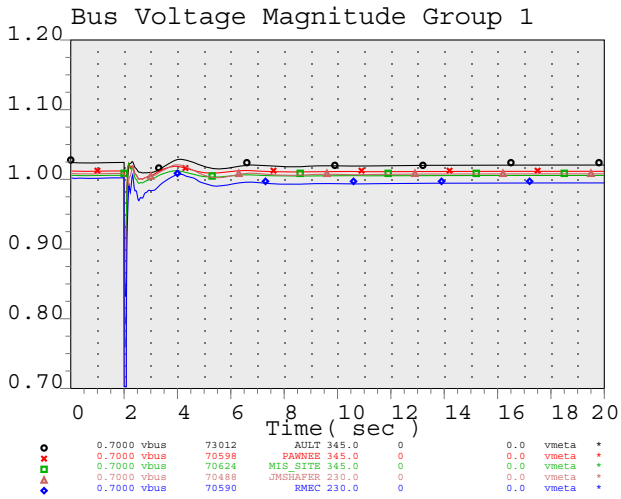


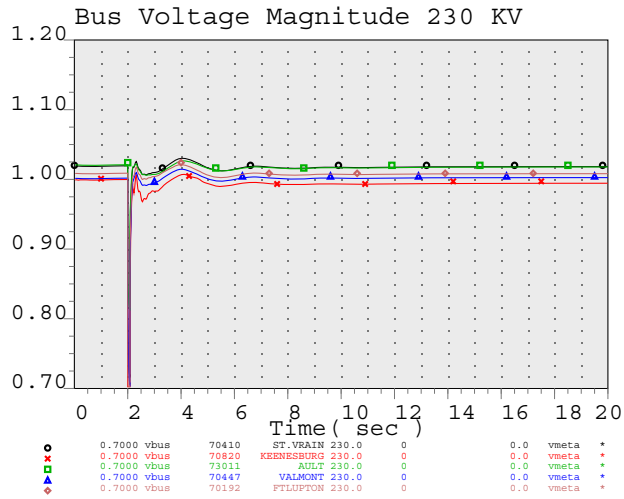


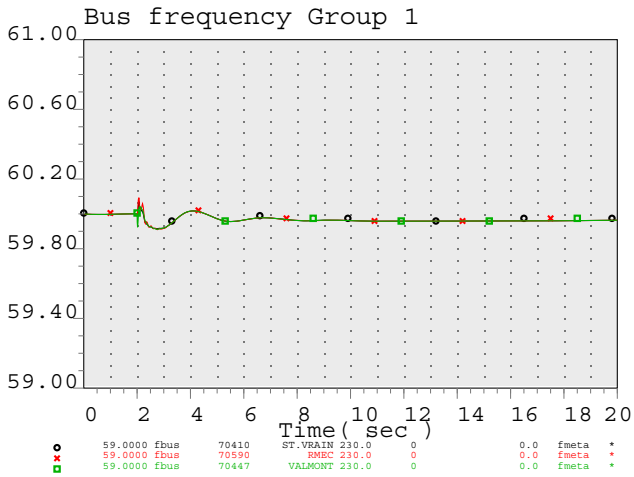


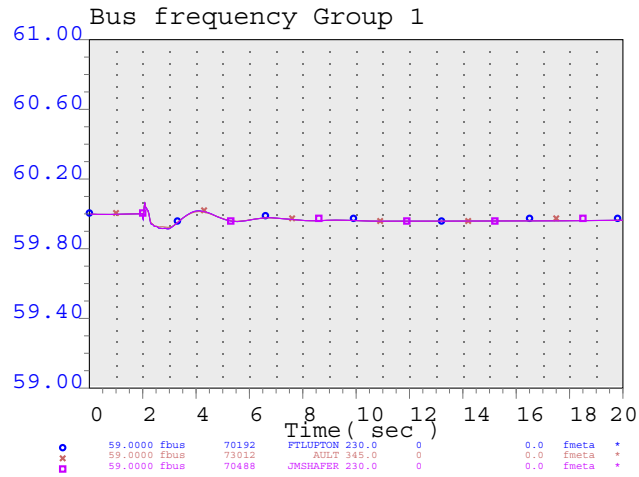


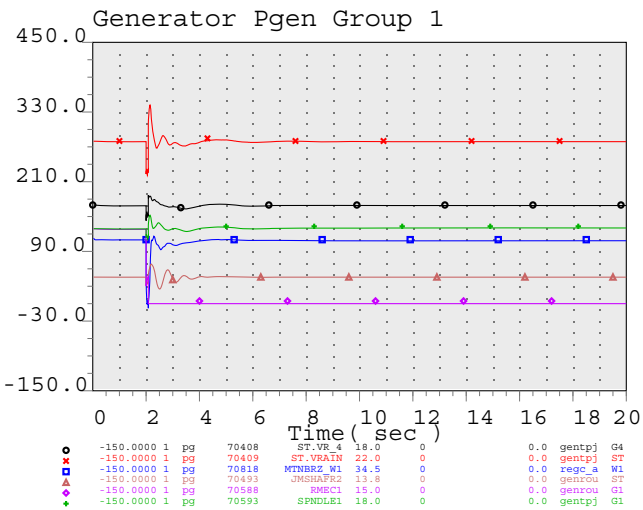
Fault: 5-cycle fault at St. Vrain 230kV
Outage: Ftlupton - St. Vrain 230kV lines #1 and #2

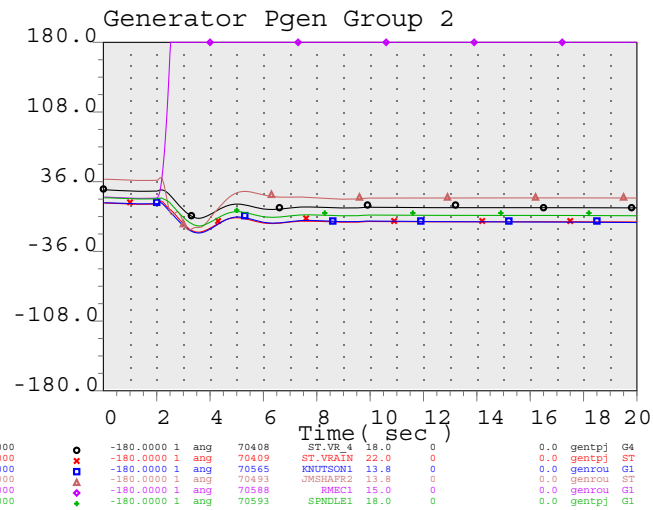




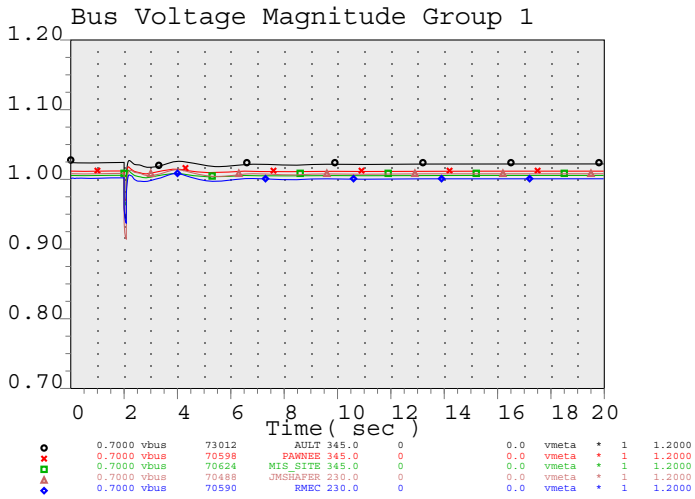


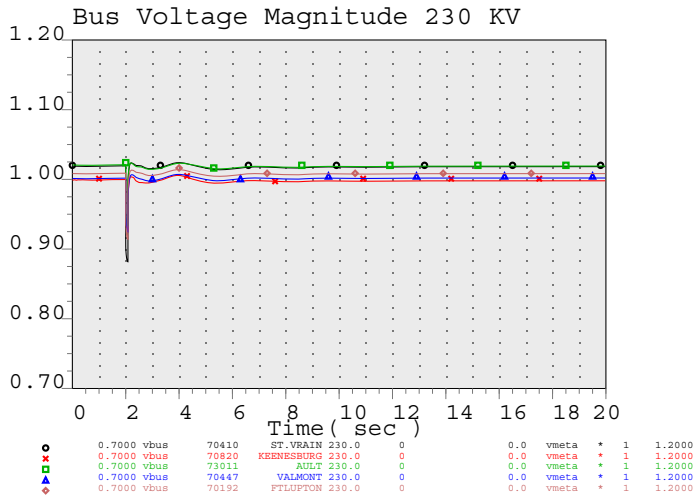


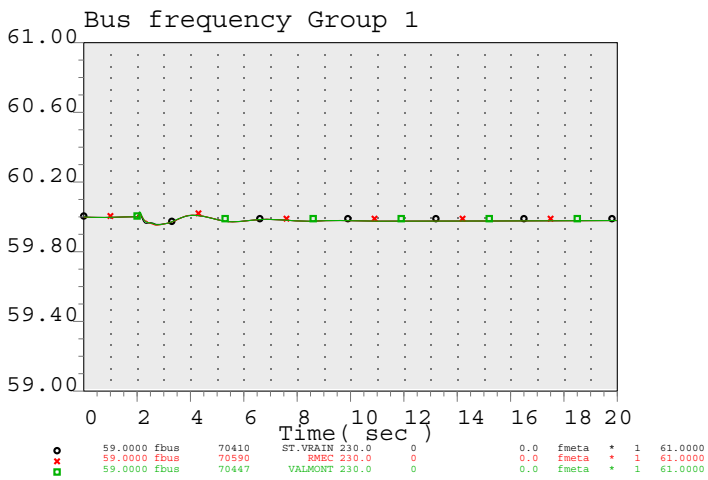


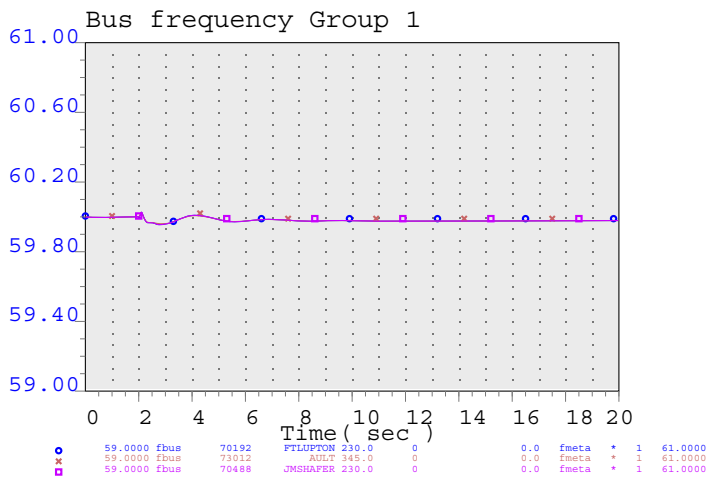


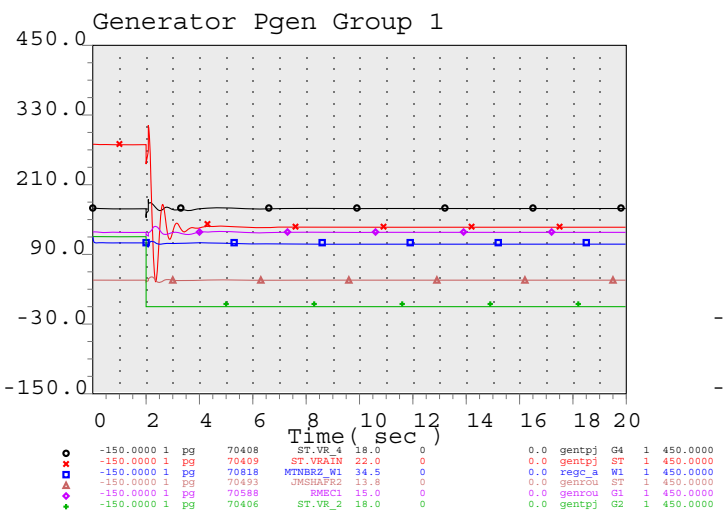
Fault: 5-cycle fault at RMEC
Outage: RMEC #1, #2 and #3 units

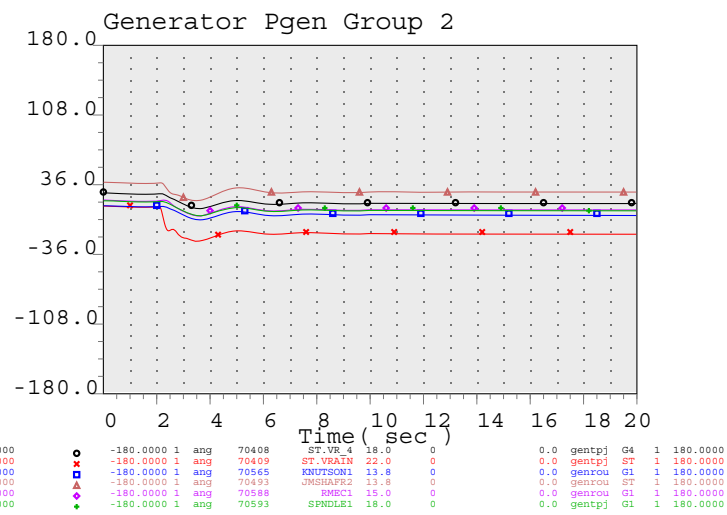




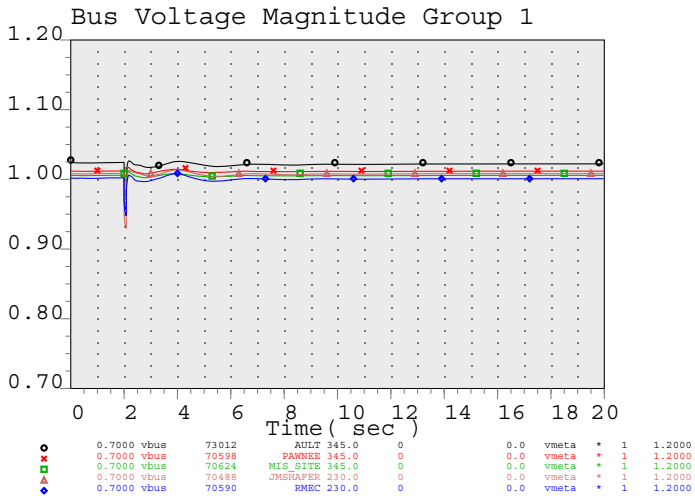


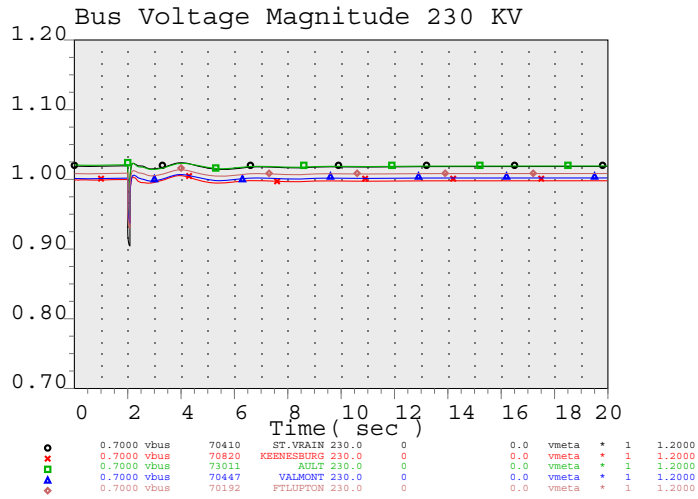


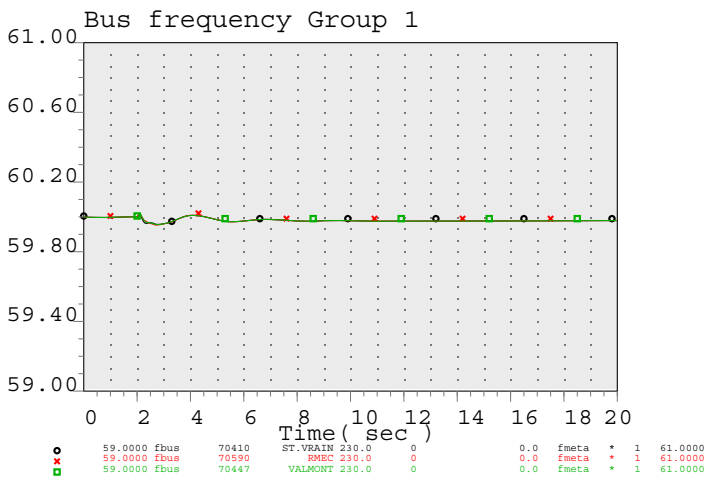


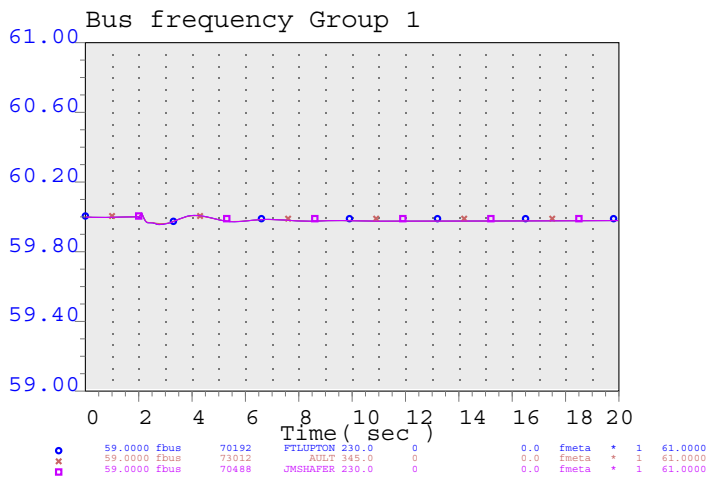


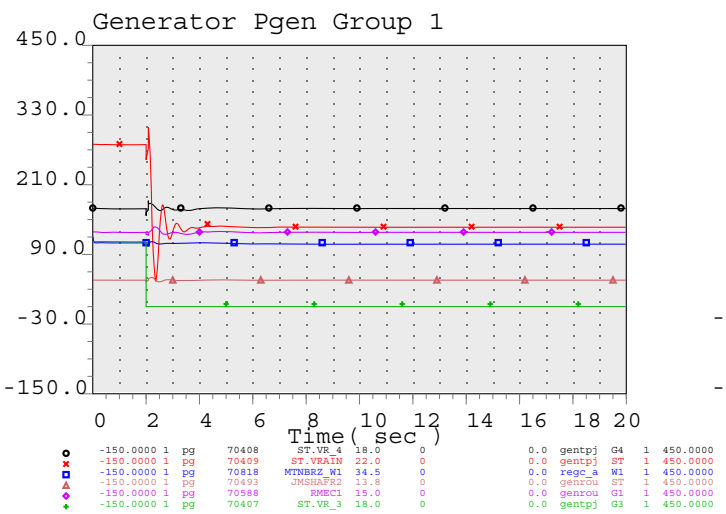
Fault: 5-cycle fault at St. Vrain #2
Outage: St. Vrain #2 and 50% reduction of St. Vrain 'ST'

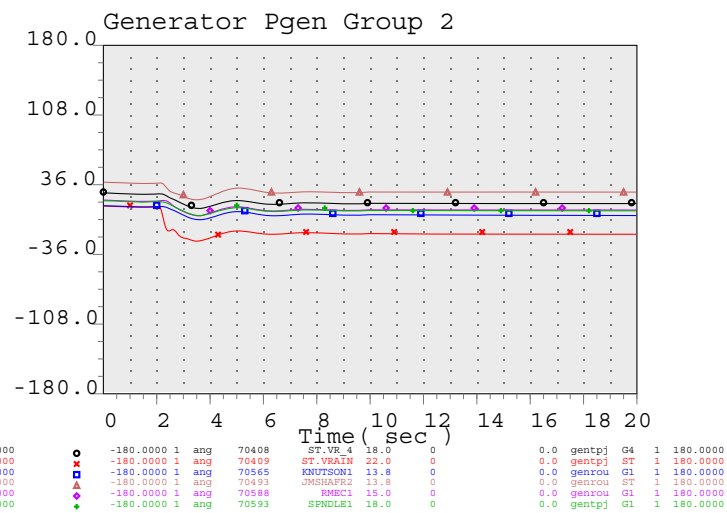










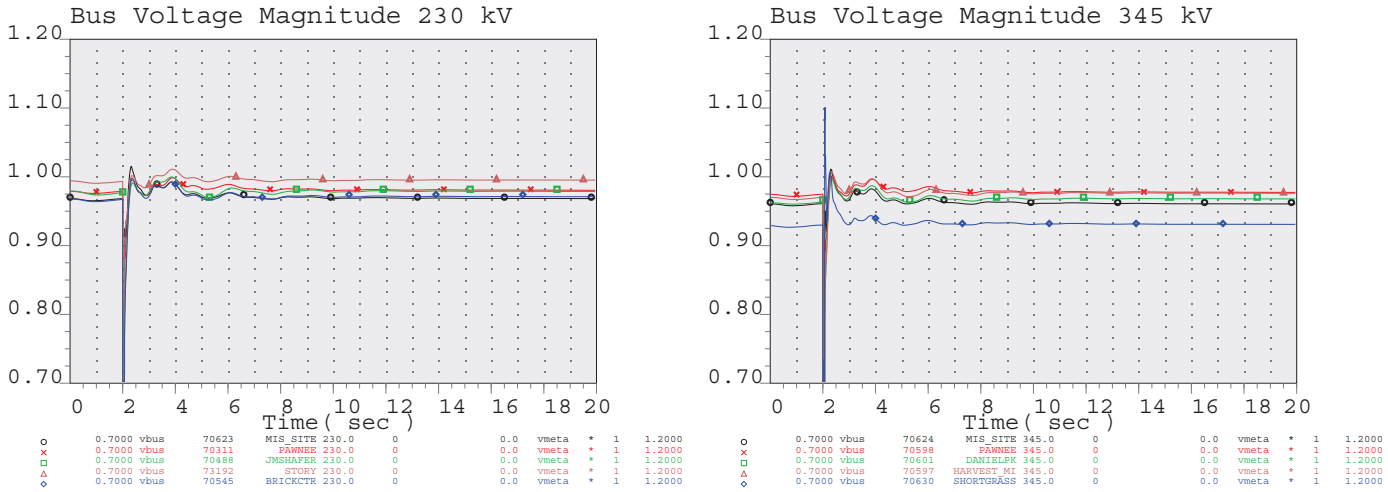


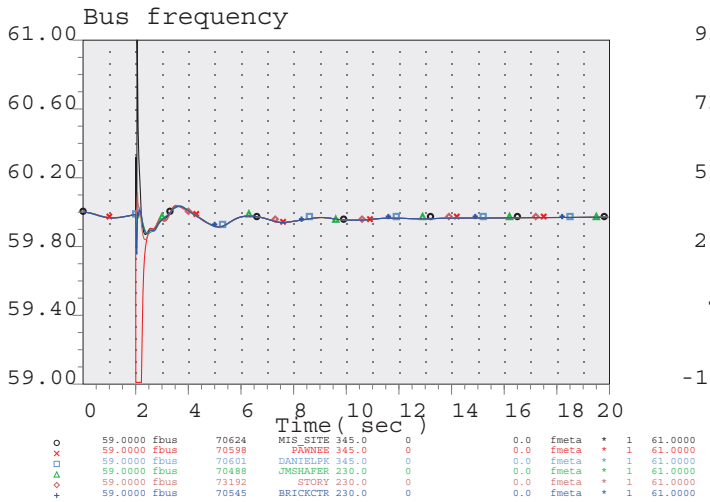
Fault: 5-cycle fault at St. Vrain #3
Outage: St. Vrain #3 and 50% reduction of St. Vrain 'ST'

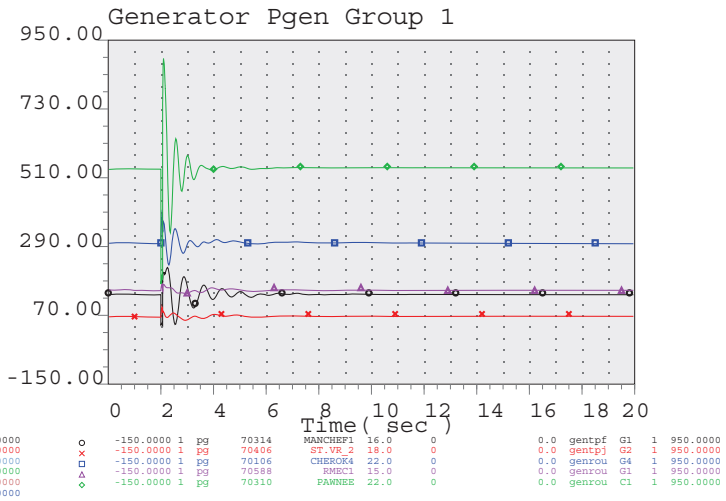
Appendix A-2

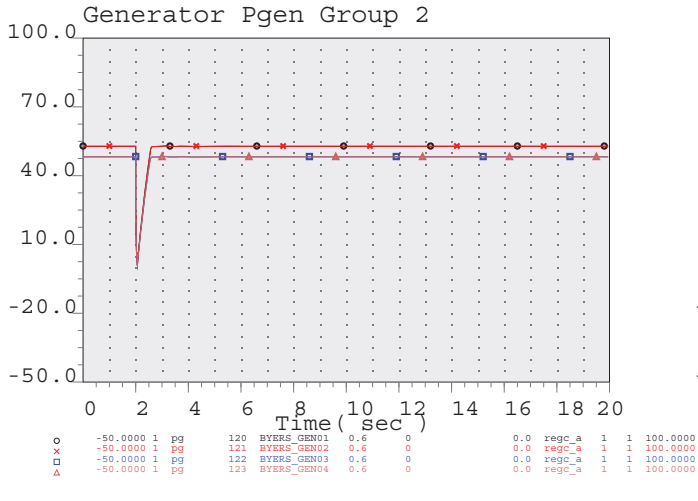
Transient Stability Plots – Eastern Colorado

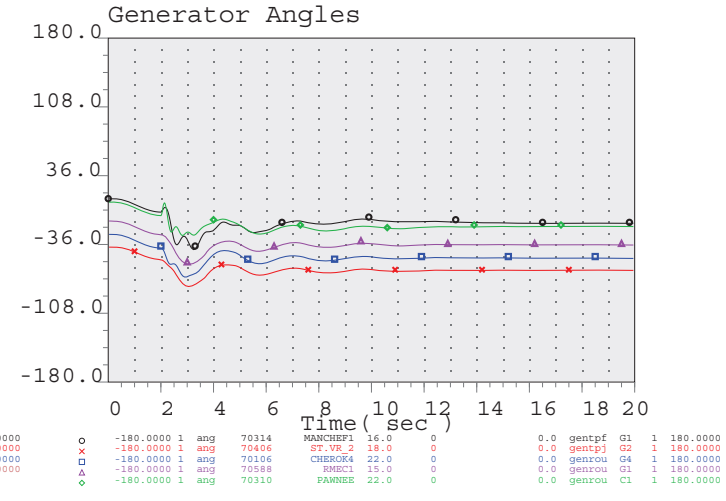
Study Pocket





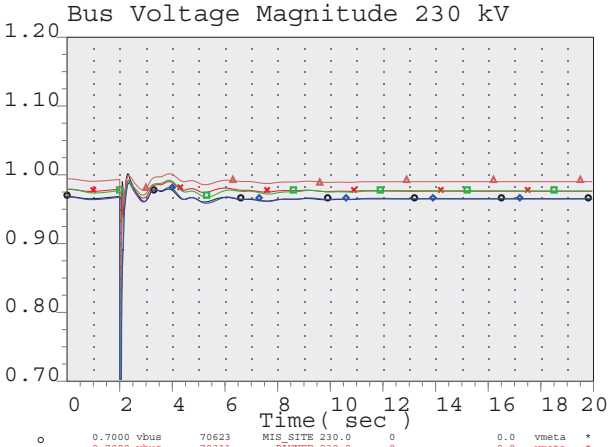






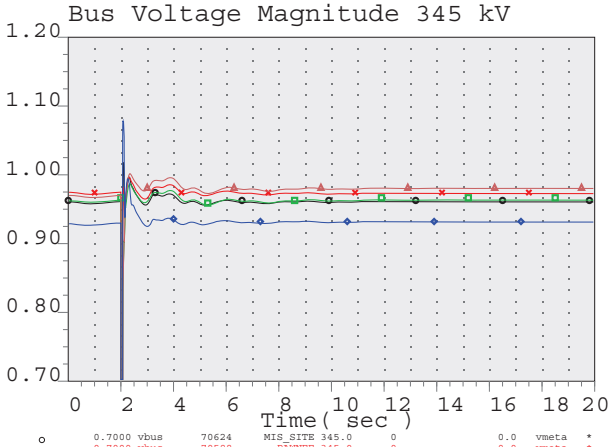
Fault:4-cycle bus fault at Pawnee 345kV
Outage:Pawnee - Missile 345kv Line #1

Bus Voltage Magnitude 230 kV



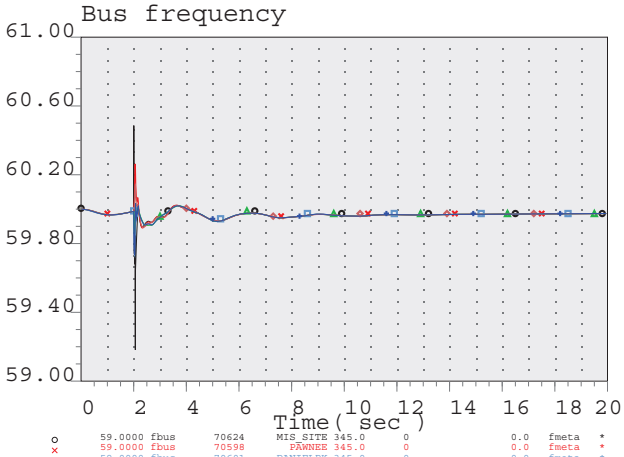
○	0.7000	vbus	70623	MIS_SITE	230.0	0	0.0	vmeta	*	1	1.2000
×	0.7000	vbus	70311	PAWNEE	230.0	0	0.0	vmeta	*	1	1.2000
□	0.7000	vbus	70488	JMSHAFER	230.0	0	0.0	vmeta	*	1	1.2000
△	0.7000	vbus	73192	STORY	230.0	0	0.0	vmeta	*	1	1.2000
◇	0.7000	vbus	70545	BRICKCTR	230.0	0	0.0	vmeta	*	1	1.2000

Bus Voltage Magnitude 345 kV



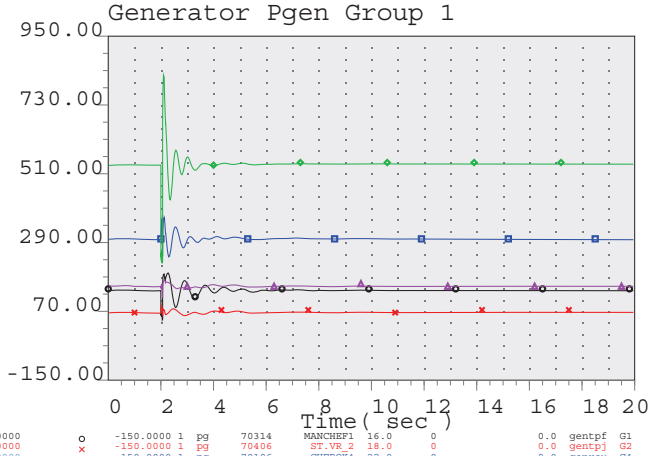
○	0.7000	vbus	70624	MIS_SITE	345.0	0	0.0	vmeta	*	1	1.2000
×	0.7000	vbus	70598	PAWNEE	345.0	0	0.0	vmeta	*	1	1.2000
□	0.7000	vbus	70601	DANIELPK	345.0	0	0.0	vmeta	*	1	1.2000
△	0.7000	vbus	70597	HARVEST_MI	345.0	0	0.0	vmeta	*	1	1.2000
◇	0.7000	vbus	70630	SHORTGRASS	345.0	0	0.0	vmeta	*	1	1.2000

Bus frequency



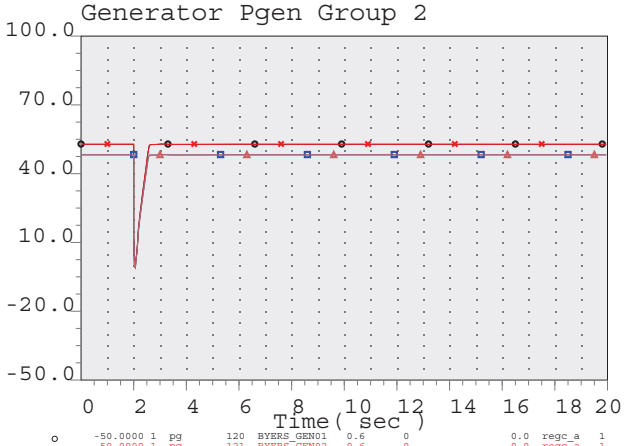
○	59.0000	fbus	70624	MIS_SITE	345.0	0	0.0	fmeta	*	1	61.0000
×	59.0000	fbus	70598	PAWNEE	345.0	0	0.0	fmeta	*	1	61.0000
□	59.0000	fbus	70601	DANIELPK	345.0	0	0.0	fmeta	*	1	61.0000
△	59.0000	fbus	70488	JMSHAFER	230.0	0	0.0	fmeta	*	1	61.0000
◇	59.0000	fbus	73192	STORY	230.0	0	0.0	fmeta	*	1	61.0000
+	59.0000	fbus	70545	BRICKCTR	230.0	0	0.0	fmeta	*	1	61.0000

Generator Pgen Group 1



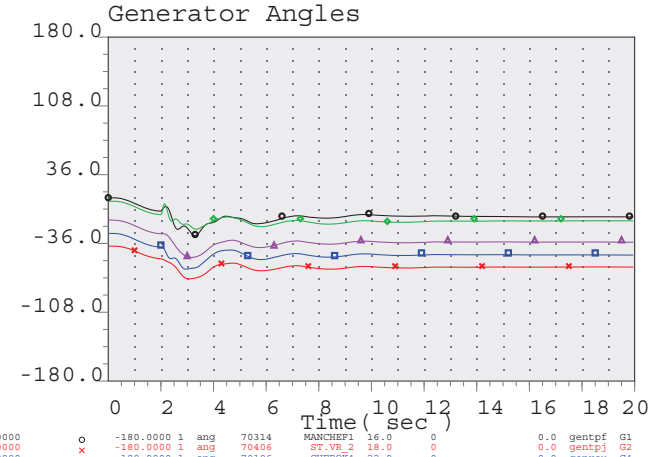
○	-150.0000	1	pg	70314	MANCHEF1	16.0	0	0.0	gentpf	G1	1	950.0000
×	-150.0000	1	pg	70406	ST_VR_2	18.0	0	0.0	gentpj	G2	1	950.0000
□	-150.0000	1	pg	70106	CHEROK4	22.0	0	0.0	genrou	G4	1	950.0000
△	-150.0000	1	pg	70588	RMEC1	15.0	0	0.0	genrou	G1	1	950.0000
◇	-150.0000	1	pg	70310	PAWNEE	22.0	0	0.0	genrou	C1	1	950.0000

Generator Pgen Group 2



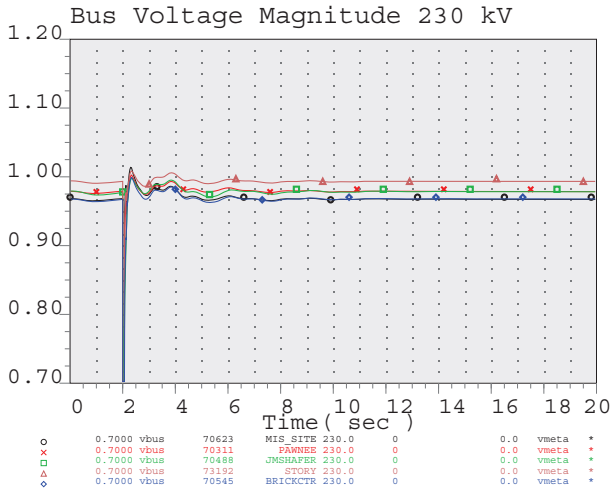
○	-50.0000	1	pg	120	BYERS_GEN01	0.6	0	0.0	regc_a	1	1	100.0000
×	-50.0000	1	pg	121	BYERS_GEN02	0.6	0	0.0	regc_a	1	1	100.0000
□	-50.0000	1	pg	122	BYERS_GEN03	0.6	0	0.0	regc_a	1	1	100.0000
△	-50.0000	1	pg	123	BYERS_GEN04	0.6	0	0.0	regc_a	1	1	100.0000

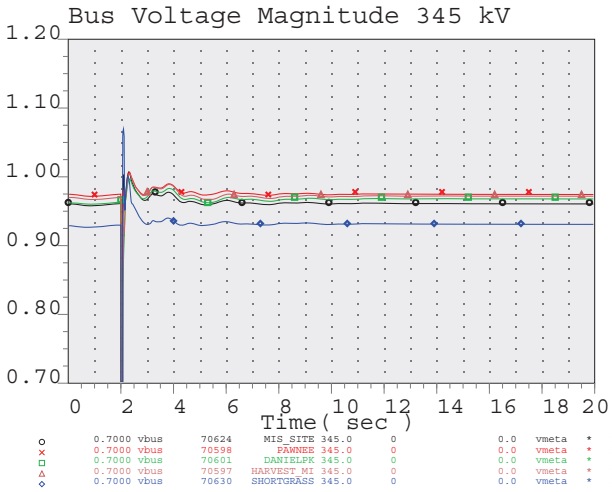
Generator Angles

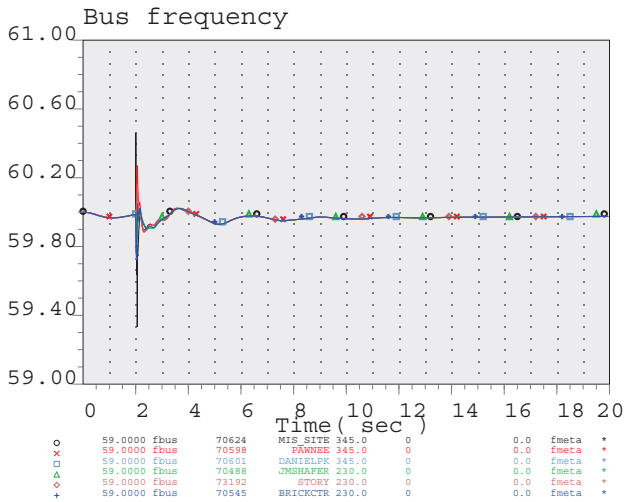


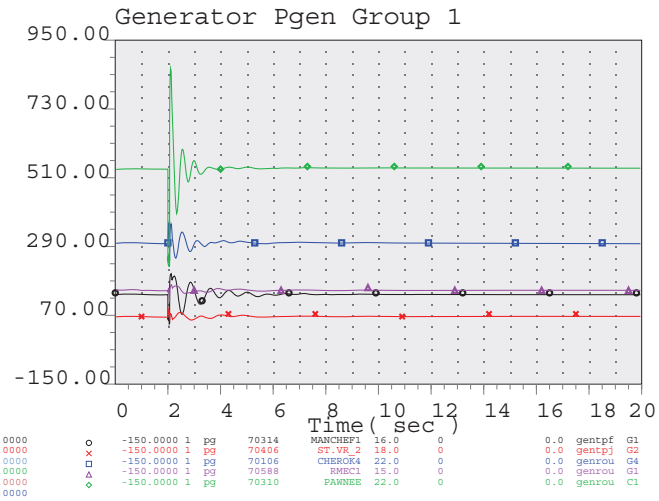
○	-180.0000	1	ang	70314	MANCHEF1	16.0	0	0.0	gentpf	G1	1	180.0000
×	-180.0000	1	ang	70406	ST_VR_2	18.0	0	0.0	gentpj	G2	1	180.0000
□	-180.0000	1	ang	70106	CHEROK4	22.0	0	0.0	genrou	G4	1	180.0000
△	-180.0000	1	ang	70588	RMEC1	15.0	0	0.0	genrou	G1	1	180.0000
◇	-180.0000	1	ang	70310	PAWNEE	22.0	0	0.0	genrou	C1	1	180.0000

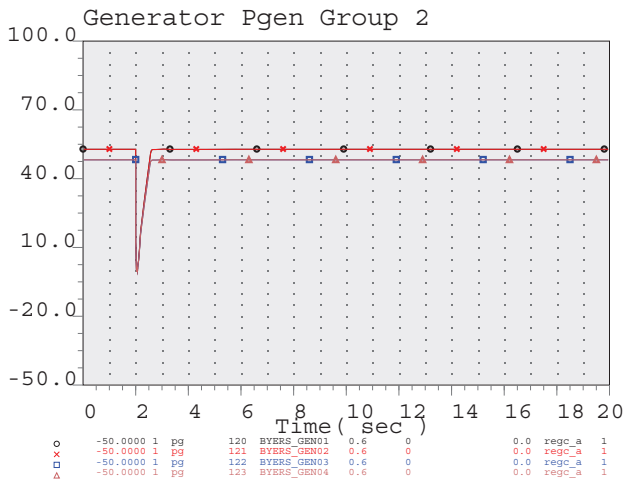
Fault:4-cycle bus fault at Missile 345kV
Outage:Missile - Smoky Hill 345kV Line #1

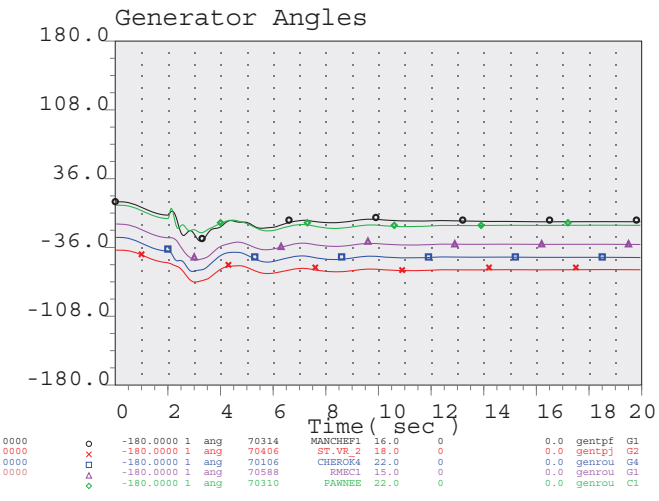




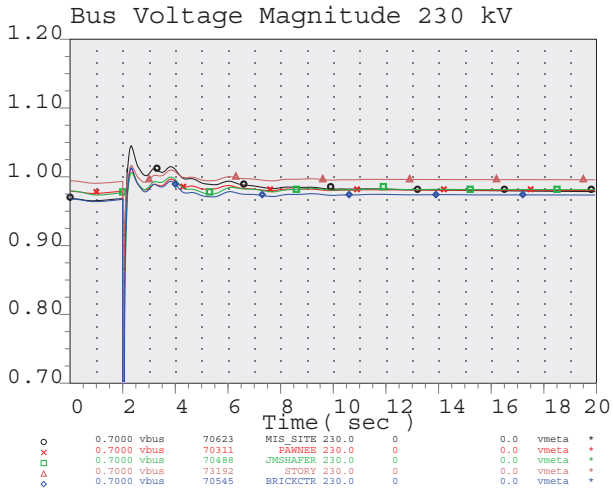


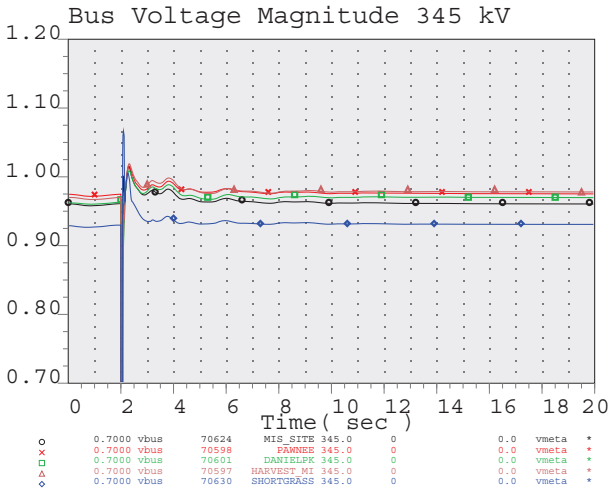


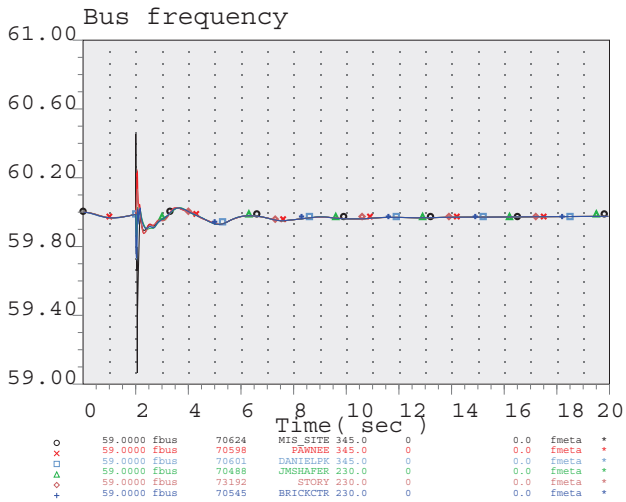


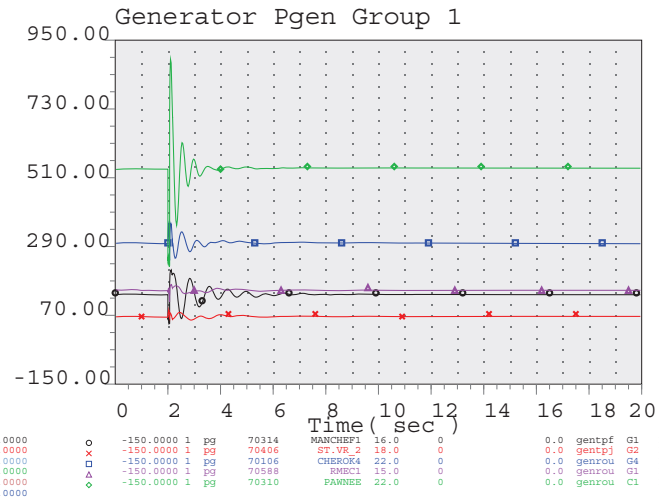


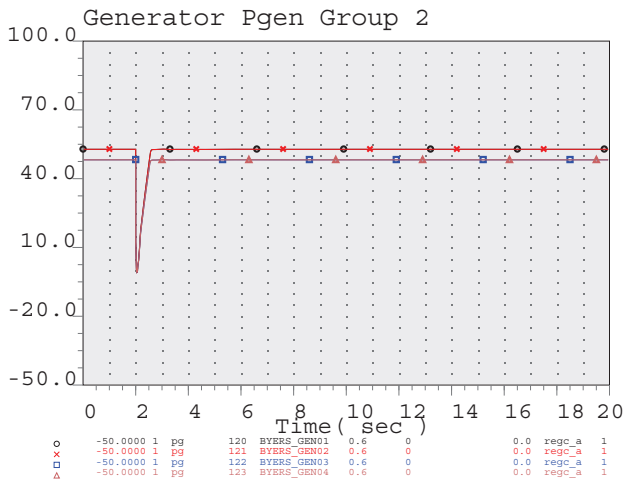
Fault:4-cycle bus fault at Missile 345kV
Outage:Missile - Daniels Park 345kV Line #1

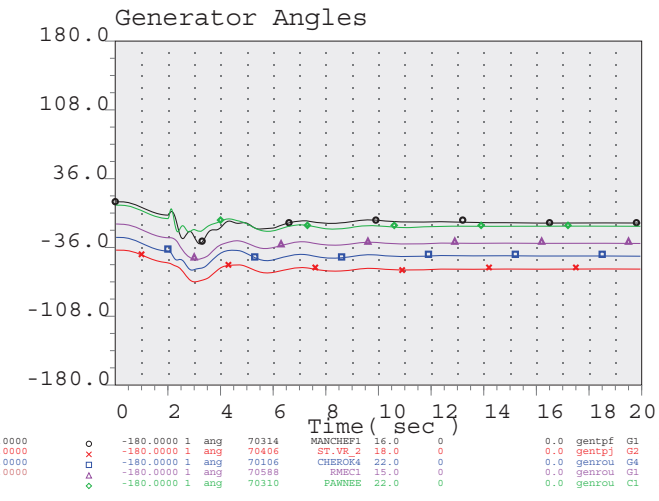




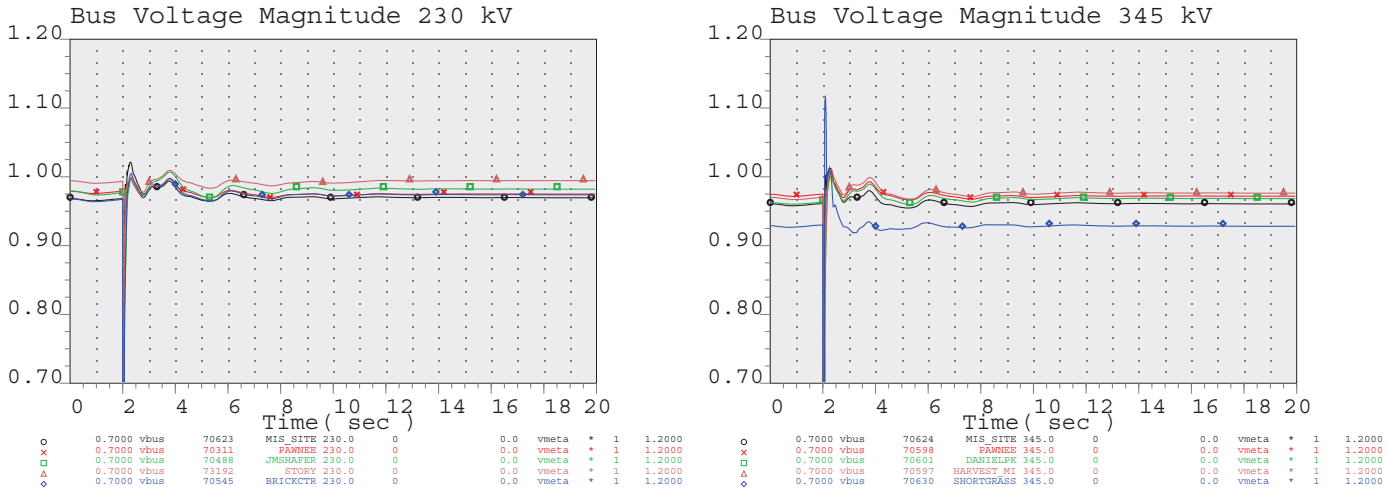


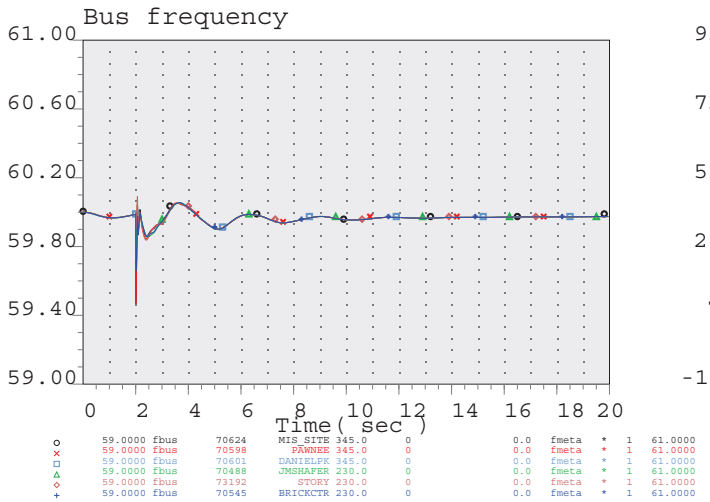


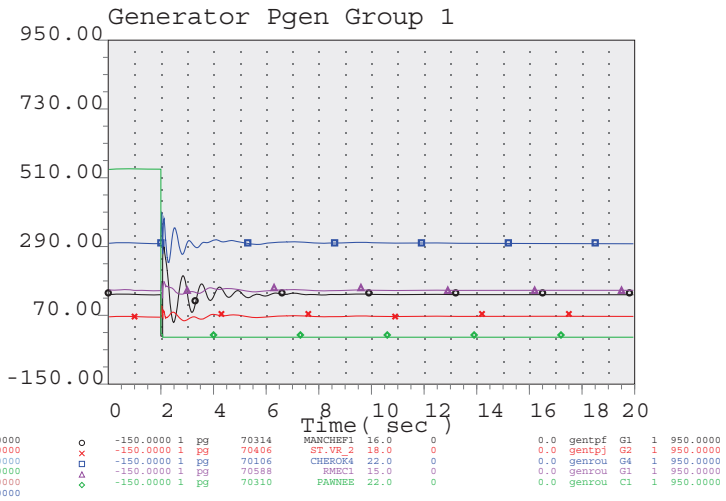


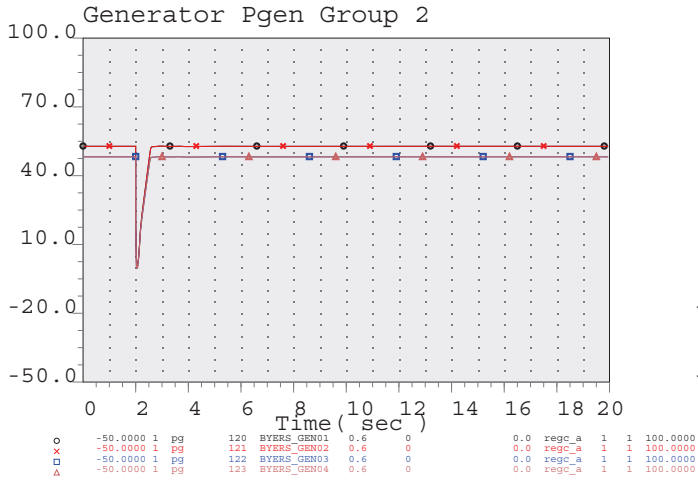


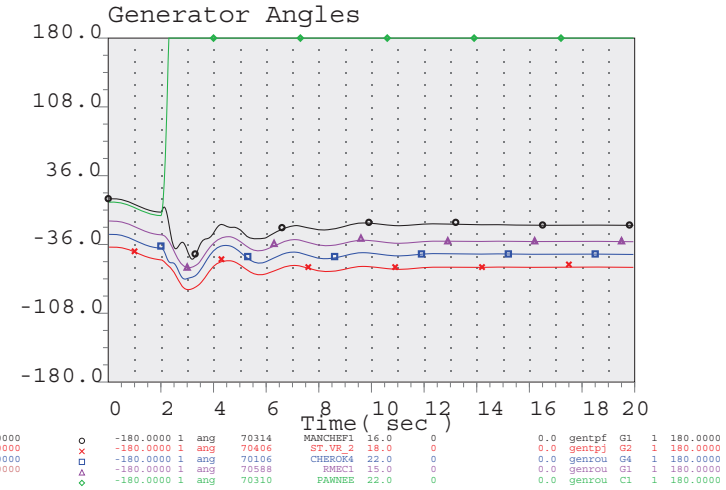
Fault:4-cycle bus fault at Missile 345kV
Outage:Missile 345/230kV Xfmr #1



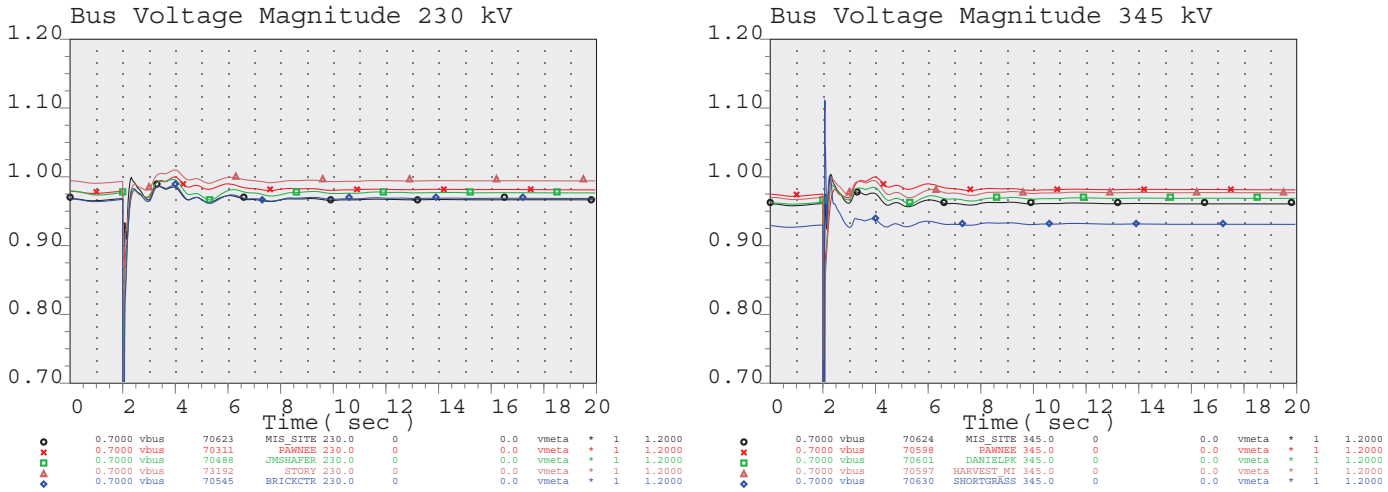


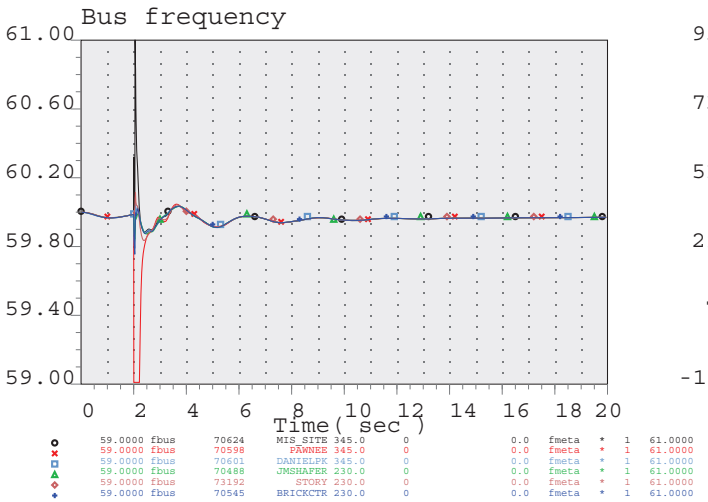


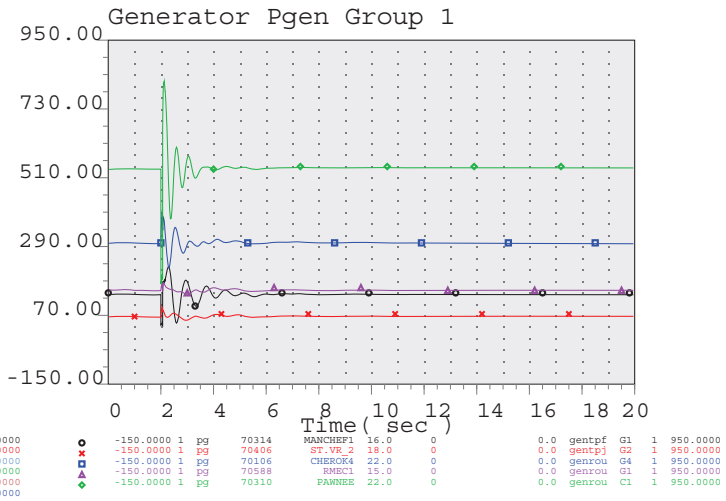


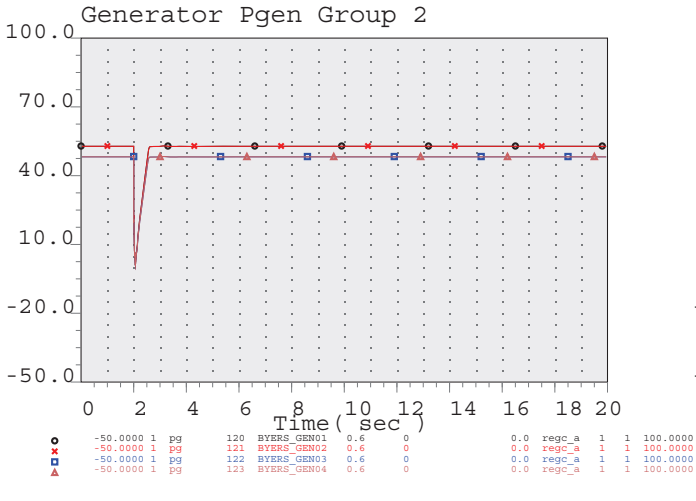


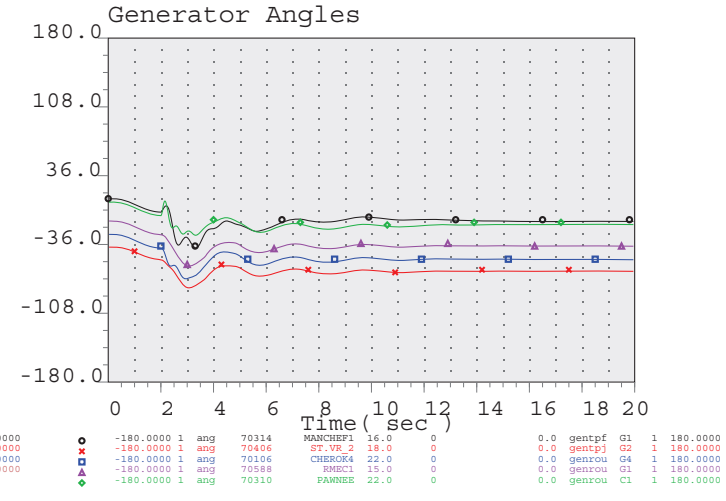
Fault:4-cycle bus fault at Pawnee 230kV
Outage:Pawnee 22/230kV Xfmr #1 and Pawnee generation



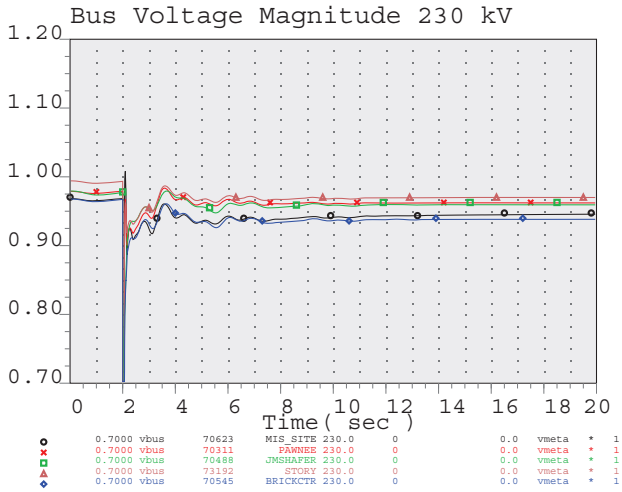


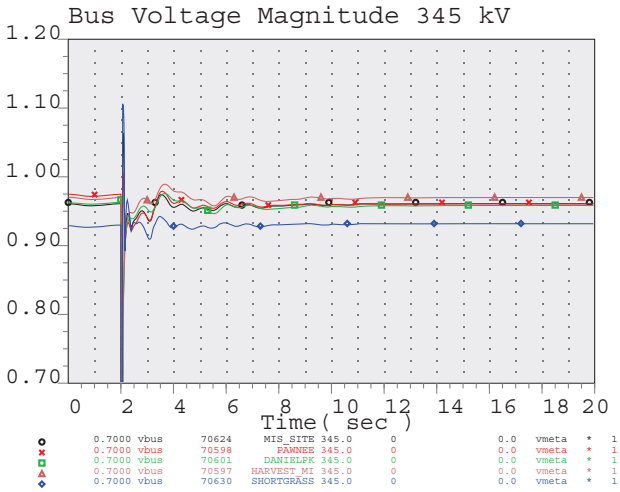


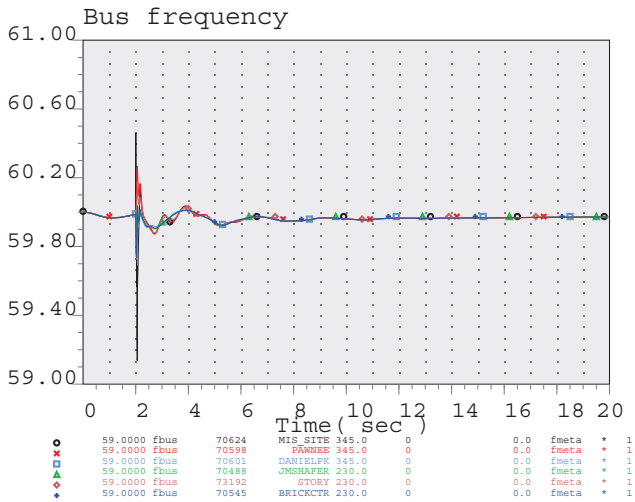


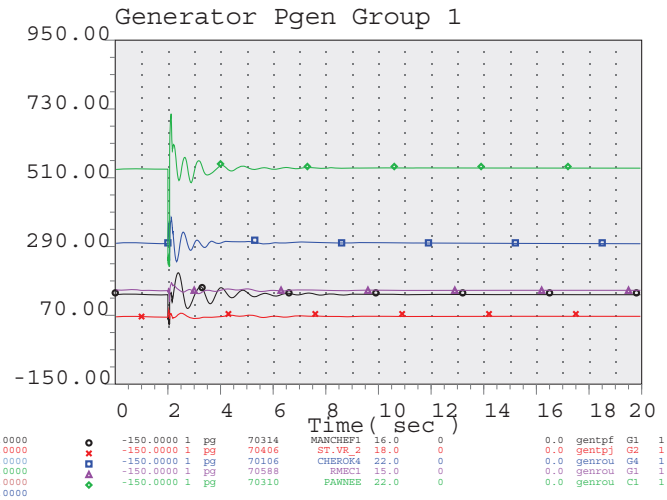


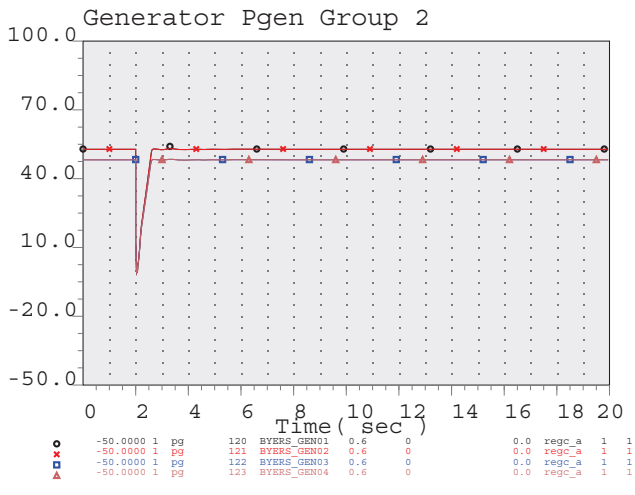
Fault:4-cycle bus fault at Pawnee 345kV
Outage:Pawnee - Missile Lines #1 and #2

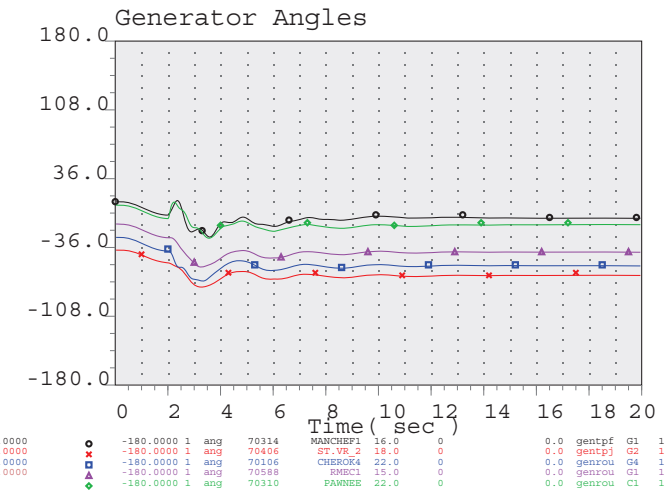












Fault:4-cycle bus fault at Missile 345kV
Outage:Missile - Smoky Hill and Missile - Daniels Park 345kV Lines