Transitional Cluster Study

Report

6/1/2020

Version History

Version	Reason for Update	Date
1.0	Draft before Customer Review	6/1/2020

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1.0 Executive Summary

The Transitional Cluster included two Generator Interconnection Request (GIR)s - GI-2018-24 and GI-2019-6.

GI-2018-24 is a net 250MW$_{ac}$ rated hybrid AC-Coupled Generating Facility requesting Energy Resource Interconnection Service (ERIS). GI-2018-24 also requested 75MW Grid Charging Service as part of the ERIS interconnection. The Point of Interconnection (POI) is a tap on the Comanche – Daniels Park 345kV line.

GI-2019-6 is a net 240MW$_{ac}$ rated Solar Photovoltaic Facility requesting ERIS. The POI is the existing PSCo's Comanche 230kV Substation.

The GIRs are studied under the Southern Colorado study pocket analysis. The studies are performed using the 2023HS Base Case.

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

1.1 GI-2018-24

Energy Resource Interconnection Service granted to GI-2018-24 is: 250MW (after required transmission system improvements in Table 14a and 14b)

The maximum allowable Grid Charging Capacity of the GI-2018-24 is 75MW (at all times of the day).

The total cost of the required Upgrades for GI-2018-24 to interconnect at the Tundra 345kV Switching Station is $16.549 Million

A Certificate of Public Convenience & Necessity (CPCN) will be required to build the new Tundra 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 is approximately 36 months after authorization to proceed has been obtained.

1.2 GI-2019-6

Energy Resource Interconnection Service of GI-2019-6 is: 240MW (after required transmission system improvements in Table 15a and 15b)

The total estimated cost of the transmission system improvements for GI-2019-6 are: **$3.13 Million** (Tables 15a and 15b)

2.0 Introduction

PSCo received three (3) GIRs in the Transitional Cluster out of which two (2) GIRs are considered valid and accepted. The total Interconnection Service requested in the Transitional Cluster is 490MW. These Transitional Cluster requests are identified by their queue numbers - GI-2018-24, and GI-2019-6. Both the GIRs requested ERIS[1]. In addition, GI-2018-24 also requested 75MW Grid Charging Service[2] as part of its 250MW ERIS. A summary of the requests received in the Transitional Cluster is given in Table 1.

Table 1 – Summary of GIRs in the Transitional Cluster

Queue Number	Date Transitional Request Received	Generation Type	Service Type	Location County/State	Interconnection Point Station or Line	Net Plant Max MW Sum | Win	In-Service Date	Comments/Status/Reason Not Completed
GI-2018-24	12/17/2019	Solar/Battery	Energy Resource	Pueblo County, CO	Comanche – Daniels Park 345 kV line	250 250	12/01/2022	Transitional Cluster Study Underway
GI-2019-6	12/17/2019	Solar	Energy Resource	Pueblo County, CO	Comanche 230 kV Line	240 240	06/1/2021	Transitional Cluster Study Underway

3.0 Description of the GIRs

3.1 Description of GI-2018-24

The GI-2018-24 is a 250MW$_{ac}$ net rated AC-coupled Solar Photovoltaic (PV) plus Battery Energy Storage (BES) hybrid Generating Facility that will be located in Pueblo County, Colorado.

This hybrid Generating Facility will consist of two distinct facility groups – 250MW Solar PV facility and 125MW BES facility.

The 250MW Solar PV facility will consist of one-hundred twenty-one (121) GE LV51511 2.3MVA, ±0.90 PF inverters, each with its own 600V/34.5kV, 2.3MVA, Z=6.0% pad-mounted step-up transformer. The 125MW BES facility will consist of fifty-seven (57) Parker 890-GTB2200 2.2MVA, 1.0 (unity) PF inverters, each with its own 480V/34.5kV, 2.2MVA, Z=6% pad-mounted step-up transformer. The Customer has confirmed that the Parker inverters are capable of

[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] Grid Charging Service shall mean the charging mode of operation of the BES Generating Facility. Grid Charging Service is part of Interconnection Service for a Storage asset and does not include Auxiliary load for station service. Grid Charging Service is evaluated consistent with the type of interconnection service requested, i.e., NRIS or ERIS.

±0.95PF inverters even though the manufacturer data sheet specifies 1.0 (unity) PF. The 34.5kV collector system of the PV and BES generators will connect to one 34.5/345kV, 255/340/425MVA, Z=8.5% main step-up transformer which will connect to PSCo's Comanche – Daniels Park 345kV line via a 0.1 mile generation tie-line.

The tap position on the Comanche – Daniels Park 345kV line will require building a new Switching Station referred to as "Tundra 345kV Switching Station", at approximately 10 miles from the Comanche Substation.

The net output of GI-2018-24 will not exceed 250MW at any time, which will be limited using the Plant Power Controller. The GI-2018-24 will operate the PV and BES generating facilities in back-feed voltage control mode. The expected operating modes of GI-2018-24 are:

i. 250MW rated generation output at the Point of Interconnection (POI) via combination of PV and BES ("Generation mode")
ii. 75MW rated load at the POI for a maximum of 4 hours when PV output is 0MW. The BES facility will not charge from the grid, i.e., act as a load during the first five (5) years and three (3) months of the Commercial Operation Date (COD), but it may utilize grid charging after that period ("Grid Charging")

The proposed Commercial Operation Date (COD) of GI-2018-24 is December 31, 2022. For the study purpose, the back-feed date is assumed to be July 1, 2022, approximately six (6) months before the COD.

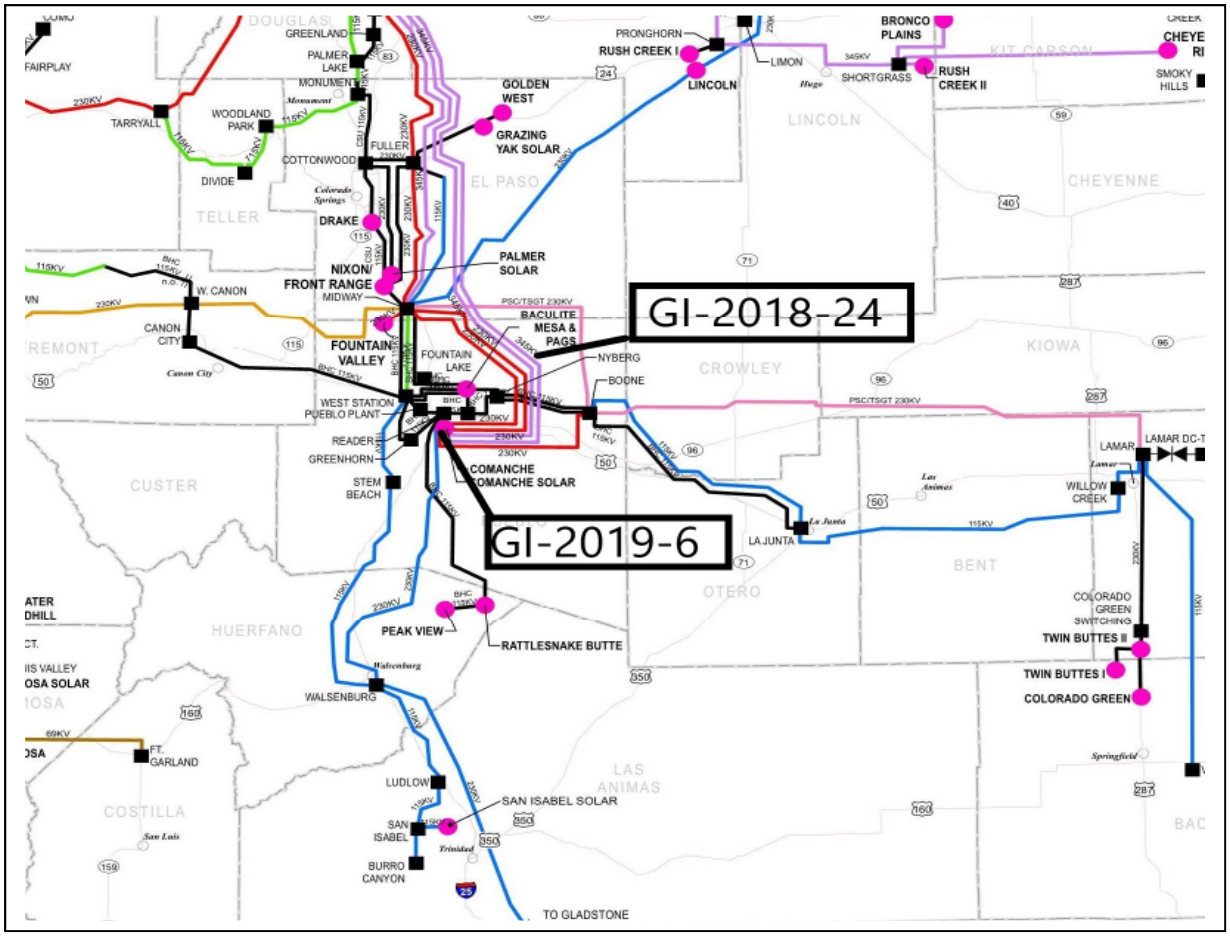
3.2 Description of GI-2019-6

The GI-2019-6 is a 240MW$_{ac}$ net rated Solar PV Generating Facility that will be located in Pueblo County, Colorado. The Generating Facility will be composed of eighty-four (84) Sungrow 250HX-US 3.15MVA, ±0.8PF inverters arranged in two arrays. Each inverter will consist of 630V/34.5kV, 3.15MVA, Z=6% pad-mounted step-up transformer. The two 34.5kV collector systems arrays will connect to one (1) 159/212/265MVA, 34.5/230/13.8kV wye-wye-delta, Z=8% main step-up transformer. The POI requested is PSCo's Comanche 230kV Substation. The Generating Facility also installs a 20Mvar (2 steps of 10Mvar) Capacitor banks on the 34.5kV collector system. The GI-2019-6 will connect to the POI via a 50 foot 230kV transmission line.

The proposed COD of GI-2019-6 is June 1, 2021. For the study purpose, the back-feed date for is assumed to be December 1, 2020, approximately six (6) months before the COD.

The approximate locations of all the GIRs in the Transitional Cluster and the surrounding transmission system are shown in Figure 1 below

Figure 1 – Approximate Locations of the POIs of the GIRs in the Transitional Cluster



4.0 Study Scope

The purpose of the study is to determine the system impact of interconnecting all the GIRs in the Transitional Cluster for simultaneous Interconnection Service. The Interconnection Service requested by each GIR is given in Table 1.

This study report also determined the maximum permissible Grid Charging Service that can be allotted to GI-2018-24 (out of the 75MW requested). The Grid Charging Service is evaluated per the corresponding generator's interconnection service type. Since GI-2018-24 requested ERIS, the Grid Charging Service only identifies the maximum permissible Grid Charging before Network Upgrades are required.

The scope of the study includes steady state (thermal and voltage) analysis, transient stability analysis, short circuit analysis, and appropriation level cost estimates. The cost estimates provide total costs and each GIR cost responsibility for Transmission Provider Interconnection Facilities and Network Upgrade costs.

The steady state analysis identifies thermal and voltage violations in the PSCo system and the neighboring systems using the study criteria in Section 4.2 and study methodology in Section 4.3. The transient stability analysis verifies that all generating units within the PSCo transmission system and the neighboring systems remain stable (in synchronism), have positive damping (angle and voltage) and satisfy acceptable dynamic performance criteria. The study criteria and study methodology for transient stability analysis are given in Section 4.2 and Section 4.3 respectively. The short circuit analysis determines the maximum available fault current at the POI and identifies if any circuit breaker(s) within the PSCo station(s) exceed their breaker duty ratings. The study criteria and study methodology for short circuit analysis are given in Section 4.2 and Section 4.3 respectively.
The study also identifies the Contingent Facilities applicable to each GIR in the Transitional Cluster.

4.1 Study Pocket Determination

As shown in Figure 1, all GIRS in the Transitional Cluster are in the Southern Colorado region and fall under the "Southern Colorado" study pocket. Hence the Transitional Cluster study analysis is based on the Southern Colorado study pocket analysis only.

4.2 Study Criteria

PSCo adheres to applicable NERC Reliability Standards and WECC Reliability Criteria, as well as its internal transmission planning criteria for studies. The following Criteria is used for the reliability analysis of the PSCo system and neighboring utility systems.

4.2.1 Steady-State Criteria

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

4.2.2 Transient Stability Criteria

Transient Voltage Stability Performance Criteria:

a. Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds of the initiating event for all P1 through P7 events for each applicable 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.

Transient Angular Stability Performance Criteria:

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.

4.2.3 Breaker Duty Analysis Criteria

Fault Current after GIR addition should not exceed 100% of the Breaker Duty rating. 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.

4.3 Study Methodology

The steady state assessment is performed using PSSE V33 and the ACCC tool. The transient stability assessment is performed using GE PSLF DYTOOLs.

The short circuit analysis is performed using CAPE.

4.3.1 Steady State Assessment methodology

The thermal and voltage violations are identified by running the same set of contingencies on the Benchmark Case and the Study Case and comparing the results. The violations identified in each Study pocket analysis are attributed to the GIRs in that Study Pocket.

For PSCo facilities, thermal violations attributable to the Study Pocket GIRs include any facilities without a pre-existing thermal violation that (i) resulted in a thermal loading >100% post the Study Pocket GIR cluster addition and (ii) contributed to an incremental loading increase of 2% or more to the benchmark case loading. Pre-existing thermal violations on the PSCo system are attributed to the Study Pocket if the overloads increased by 1% or more. The Study Pocket thermal violations are then attributed to individual GIRs in the Study Pocket by calculating their individual contributions using DFAX criteria.

DFAX contribution criteria for identifying thermal overloads applicable to each GIR: ≥1%

For non-PSCo facilities, thermal violations attributed to the Study Pocket GIRs include all new facility overloads with a thermal loading of >100% and existing thermal overloads that increased by 1% or more from the benchmark case overload post the Study Pocket GIR Cluster addition.

Any non-PSCo facility overloads are identified as Affected System violations in the study, except if the violation is attributable to an ERIS request.

The voltage violations assigned to the Study Pocket GIR Cluster include new voltage violations which resulted in a further variation of 0.1 per unit. The voltage violations are attributed to individual GIRs in the Study Pocket by calculating their individual contributions (0.005 per unit or higher) to the violations.

DFAX contribution criteria for identifying voltage violations applicable to each GIR: 0.005 p.u.

Any non-PSCo system voltage violations are identified as Affected System violations in the study, except if the violation is attributable to an ERIS request.

4.3.2 Transient Stability Study Methodology:

All generators in the Study Pocket should meet the Transient stability criteria. If any violations are found, the contributing GIR(s) will be identified for performance violations and mitigations will be attributed to the contributing generator(s).

4.3.3 Contingency Analysis Area

The transmission system on which steady state contingency analysis is run includes the WECC designated areas 70 and 73, and WECC designated zone 121.

The following worst case contingencies are considered for the Southern Colorado study pocket transient stability analysis:

- 3-phase fault at Boone 230kV bus, loss of Boone 230/115kV transformer
- 3-phase fault at Boone 230kV bus, loss of Lamar – Boone 230kV line and all generation at Lamar
- 3-phase fault at Boone 230kV bus, loss of Boone – Comanche 230kV line
- 3-phase fault at Boone 230kV bus, loss of Boone – Midway 230kV line
- 3-phase fault at Comanche 345kV, loss of Comanche # 3 generator
- 3-phase fault at Lamar 230kV, loss of Lamar – Boone 230kV line and all generation at Lamar
- 3-phase fault at Midway 230kV bus, loss of all Fountain Valley gas units
- 3-phase fault at Midway 345kV bus, loss of Midway – Waterton 345kV line & Midway 230/345kV transformer
- 3-phase fault at Comanche 345kV bus, loss of Comanche – Daniels Park 345kV line 1 & 2

- 3-phase fault at Daniels Park 345kV bus, loss of Comanche – Daniels Park 345kV line 1 & 2

4.4 Study Area(s) considered for the Transitional Cluster GIR

The study area or monitored area is the electrical system consisting of PSCo's transmission system and the neighboring transmission systems that may be impacted by or that could impact interconnection of the Study Pocket GIR(s).

4.4.1 Southern Pocket Study Area

The Study Area for the Southern Study pocket includes WECC designated zones 121, 700, 703, 704, 705, 709, 710, 712, 752 and 757. The neighboring utilities 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) systems in the study area.

5.0 Base Case Modeling Assumptions

The 2023HS case developed for the 2019 Colorado Coordinated Planning Group TPL1-4 studies is selected as the starting case. The case was reviewed by PSCo and neighboring utilities within the Colorado Coordinated Planning Group (CCPG) footprint and updates are incorporated. The base case year selected is consistent with the COD of GI-2018-24. Although GI-2019-6 requested a 2021 COD, there are no major system changes expected in the Southern Colorado study pocket between 2021 and 2023, so using the 2023HS case is acceptable.

5.1 Base Case Modeling

The Base Case is created from the starting case by including the following un-built transmission projects. All transmission planned projects in PSCo's 10 year transmission plan that are expected to be in-service before July 2023, and have internal approval are modeled in the Base Case.
The PSCo planned projects are described at:
http://www.oasis.oati.com/woa/docs/PSCO/PSCOdocs/FERC_890_Q1_2020_Transmission_Plan_Presentation.pdf
The PSCo projects modeled in the Base Case include the following:

- Cloverly 115kV Substation – ISD 2021
- Graham Creek 115kV Substation – ISD 2022
- Husky 230/115kV Substation – ISD 2022

- Ault – Husky 230kV line – ISD 2022
- Husky – Graham Creek – Cloverly 115kV line – ISD 2022
- Monument – Flying Horse 115kV Series Reactor – ISD 2021
- Avery Substation – ISD 2021
- High Point Substation –ISD 2022
- Titan Substation – ISD 2022
- Gilman – Avon 115kV line – ISD 2022
- Upgrade Villa Grove – Poncha 69kV Line to 73MVA – ISD 2021
- Upgrade Poncha - Sargent - San Luis Valley 115kV line to 120MVA – ISD 2021

All transmission facilities are modeled at their expected ratings for 2023 Summer season. Also, the following facilities are modeled at their planned future ratings:

- Upgrade Allison – SodaLakes 115kV line to 318MVA – ISD 2021
- Upgrade Buckley34 – Smokyhill 230kV line to 506MVA – ISD 2021
- Upgrade Daniels Park – Priarie1 230kV line to 576MVA – ISD 2021
- Upgrade Greenwood – Priarie1 230kV line to 576MVA – ISD 2021
- Upgrade Daniels Park – Priarie3 230kV line to 576MVA – ISD 2021
- Upgrade Greenwood – Priarie3 230kV line to 576MVA – ISD 2021
- Upgrade Midway 230kV bus tie to 576MVA – ISD 2023
- Upgrade Waterton – Martin2 tap 115kV line to 189MVA – ISD 2021
- Upgrade Dainels Park 345/230kV # T4 to 560MVA – ISD 2021
- Upgrade Leetsdale – Monaco 230kV line to 560MVA – ISD 2021
- Upgrade Greenwood – Monaco 230kV line to 560MVA – ISD 2021
- Comanche – GI-2014-9 – MidwayPS 230kV line to 478MVA
- Upgrade Waterton – Martin1 tap 115kV line to 189MVA – ISD 2023

The Base Case model includes the existing PSCo generation resources. In addition, the following higher-queued generation which have an LGIA are modeled in the Base Case: GI-2009-8, GI-2014-2, GI-2014-6, GI-2014-8, GI-2014-9, GI-2014-12 and GI-2014-13. While the higher-queued NRIS requests are dispatched at 100% nameplate, the higher-queued ERIS requests are modeled offline.

The following Network Upgrade assigned to the higher-queued generation is also modeled in the Base Case:

- MidwayPS 230/115kV, 100MVA transformer replaced with 150MVA unit – Network Upgrade assigned to GI-2014-12.

5.1.1 Affected System Model

The following additional changes were made to the TSGT model in the Base Case per further review and comment from TSGT:

- 100MW TSGT_0809 solar facility tapping Gladstone – Walsenburg 230kV line – ISD 2023
- Fuller – Vollmer – Black Squirrel 115 kV line modeled at 173 MVA – ISD 2022
- Fuller 230/115kV, 100MVA #2 transformer – ISD 2023

The following additional changes were made to the Black Hills Energy (BHE) model in the Base Case per further review and comment from BHE:

- Fountain Valley – DesertCove 115kV line was modeled at 222MVA. ISD 1/2021
- Fountain Valley – MidwayBR 115kV line was modeled at 222MVA. ISD 1/2021
- Pueblo West Substation – ISD 1/2021
- Skyline Ranch Substation – ISD 10/2021
- West Station – Greenhorn 115kV line Rebuild – ISD 9/2022

The following additional changes were made to the Colorado Springs Utilities (CSU) model in the Base Case per further review and comment from CSU:

- 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
- Grazing Yak Solar – ISD 2020
- Briargate S 115/230kV transformer project tapping the Cottonwood – Fuller 230kV line – ISD 2023

6.0 Generation Interconnection Service Analysis

Since the Transitional Cluster GIRs fall in one study pocket only, the Generation Interconnection Service analysis is based on the Southern Colorado study pocket results.

6.1 Voltage and Reactive Power Capability Evaluation

All GIRs received in the Transitional Cluster are non-Synchronous generators, accordingly, the following voltage regulation and reactive power capability requirements at the POI are applicable to each GIR:

- Xcel Energy's OATT requires all non-synchronous Generator Interconnection Customers to provide dynamic reactive power within the power factor range of 0.95 leading to 0.95 lagging at the high side of the generator substation. Furthermore, Xcel Energy requires every Generating Facility to have dynamic voltage control capability to assist in maintaining the POI voltage schedule specified by the Transmission Operator.
- It is the responsibility of the Interconnection Customer to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (MVAR), and the locations (on the Interconnection Customer's facility) of any additional static reactive power compensation needed within the generating plant in order to have adequate reactive capability to meet the +/- 0.95 power factor at the high side of the main step up transformer/POI. Finally, it is the responsibility of the Interconnection Customer to compensate their generation tie-line to ensure minimal reactive power flow under no load conditions.

The reactive power analysis looks for the capability of the GIR to maintain ±0.95pf at the high side of the main step-up transformer and maintain normal steady state operating voltage range (0.95-1.05 p.u.) at the POI. All GIRs are required to design their interconnection to meet the POI voltage control requirements that will be specified by PSCo's Transmission Operations group.

The Interconnection Customer is required to demonstrate to the satisfaction of PSCo's Transmission Operations group prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and the regulating voltage of the POI.

6.1.1 GI-2018-24 Reactive Capability Evaluation:

The analysis indicates that GI-2018-24 is capable of maintaining ±0.95pf at the generator terminal and high side of the main step-up transformer, while staying within 0.95-1.05p.u. voltage at the POI for 100%, 10% and 0% output levels. According to the Interconnection Customer, GI-2018-24 hybrid Generating Facility will operate in back-feed voltage control mode, so PV and BES generator capabilities are not evaluated individually.

Table 2 Reactive capability evaluation of GI-2018-24

Gen MW(PV&BESS) / Mvar (PV&BESS)	Gen Voltage (PV/BESS) (p.u.) -	Main Step-up Transformer High Side				POI			
		Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor

250MW / -176Mvar	0.874 / 0.866	0.979	244	-243.8	0.707 (lead)	0.979	244	-243.8	0.707 (lead)
250MW / 176Mvar	1.127 / 1.14	1.046	246.5	137.7	0.873 (lag)	1.046	246.5	137.7	0.873 (lag)
25MW / 6.6Mvar	1.022 / 1.024	1.017	24.9	8.2	0.950 (lag)	1.017	24.9	8.2	0.950 (lag)
25MW / -10Mvar	1.011 / 1.01	1.015	24.9	8.2	0.950 (lag)	1.015	24.9	8.2	0.950 (lag)
0MW / -87Mvar	0.958 / 0.935	1	-0.4	-89.9	N/A	1	-0.4	-89.9	N/A

6.1.2 GI-2019-6 Reactive Capability Evaluation:

The analysis indicates that GI-2019-6 is capable of maintaining ±-0.95pf at the generator terminals and high side of the main step-up transformer, while staying within 0.95-1.05p.u. voltage at the POI for 100%, 10% and 0% output levels.

Table 3 - Reactive Capability Evaluation of GI-2019-6

Gen MW / Mvar	20 Mvar Shunt Status	Gen Voltage (p.u.)	Main Step-up Transformer High Side				POI			
			Voltage (p.u.)	MW	Mvar	Power Factor	Voltage (p.u.)	MW	Mvar	Power Factor
240 MW / -104.6Mvar	off	0.938	1.024	237.3	-161.5	0.827 (lead)	1.024	237.3	-161.5	0.827 (lead)
240 MW / 104.6Mvar	on	1.137	1.048	239	89.7	0.936 (lag)	1.048	239	89.7	0.936 (lag)
24.3MW / -12.2Mvar	off	1.034	1.039	24.3	-8.0	0.95 (lead)	1.039	24.3	-8	0.95 (lead)
24.3MW / 3.8Mvar	off	1.047	1.040	24.3	8.0	0.95 (lag)	1.040	24.3	8	0.95 (lag)
0MW / -104.6Mvar	off	0.946	1.029	-0.9	-109.6	N/A	1.029	-0.9	-109.6	N/A

6.2 Southern Colorado Study Pocket Analysis

6.2.1 Benchmark Case Modeling

The Benchmark Case for evaluating the Southern Colorado study pocket GIRs is developed from the Base Case described in Section 5.1 of this report by changing the study pocket generation dispatch to reflect a heavy south to north flow on the Comanche – Midway – Jackson Fuller –

Daniels Park transmission system. This was accomplished by adopting the generation dispatch given in Table 4 for the Southern Colorado study pocket. The generation dispatch of the neighboring systems was provided by the neighboring utilities.

Table 4 – Generation Dispatch Used to Stress the Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
APT_DSLS 4.16	G1	0	0	10	BHE
BAC_MSA GEN1 13.8	G1	1	59.4	90	BHE
BAC_MSA GEN2 13.8	G1	1	59.4	90	BHE
BAC_MSA GEN4 13.8	G1	1	26.4	40	BHE
BAC_MSA GEN4 13.8	G2	1	26.4	40	BHE
BAC_MSA GEN4 13.8	S1	1	16.4	24.8	BHE
BAC_MSA GEN5 13.8	G1	1	26.4	40	BHE
BAC_MSA GEN5 13.8	G2	1	26.4	40	BHE
BAC_MSA GEN5 13.8	S1	1	16.4	24.8	BHE
BAC_MSA GEN6 13.8	G1	1	26.4	40	BHE
BUSCHRNCH_LO 0.7	1	1	35.2	60	BHE
BUSCHRWTG1 0.7	G1	1	16.9	28.8	BHE
E_CANON 69	G1	0	0	8	BHE
PP_MINE 69	G1	0	0	3	BHE
PUB_DSLS 4.16	G1	0	0	10	BHE
R.F.DSLS 4.16	G1	0	0	10	BHE
RTLSNKWNDLO 0.7	G1	1	35.2	60	BHE
ALMSACT1 13.8	G1	0	0	17	PSCo
ALMSACT2 13.8	G2	0	0	14	PSCO
COGENTRIX_PV 34.5	S3	1	19.5	30	PSCO
COMAN_1 24	C1	1	360	360	PSCO
COMAN_2 24	C2	1	365	365	PSCO
COMAN_3 27	C3	1	788	788	PSCO
COMAN_PV 34.5	S1	1	102	120	PSCO
CO_GRN_E 34.5	W1	1	64.8	81	PSCo
CO_GRN_W 34.5	W2	1	64.8	81	PSCo
FTNVL1&2 13.8	G1	1	36	40	PSCO

FTNVL1&2 13.8	G2	1	36	40	PSCO
FTNVL3&4 13.8	G3	1	36	40	PSCO
FTNVL3&4 13.8	G4	1	36	40	PSCO
FTNVL5&6 13.8	G5	1	36	40	PSCO
FTNVL5&6 13.8	G6	1	36	40	PSCO
GSANDHIL_PV 34.5	S1	1	12.4	19	PSCO
JKFULGEN 0.69	W1	1	199.5	249.4	PSCO
LAMAR_DC 230	DC	0	0	210	PSCO
SOLAR_GE 34.5	S2	1	19.5	30	PSCO
SUNPOWER 34.5	S1	1	33.8	52	PSCO
TWNBUTTE 34.5	W1	1	60	75	PSCO
SI_GEN 0.6	1	1	24	30	TSGT
TBII_GEN 0.69	W	1	60	76	TSGT
TSGT_0809 0.62	PV	1	80	100	TSGT
GI-2009-8 34.5	S1	1	30	30	PSCO
GI-2014-2 34.5	S1	0	0	35	N/A
GI-2014-12 34.5	S9	1	53	53	PSCO
GI-2014-13 34.5	S1	0	0	52	N/A
GI-2014-6 34.5	S1	1	100	100	PSCO
GI-2014-8 34.5	1	1	60	60	PSCO
GI-2014-9 34.5	W1	1	70	70	PSCO

6.2.2 Study Case Modeling

The Study Case is created from the Benchmark Case by modelling the GI-2018-24 and GI-2019-6 at the Tundra 345kV Switching Station and the Comanche 230kV Substation POIs respectively, using the GIR modelling data provided by the Interconnection Customer. The output of the two GIRs is sunk to the PSCo Fort Saint Vrain Generation in the Northern Colorado.

6.2.3 Steady State Analysis

The results of the single contingency analysis (P1 and P2-1) are given in Table 5 below.

Table 5 Power Flow Analysis Results of Southern Colorado Study Pocket GIRs – Overloads Identified Under Single Contingency Analysis

Overloaded Facility	Type	Owner	Facility Normal Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to Study Pocket GIRs	Single Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Daniels Park – Prairie 1 230kV # 1	Line	PSCo	576	511.5	88.8%	593.3	103.0%	14.2%	Daniels Park – Prairie 3 230kV # 1
Daniels Park – Prairie 3 230kV # 1	Line	PSCo	576	506.3	87.9%	588.1	102.1%	14.2%	Daniels Park – Prairie 1 230kV # 1
Palmer Lake – Monument 115kV # 1	Line	CSU	108	110.1	101.9%	132.6	122.8%	20.9%	Daniels park – Fuller 230kV # 1

For the stressed generation dispatch used in Table 4, the addition of Southern Pocket GIs (GI-2018-24 and GI-2019-6) resulted in two new overloads in the PSCo system and an increase in the overload on CSU's Palmer Lake – Monument 115kV line.

Table 6 Power Flow Analysis Results of Southern Colorado Study Pocket GIRs – Overloads Identified Under Multiple Contingencies

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading Without Southern Pocket GIRs		Facility Loading With Southern Pocket GIRs		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Kelker West – Rock Island 115kV # 1	Line	CSU	180	186.7	103.7%	188.8	104.9%	1.2%	P4: Cottonwood 230kV Bus tie

Fountain South – RD Nixon 115kV # 1	Line	CSU	212	242.1	114.2%	248.9	117.4%	3.2%	P7: Frontrange – Kelker South 230kV line #1 & Kelker North – RD Nixon 230kV line # 1
Black Forest Tap – Black Squirrel 115kV # 1	Line	TSGT	173	175.8	101.6%	195.8	113.2%	113.2%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Fuller 230/115kV # 1	Xfmr	TSGT	100	95.4	95.4%	104.7	104.7%	9.3%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Fuller 230/115kV # 2	Xfmr	TSGT	100	95.4	95.4%	104.7	104.7%	9.3%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Gresham – Black Forest Tap 115kV # 1	Line	TSGT	173	166.3	96.1%	190.1	109.9%	13.8%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Midway PS – Midway WAPA 230kV	Line	PSCo / WAPA	576	606.0	105.2%	708.5	123.0%	17.8%	P7: Midway – Waterton 345kV Line #1 & Midway – Fuller 230kV Line # 1
Monument – Gresham 115kV # 1	Line	TSGT	145	162.3	111.9%	186.0	128.3%	16.4%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Palmer Lake – Monument 115kV # 1	Line	PSCo / CSU	108	172.0	159.3%	202.4	187.4%	28.1%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Vollmer – Black Squireel 115kV # 1	Line	TSGT	173	201.5	116.5%	225.9	130.6%	14.1%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Vollmer – Fuller 115kV #1	Line	TSGT	173	202.2	116.9%	227.0	131.2%	14.3%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Comanche – Midway 230kV # 1	Line	PSCo	478	393.9	82.4%	510.0	106.7%	24.3%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Comanche – GI-2014-9 230kV # 2	Line	PSCo	478	372.4	77.9%	503.8	105.4%	27.5%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Daniels Park – Fuller 230kV # 1	Line	PSCo	478	630.0	131.8%	772.0	161.5%	29.7%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1

Fountain Valley – MidwayBR 115kV # 1	Line	BHE	171	140.4	82.1%	179.4	104.9%	22.8%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Hyde Park – Pueblo Plant 115kV # 1	Line	BHE	160	149.0	93.1%	190.6	119.1%	26.0%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
MidwayPS 230/115kV # 1	Xfmr	PSCo	150	160.5	107.0%	195.5	130.3%	23.3%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
MidwayPS – Fuller 230kV # 1	Line	PSCo	382.4	419.1	109.6%	497.5	130.1%	20.5%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Midway – GI-2014-9 230kV # 2	Line	PSCo	478	437.9	91.6%	543.9	113.8%	22.2%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Pueblo Plant – Reader 115kV # 1	Line	BHE	160	166.6	104.1%	208.3	130.2%	26.1%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
West Canyon – Hogback 115kV # 1	Line	BHE	120	116.0	96.7%	141.0	117.5%	20.8%	P4: Midway – Fuller 230kV Breaker Failure
West Canyon 230/115kV # 1	Line	BHE	100	96.5	96.5%	118.9	118.9%	22.4%	P4: Midway – Fuller 230kV Breaker Failure

The multiple contingency analysis shows several new overloads and increases to existing overloads after the addition of the Southern Colorado study pocket GIRs. PSCo is in the process of identifying system mitigations which may include automatic generation adjustments schemes for the PSCo multiple contingencies studied in Table 6 above. These future mitigations will address the existing and Study Case overloads, all GIRs in the Southern Colorado study pocket may become part of the mitigations and included in automatic generation adjustments.

The two GIRs in the Transitional Cluster are ERIS, so the study determined the maximum allowable output of each GIR by calculating the DFAX contribution of each GIR to the worst system overload from Table 5 above. For the worst case overload from Table 5 – Palmer – Monument 115kV line; GI-2018-24 and GI-2019-6 have DFAX values of 2.87% and 6.07% and the following maximum outputs of the GIRs are identified:

the maximum output of GI-2018-24 before Network Upgrades are needed is 10MW
the maximum output of GI-2019-6 before Network Upgrades are needed is 0MW

However, for less stressed dispatch conditions when the existing generation in the Southern Colorado study pocket is lower, it is expected that the maximum output of 250MW for GI-2018-24 and 240MW for GI-2019-6 may be allowed, depending on the available firm and non-firm capacity of the transmission system.

6.2.4 Transient Stability Results

The following results were obtained for the disturbances analysed:

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

Since GI-2018-24 is a hybrid facility composed of two types of inverters, additional transient stability simulations were performed by modelling GI-2018-24 in PV only, PV+BES and BES only operating modes. The results of the contingency analysis are shown in Table 7. The transient stability plots are shown in Appendix A to this report.

Table 7 Transient Stability Analysis Results

#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Boone 230kV	3ph	Boone 230/115kV Transformer	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
2	Boone 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
3	Boone 230kV	3ph	Boone – Comanche 230kV	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
4	Boone 230kV	3ph	Boone – Midway 230kV	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
5	Comanche 345 kV	3ph	Comanche#3 generator	4.0	Maximum transient voltage dips within criteria	Stable with positive damping
6	Lamar 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
7	MidwayPS 230kV	3ph	All Fountain Valley gas units	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
8	MidwayPS 345kV	3ph	MidwayPS – Waterton 345kV line & Midway 230/345kV xfmr	4.0	Maximum transient voltage dips within criteria	Stable with positive damping
9	Comanche 345kV	3ph	Comanche – Daniels Park 345kV line #2 and Comanche – Tundra POI 345KV Line # 1	4.0	Maximum transient voltage dips within criteria	Stable with positive damping
10	Daniels Park 345kV	3ph	Comanche – Daniels Park 345kV line #2 and Daniels Park – Tundra POI 345kV Line # 1	4.0	Maximum transient voltage dips within criteria	Stable with positive damping

6.2.5 Short Circuit and Breaker Duty Analysis Results

A breaker duty study on the PSCo transmission system did not identify any circuit breakers that became over-dutied"[3] as a result of adding the Southern Colorado GIRs.

The short-circuit fault current values and Thevenin equivalent impedances at each GIR POI are shown in Tables 8 and 9. The analysis is performed for the entire Southern Colorado Cluster together and individual POI short circuit and Thevenin equivalent impedance values are reported separately.

Table 8 – Short Circuit Parameters at the Tundra 345kV Switching Station

	Before the Southern Colorado Cluster addition	After Southern Colorado Cluster addition
Three Phase Current	8380A	8591A
Single Line to Ground Current	6093A	7200A
Positive Sequence Impedance	1.964+j23.743 ohms	2.166+j23.537 ohms
Negative Sequence Impedance	1.999+j23.744 ohms	2.199+j23.536 ohms
Zero Sequence Impedance	7.362+j49.810 ohms	20.696+j39.409 ohms

Table 9 – Short Circuit Parameters at the Comanche 230kV Substation

	Before the Southern Colorado Cluster addition	After Southern Colorado Cluster addition
Three Phase Current	24568A	25242A
Single Line to Ground Current	28713A	29603A
Positive Sequence Impedance	0.402+j5.436 ohms	0.467+j5.405 ohms
Negative Sequence Impedance	0.416+j5.454 ohms	0.482+j5.423 ohms
Zero Sequence Impedance	0.155+j3.036 ohms	0.210+j2.901 ohms

6.2.6 Affected Systems

There are no Affected Systems identified in the Southern Colorado study pocket analysis.

6.2.7 Summary of Analysis

The maximum ERIS identified for GI-2018-24 is 250MW

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

The maximum ERIS identified for GI-2019-6 is 240MW

The GI-2018-24 and GI-2019-6 may be included as part of the automatic generation adjustment schemes currently being evaluated for the Comanche – Daniels Park 345kV, Midway – Waterton 345kV and Midway – Fuller multiple contingency mitigation plans.

Even though the maximum allowable generation output of each GIR is limited based on Table 4 results above, for less stressed dispatch conditions when the generation in the Southern Colorado study pocket is lower, it is expected that the maximum output of 250MW for GI-2018-24 and 240MW for GI-2019-6 may be possible, depending on the available firm and non-firm capacity of the transmission system.

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 to 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 Network Upgrades for Interconnection, by each POI are shown in Table 10.

Table 10 – Total cost of Station Network Upgrades by POI

POI	Total Cost	GIRs Sharing the POI
Tundra Switching Station	$15,496,000	GI-2018-24
Comanche 230kV Substation	$2,702,000	GI-2019-6

No other Network Upgrades were identified in this study.

7.2 Cost Estimates of Station and Other Network Upgrades by GIR

Table 11 – Allocation of Tundra Switching Station Costs to each GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 10)
GI-2018-24	250MW	100%	$15,496,000

Table 12 – Allocation of Comanche 230kV Substation POI costs to each GIR

GIR	GIR MW	% Share per Section 4.2.4(a) of Attachment N	Costs allocated to GIR (% share x total costs from Table 10)
GI-2019-6	240MW	100%	$2,702,000

7.2.1 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2018-24

The total cost of the required Upgrades for GI-2018-24 to interconnect at the Tundra 345kV Switching Station is **$16.549 Million**

- **The cost of Transmission Provider's Interconnection Facilities is $1.053 Million**
- **The cost of Station Network Upgrades is $15.496 Million**

Figure 2 is a conceptual one-line of the GI-2018-24 POI – Tundra 345kV Switching Station

The list of improvements required to accommodate the interconnection of GI-2018-24, the Customer's 250MW hybrid Generating Facility output are given in Tables 14a and 14b. A CPCN will be required to build the new Tundra 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 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 14a – GI-2018-24 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)

Tundra 345kV Switching Station	Tap Comanche – Daniels Park 345kV line to interconnect GI-2018-24. The new equipment includes: • One 345kV deadend and one girder • Three 345kV arresters • One 345kV 3000A Switch • One set (of three) high side metering units • Fiber communication equipment • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing.	$0.978
	Transmission line tap into substation:	$0.055
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.020
	Total Cost Estimate for Transmission Providers Interconnection Facilities	**$1.053**
Time Frame	**Site, design, procure and construct**	**36 Months**

Table 14b – GI-2018-24 Station Network Upgrades

Element	Description	Cost Est. (Millions)
Tundra 345kV Switching Station	Install a new three position ring bus switching station on the 345kV Comanche - Daniels Park line. The new equipment includes: • Three 345kV 3000A circuit breakers • Fourteen 345kV 3000A disconnect switches (assume all switch stands will be installed) • Six 345kV CCVTs • Two Line Traps • Six 345kV Surge Arresters • Four Deadend Structures • One Electrical Equipment Enclosure • Station controls and wiring • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	$11.708
Tundra 345kV Switching Station	Install required communications in the EEE at the new switching station	$0.464
PSCo's Comanche 345kV Bus	Update primary and secondary line relaying and associated breaker fail on line to GI-2018-24.	$0.643
PSCo's Daniels Park 345kV Bus	Update primary and secondary line relaying and associated breaker fail on line to GI-2018-24.	$0.663

PSCo's Comanche – Daniels Park 345kV Line #1	Terminate the transmission line into the new switching station	$1.822
	Siting and Land Rights support for substation construction	$0.196
	Total Cost Estimate for Network Upgrades for Interconnection	**$15.496**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.2 Summary of Interconnection Facilities and Network Upgrades Costs allocated to GI-2019-6

The total cost of the required Upgrades for GI-2019-6 to interconnect at the existing Comanche 230kV Substation is **$3.130 Million**

- **The cost of Transmission Provider's Interconnection Facilities is $0.428 Million**
- **The cost of Station Network Upgrades is $2.702 Million**

Figure 3 is a conceptual one-line of the GI-2019-6 POI at the existing Comanche 230kV Substation.

The list of improvements required to accommodate the interconnection of GI-2019-6, the Customer's 240MW Solar PV Generating Facility output are given in Tables 15a and 15b. A CPCN will not be required to build these improvements at the Comanche 230kV Substation.

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

Table 15a – GI-2019-6 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
Comanche Substation 230kV Bus	Interconnect GI-2019-6 Generating Facility. The new equipment includes: • One 230kV gang switch • Three 230kV arresters • One 230kV Deadend • Fiber Communication • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing	$0.358

	Transmission line tap into substation:	$0.045
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	$0.025
	Total Cost Estimate for Transmission Providers Interconnection Facilities	**$0.428**
Time Frame	**Site, design, procure and construct**	**12 Months**

Table 15b – GI-2019-6 Station Network Upgrades

Element	Description	Cost Est. (Millions)
Comanche Sub 230kV Bus	Install a new bay position at the Comanche 230kV Substation to interconnect the 240MW Generating Facility. The new equipment includes: • Five 230kV gang switches • Two 230kV Gas Circuit Breakers • Three 230kV Metering CT/PT Combo Units • One 230kV Deadend • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • 230kV Bus Relaying	$2.692
	Siting and Land Rights support for substation construction	$0.010
	Total Cost Estimate for Network Upgrades for Interconnection	**$2.702**
Time Frame	**Site, design, procure and construct**	**12 Months**

8.0 Summary of Generation Interconnection Service Results

The ERIS results are contingent upon the completion of the Contingent Facilities identified in Section 9 of this report.

If there is a change in status of one or more higher-queued Interconnection Requests due to withdrawal from the queue, a restudy will be performed as needed and Contingent Facilities required will be updated.

The Customer is required to design and build the Generating Facility to mitigate for any potential inverter interactions with the neighboring inverter based Generating Facility(ies) and/or the inverters of the hybrid Generating Facility.

Interconnection Service in and itself does not convey transmission service.

8.1 Cost Estimate Assumptions

The PSCo Engineering has developed Appropriation Level cost estimates (AE) for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the Transitional Cluster GIRs simultaneously on the transmission system. The cost estimates are in 2020 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.

- A level of accuracy of ±20% is specified for AE's.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The GI-2018-24 and GI-2019-6 Generating Facilities are not 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-2018-24:

The total estimated cost of the transmission system improvements for GI-2018-24: $16.549 Million (Tables 14a and 14b)

Energy Resource Interconnection Service of GI-2018-24 is: 250MW (after required transmission system improvements in Table 14a and 14b)

Note: the maximum output of GI-2018-24 shall not exceed 250MW at any time, which will be limited using the Plant Controller. The GI output will also be monitored by PSCo operations. Additional monitoring and control requirements will be added to the Large Generator Interconnection Agreement (LGIA) to ensure the Interconnection Service amount is not exceeded. The construction of the Tundra 345kV Switching Station will require a CPCN. 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-2018-24.

PSCo is in the process of identifying system mitigations which may include automatic generation adjustment schemes for the PSCo's multiple contingencies evaluated in Table 6. GI-2018-24 may become part of the mitigations and included in automatic generation adjustments.

8.3 GI-2019-6:

The total estimated cost of the transmission system improvements for GI-2019-6 are: $3.13 Million (Tables 15a and 15b)

Energy Resource Interconnection Service of GI-2019-6 is: 240MW (after required transmission system improvements in Table 15a and 15b)

PSCo is in the process of identifying system mitigations which may include automatic generation adjustment schemes for the PSCo's multiple contingencies evaluated Table 6. GI-2019-6 may become part of the mitigations and included in automatic generation adjustments.

Figure 2 – Preliminary One-line of the GI-2018-24 POI at the Tundra Switching Station

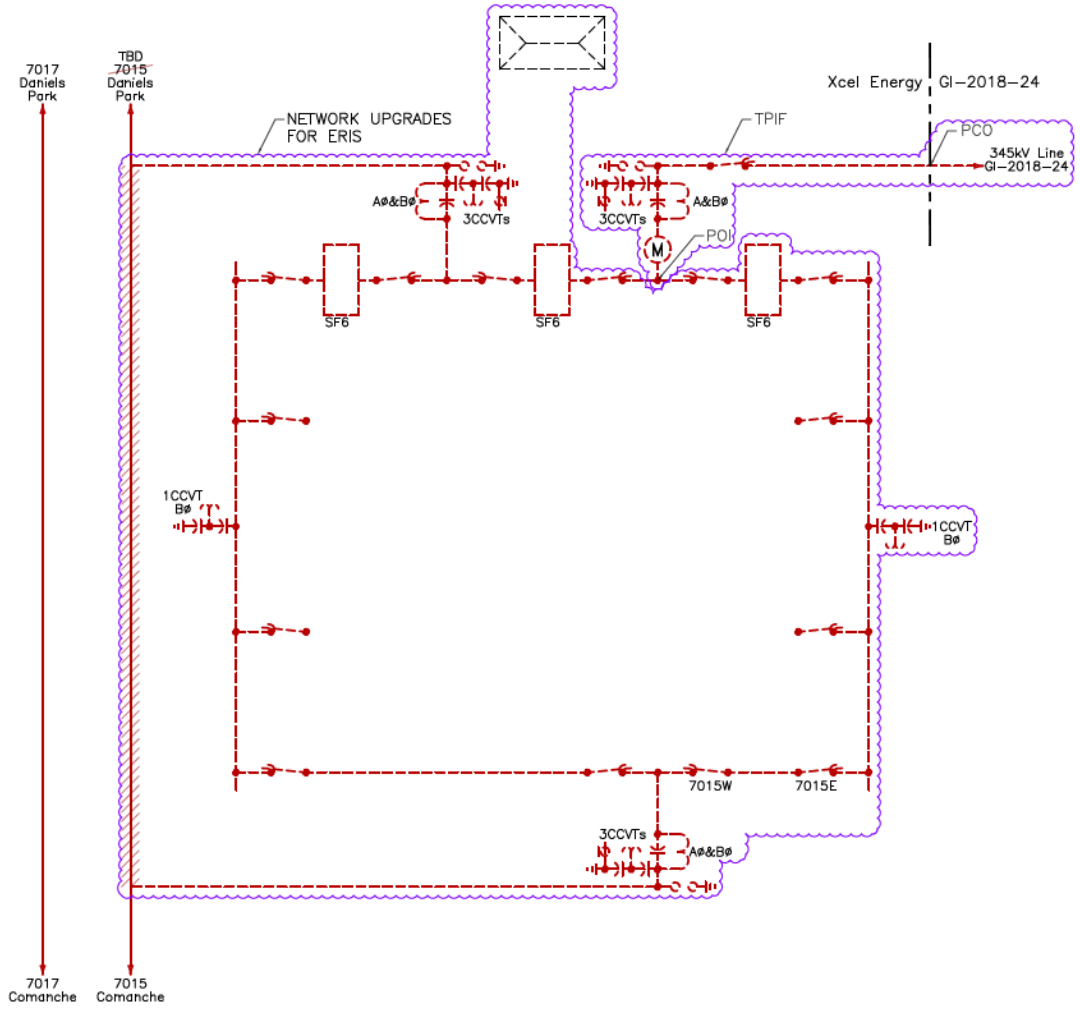
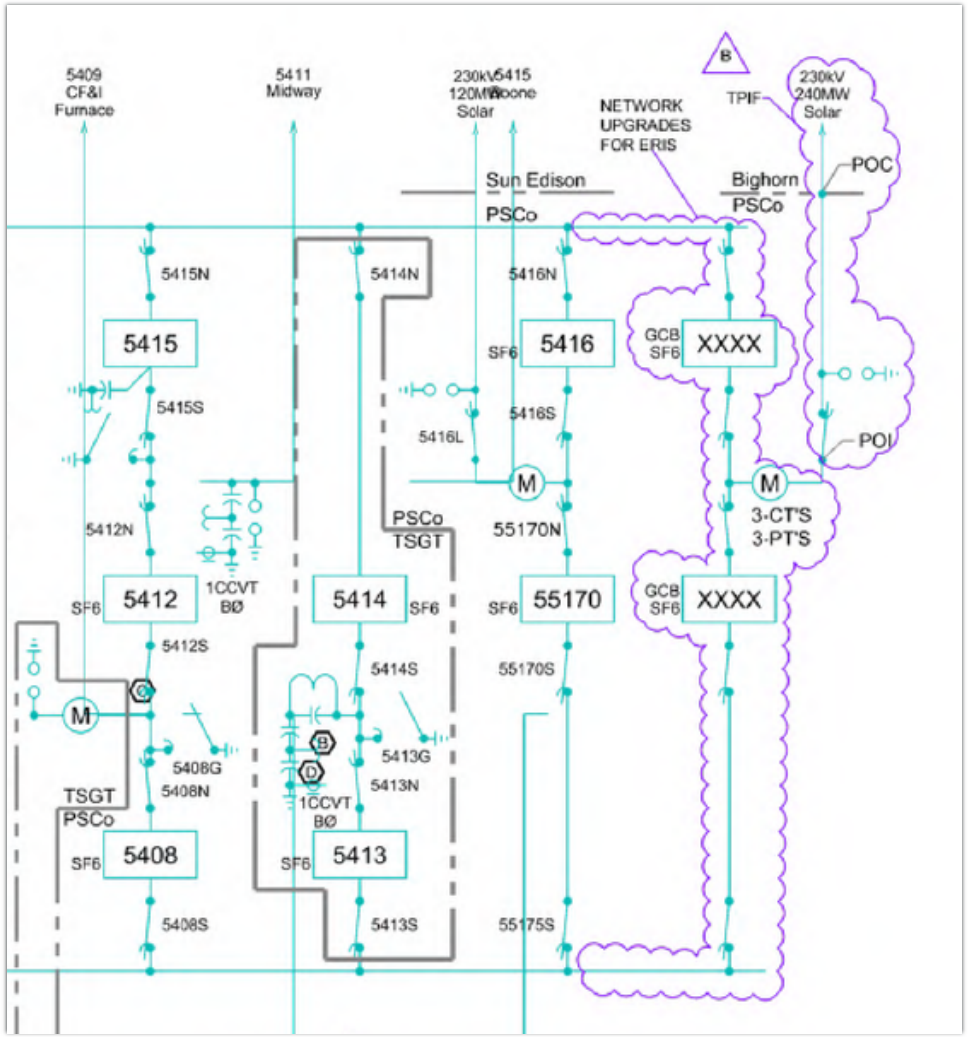


Figure 3 – Preliminary one-line of GI-2019-6 POI at the Comanche 230kV Substation



9.0 Contingent Facilities

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

The Contingent Facilities were identified by modeling each unbuilt facility noted below and running a single contingency analysis. If the single contingency analysis in the scenario with the unbuilt facility resulted in overloads, the DFAX contribution from each GIR is calculated and any GIRs with a DFAX of ≥1% is assigned the unbuilt facility as a Contingent Facility.

The contingent facilities identified for GI-2018-24 and GI-2019-6 are as follows. See Table 18 for DFAX contribution of each GIR.

1. The following Network Upgrades assigned to the higher-queued Generation Interconnection Requests:
    - MidwayPS 230/115kV, 100MVA transformer replaced with 150MVA unit – Network Upgrade assigned to GI-2014-12
2. The following unbuilt transmission projects/planned facility rating uprates modeled in the Base Case:
    - PSCo's Monument – Flying Horse 115kV Series Reactor project
    - PSCo's terminal upgrade project to uprate the Daniels Park – Prairie3 230kV line to 576MVA
    - PSCo's terminal upgrade project to uprate the Greenwood – Monaco 230kV line to 560MVA
    - PSCo's terminal upgrade project to uprate the Daniels Park – Prairie1 230kV line to 576MVA
    - PSCo's upgrade project to uprate the MidwayPS – MidwayBR 230kV line to 575MVA
    - TSGT's planned project to uprate the Fuller – Vollmer – Black Squirrel 115 kV line to 173 MVA
    - PSCo's upgrade to uprate Greenwood – Priarie1 230kV line to 576MVA
    - PSCo's upgrade to uprate Greenwood – Priarie3 230kV line to 576MVA

- PSCo's upgrade to uprate Dainels Park 345/230kV # T4 to 560MVA
- PSCo's upgrade to uprate MidwayPS – GI-2014-9 230kV line to 478MVA
- Briargate S 115/230kV transformer project (this facility is only identified for GI-2019-6)

3. Interconnection Facilities for each GIR identified in this report

   See Table 14a and 14b for Interconnection Facilities assigned to GI-2018-24

   See Table 15a and 15b for Interconnection Facilities assigned to GI-2019-6

Table 16 DFAX Contribution of GIRs to Contingent Facilities

Contingent Facility	DFAX for GI-2018-24	DFAX for GI-2019-6	Contingency
MidwayPS 230/115kV, 100MVA transformer replaced with 150MVA unit	3.84%	4.2%	Daniels Park - Tundra 345 KV line (Overload on MidwayPS 230/115kV, 100MVA transformer)
PSCo's Monument – Flying Horse 115kV Series Reactor project	6.16%	6.64%	Daniels Park - Tundra 345 KV line (Overload on Palmer-Monument 115kV line)
PSCo's terminal upgrade project to uprate the Daniels Park – Prairie3 230kV line to 576MVA	17.87%	16.68%	Daniels Park - Prairie1 230 KV line (Overload on Daniels Park – Prairie3 230kV line)
PSCo's terminal upgrade project to uprate the Greenwood – Monaco 230kV line to 503MVA	10.75%	8.97%	Smokyhil - Buckly34 230 KV line (Overload on Greenwood – Monaco 230kV line)
PSCo's terminal upgrade project to uprate the Daniels Park – Prairie1 230kV line to 576MVA	17.87%	16.68%	Daniels Park – Prairie3 230 KV line (Overload on Daniels Park – Prairie 1 230kV line)
PSCo's upgrade project to uprate the MidwayPS – GI-2014-9 POI 230kV line to 478MVA	14.69%	15.97%	Daniels Park - Tundra 345 KV line (Overload on MidwayPS – GI-2014-9 230kV line)
PSCo's upgrade project to uprate the MidwayPS – MidwayBR 230kV line to 575MVA	9.64%	19.62%	Midwayps - Fuller 230 KV line (Overload on the MidwayPS – Midway BR 230kV line)
TSGT's planned project to uprate the Fuller – Vollmer – Black Squirrel 115 kV line to 173 MVA	2.41%	4.98%	Daniels Park -fuller 230 KV line (Overload on the Fuller – Vollmer – Black Squirrel 115kV line)
PSCo's upgrade to uprate Greenwood – Priarie1 230kV line to 576MVA	17.64%	16.46%	Daniels Park – Prairie3 230 KV line (Overload on Greenwodd – Prairie1 230kV line)
PSCo's upgrade to uprate Greenwood – Priarie3 230kV line to 576MVA	17.64	16.46%	Daniels Park - Prairie1 230 KV line (Overload on Greenwood – Prairie 3 230kV line)

PSCo's upgrade to uprate Dainels Park 345/230kV # T4 to 560MVA	18.78%	9.98%	Daniels Park 230/345 KV transformer T3 (Overload on Daniels Park 345/230kV # T4)
Briargate S 115/230kV transformer project	N/A	1.75%	Cottonwood N – Kettleck S 115kV line (Overload on Briargate S – Cottonwood S 115kV line)

10.0 Grid Charging Capacity Evaluation

GI-2018-24 requested evaluation of the Grid Charging capacity to charge the 125MW BES facility at a rate of 75MW for 4hrs. The GIR may not start operating in the grid charging mode until after five (5) years and three (3) months from the COD of the Generating Facility. Since the COD of GI-2018-24 is December 2022, the expected start date of the grid charging mode of operation is 2027.

10.1 Study Methodology

The Grid Charging Capacity is evaluated per the Cluster study process. There is only one GIR in the Transitional Cluster requesting this mode of operation and the GIR is in the Southern Colorado. The study used the same Criteria shown in Section 4.2 of this report.

The scope of the studies included steady state assessment, transient stability assessment, short circuit analysis and appropriate level cost estimates.

Since the Interconnection Facility costs are identified as part of the Generation Interconnection Service, the cost estimates identified for Grid Charging operation only include the additional Interconnection Facilities and Network Upgrade costs required to accommodate charging from the grid (in addition to costs identified in Tables 16a and 16b) for the ERIS requested.

10.2 Power Flow Modeling Assumptions

The Benchmark Case is created from the Base Case described in Section 5.1 by adopting the generation dispatch given in Table 17 below. The PSCo loads in the Southern Colorado study area are modeled at their expected 2027 values. The Grid Charging evaluation also included a scenario case with Comanche Unit #1 & 2 offline to reflect their planned retirements in 2022 and 2025 respectively.

Table 17 – Generation dispatch used to Stress the Benchmark Case for storage charging evaluation (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
APT_DSLS 4.16	G1	0	0	10	BHE
BAC_MSA GEN1 13.8	G1	1	59.4	90	BHE
BAC_MSA GEN2 13.8	G1	1	59.4	90	BHE
BAC_MSA GEN4 13.8	G1	1	26.4	40	BHE
BAC_MSA GEN4 13.8	G2	1	26.4	40	BHE
BAC_MSA GEN4 13.8	S1	1	16.4	24.8	BHE
BAC_MSA GEN5 13.8	G1	1	26.4	40	BHE
BAC_MSA GEN5 13.8	G2	1	26.4	40	BHE
BAC_MSA GEN5 13.8	S1	1	16.4	24.8	BHE
BAC_MSA GEN6 13.8	G1	1	26.4	40	BHE
BUSCHRNCH_LO 0.7	1	1	12.6	60	BHE
BUSCHRWTG1 0.7	G1	1	6	28.8	BHE
E_CANON 69	G1	0	0	8	BHE
PP_MINE 69	G1	0	0	3	BHE
PUB_DSLS 4.16	G1	0	0	10	BHE
R.F.DSLS 4.16	G1	0	0	10	BHE
RTLSNKWNDLO 0.7	G1	1	35.2	60	BHE
ALMSACT1 13.8	G1	0	0	17	PSCo
ALMSACT2 13.8	G2	0	0	14	PSCO
COGENTRIX_PV 34.5	S3	1	0	30	PSCO
COMAN_1 24	1	360	360	360	PSCO
COMAN_2 24	C2	365	365	365	PSCO

COMAN_3 27	C3	1	788	788	PSCO
COMAN_PV 34.5	S1	0	0	120	PSCO
CO_GRN_E 34.5	W1	1	17	81	PSCo
CO_GRN_W 34.5	W2	1	17	81	PSCo
FTNVL1&2 13.8	G1	0	0	40	PSCO
FTNVL1&2 13.8	G2	0	0	40	PSCO
FTNVL3&4 13.8	G3	0	0	40	PSCO
FTNVL3&4 13.8	G4	0	0	40	PSCO
FTNVL5&6 13.8	G5	0	0	40	PSCO
FTNVL5&6 13.8	G6	0	0	40	PSCO
GSANDHIL_PV 34.5	S1	0	0	19	PSCO
JKFULGEN 0.69	W1	1	199.5	249.4	PSCO
LAMAR_DC 230	DC	0	0	210	PSCO
SOLAR_GE 34.5	S2	0	0	30	PSCO
SUNPOWER 34.5	S1	0	0	52	PSCO
TWNBUTTE 34.5	W1	1	15.8	75	PSCO
SI_GEN 0.6	1	0	0	30	TSGT
STEM_PV 0.48	PV	0	0	100	TSGT
TBII_GEN 0.69	W	1	16	76	TSGT
TSGT_0809 0.62	PV	0	0	100	TSGT
GI-2009-8 34.5	S1	0	0	30	PSCO
GI-2014-2 34.5	S1	0	0	35	N/A
GI-2014-12 34.5	S9	0	0	53	PSCO
GI-2014-13 34.5	S1	0	0	52	N/A
GI-2014-6 34.5	S1	0	0	100	PSCO

GI-2014-8 34.5	1	0	0	60	PSCO
GI-2014-9 34.5	1	0	0	70	PSCO

A Study Case was created from the Benchmark Case by modeling GI-2018-24 at the Tundra 345kV Switching Station, tapping the Comanche – Daniels Park 345kV line at approximately 10 miles from the Comanche Substation. The GIR was modeled in charging mode by modeling a negative generator, with the same Mvar control capability as the generating mode.
Also, GI-2019-6 is modelled at the Comanche 230kV Substation POI, but modelled offline.

10.3 Grid Charging Analysis

The steady state assessment is performed as described in Section 4.3.1 of this report.

The transient stability analysis is performed as described in Section 4.3.2 of this report.

The contingency and monitoring criteria as described in 3.3.3 and 3.4.1 are used.

10.3.1 Steady State Assessment

The single contingency analysis (P1 and P2-1) and multiple contingency analysis (P4, P5 and P7) did not identify any overloads in the Study Case and the Scenario Case with Comanche 1 & 2 offline.

10.3.2 Transient Stability Study Results

The Transient Stability analysis is only performed on the Study Case. The results are shown in the Table 18 below.

Table 18 Transient Stability Analysis Results

#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Boone 230kV	3ph	Boone 230/115kV Transformer	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
2	Boone 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
3	Boone 230kV	3ph	Boone – Comanche 230kV	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
4	Boone 230kV	3ph	Boone – Midway 230kV	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
5	Comanche 345 kV	3ph	Comanche#3 generator	4.0	Maximum transient voltage dips within criteria	Stable with positive damping
6	Lamar 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
7	MidwayPS 230kV	3ph	All Fountain Valley gas units	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
8	MidwayPS 345kV	3ph	MidwayPS – Waterton 345kV line & Midway 230/345kV xfmr	4.0	Maximum transient voltage dips within criteria	Stable with positive damping
9	Comanche 345kV	3ph	Comanche – Daniels Park 345kV line #2 and Comanche – Tundra POI 345KV Line # 1	4.0	Maximum transient voltage dips within criteria	Stable with positive damping
10	Daniels Park 345kV	3ph	Comanche – Daniels Park 345kV line #2 and Daniels Park – Tundra POI 345kV Line # 1	4.0	Maximum transient voltage dips within criteria	Stable with positive damping

The following results were obtained for the disturbances analyzed on the Study Case and the Scenario Case:

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

The transient stability plots are shown in Appendix B.

10.3.3 Summary

The steady state of transient stability studies did not identify any violations.

The maximum allowable Grid Charging Capacity of the GI-2018-24 is 75MW.

10.4 Cost Estimates

The load mode of operation did not identify any additional Interconnection Facilities and Station Network Upgrades other than what was identified for the interconnection of the Generating Facility.

10.5 Summary of Grid Charging Capacity

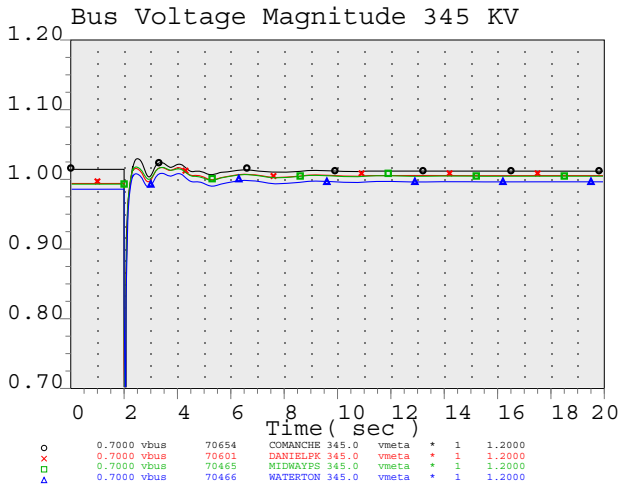
The Grid Charging Capacity of GI-2018-24 is 75MW at any time of the day

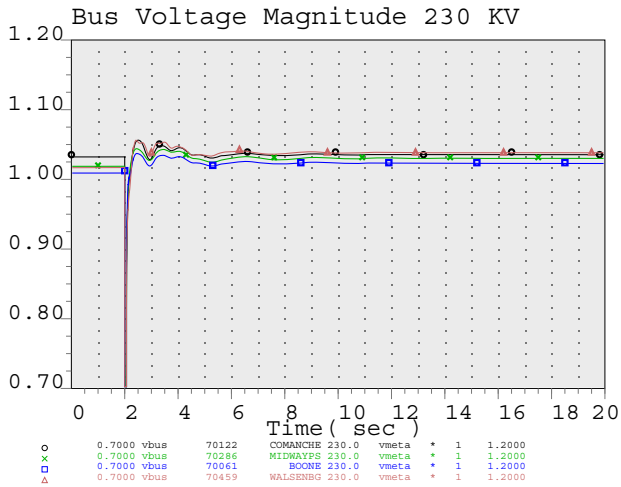
The Generating Facility should be capable of voltage control and frequency control in the Grid Charging mode, similar to the generation mode. The Generating Facility shall not ride through during faults during grid charging mode. The interconnection Guidelines for BES facilities in charging mode are under development and may change between now and 2027. GI-2018-24 hybrid facility shall be capable of meeting these future interconnection requirements for charging mode of operation from the transmission system.

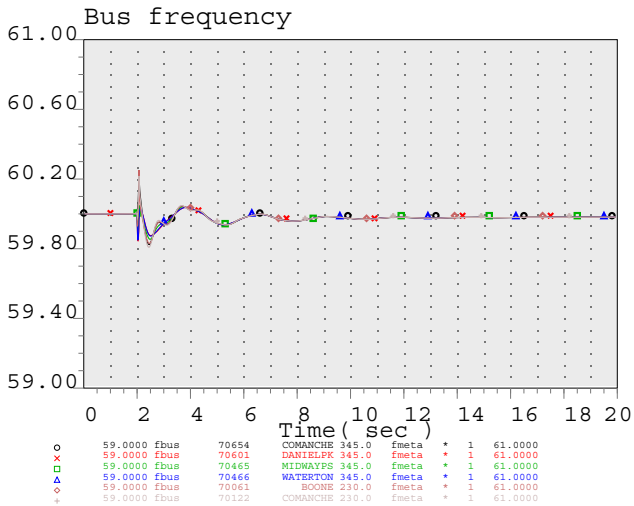
Grid Charging capacity in and of itself does not grant any transmission service for this mode of operation.

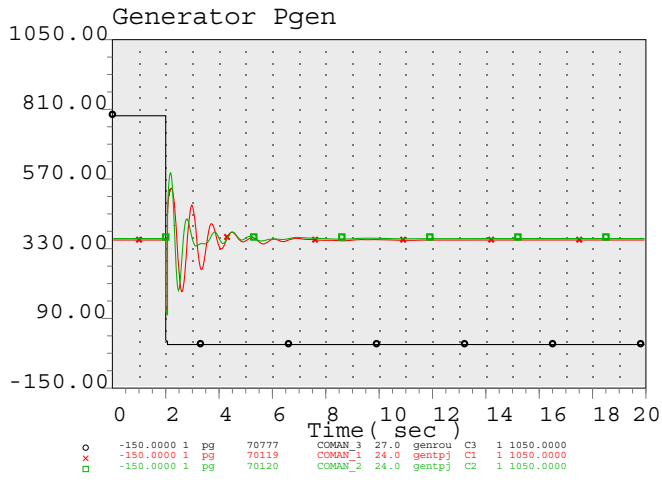
Appendix A

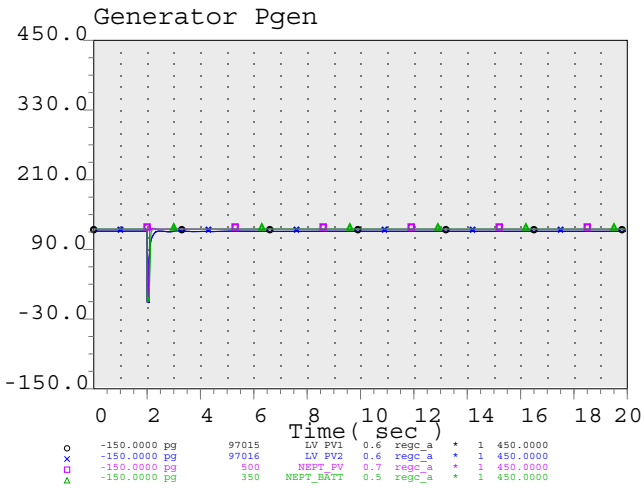
Transient Stability Plot - Generation Interconnection Service

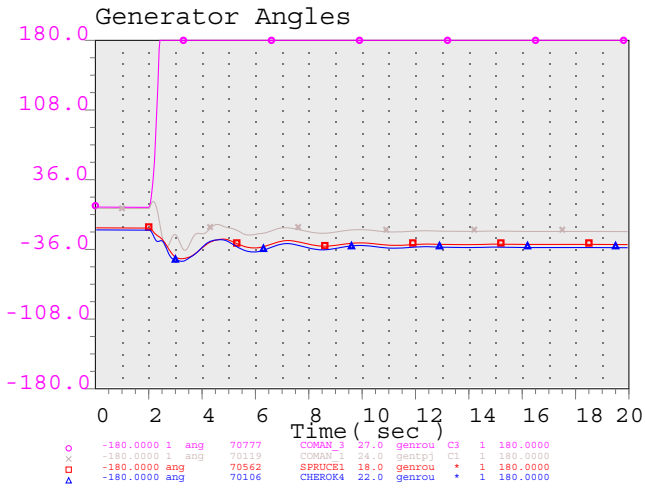




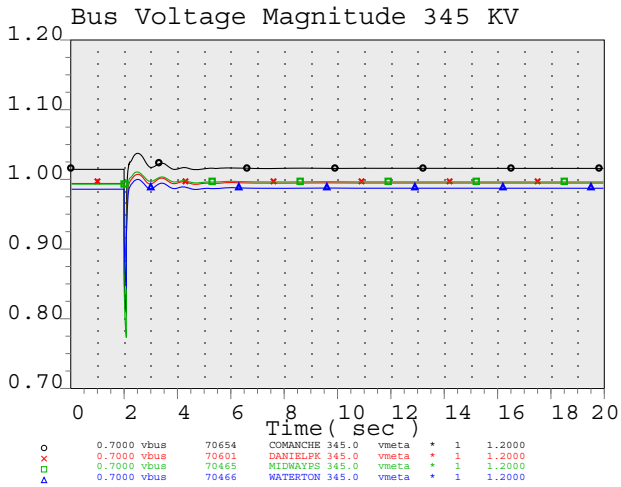


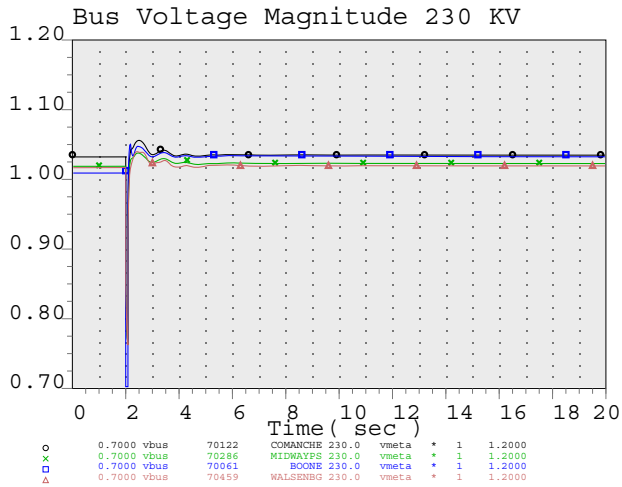


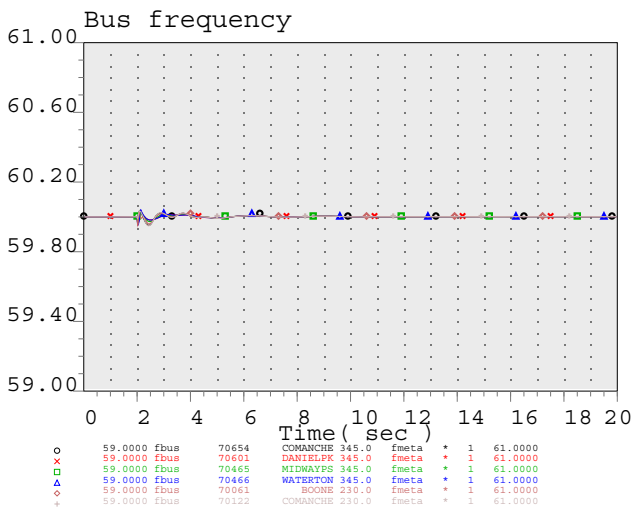


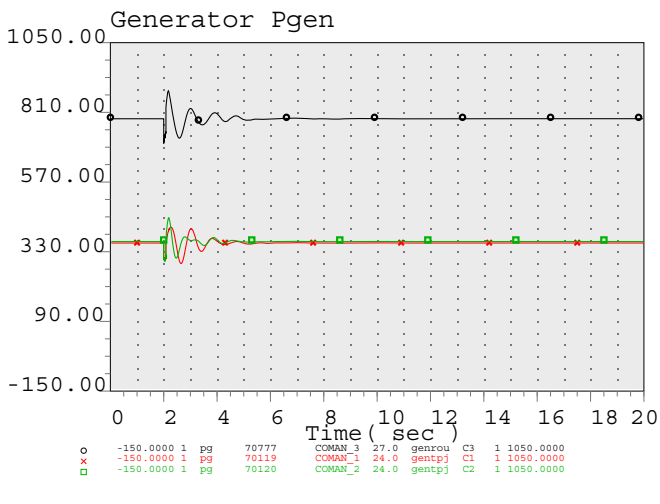


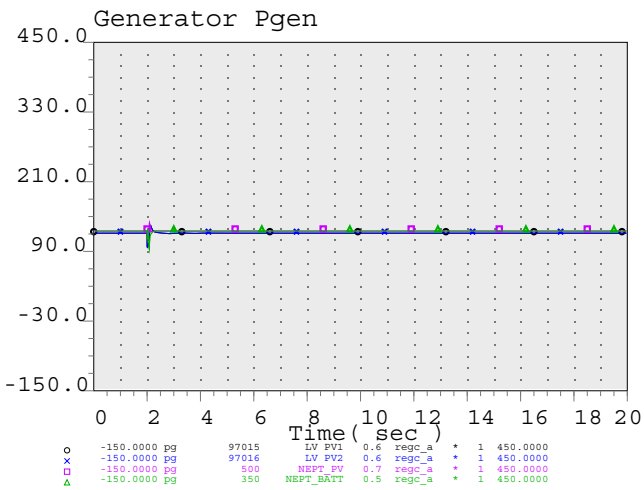
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: Comanche unit 3

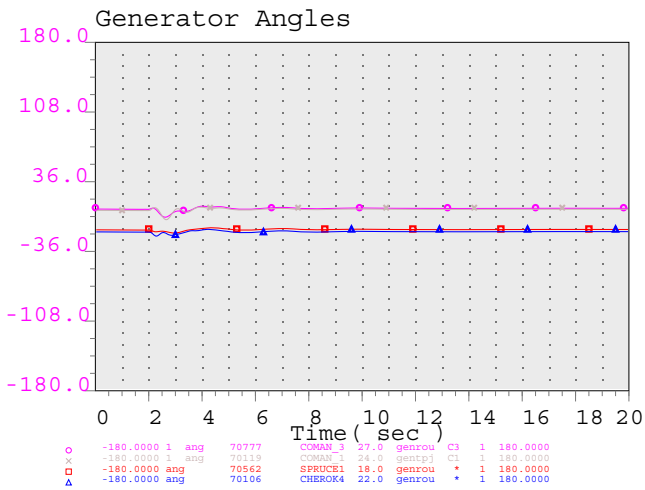




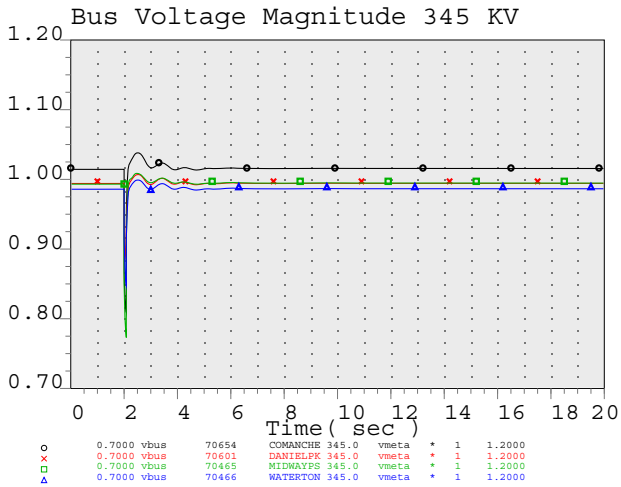


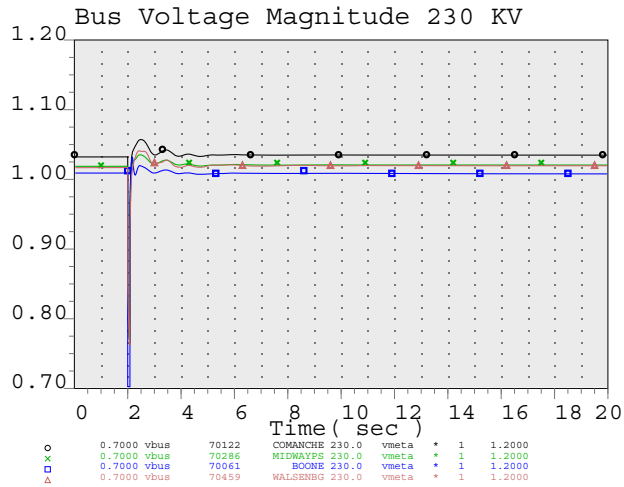


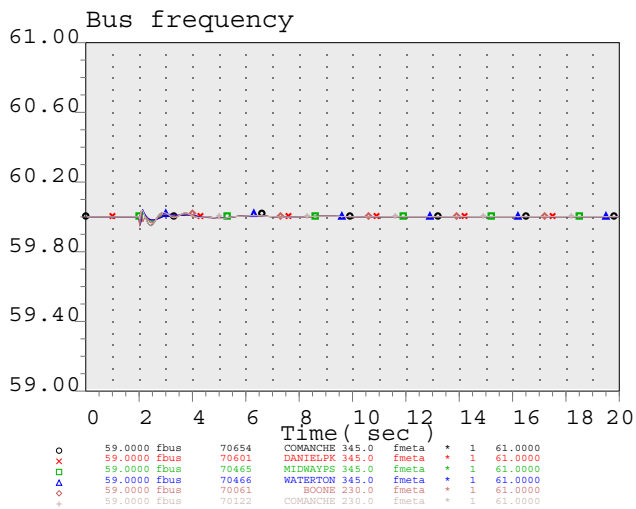


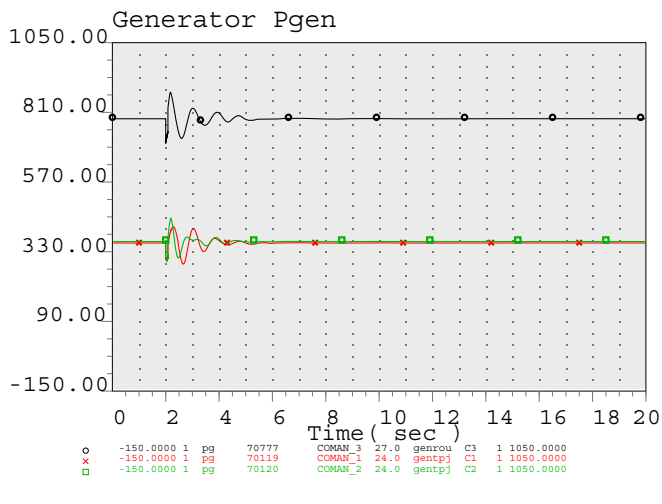


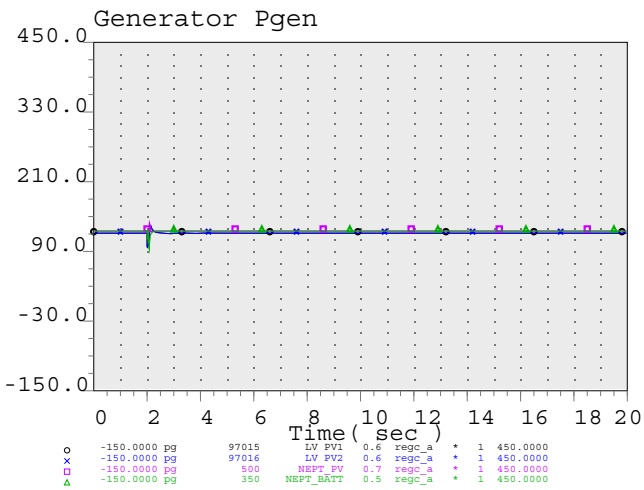
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage:lose Boone 230/115 KV bank

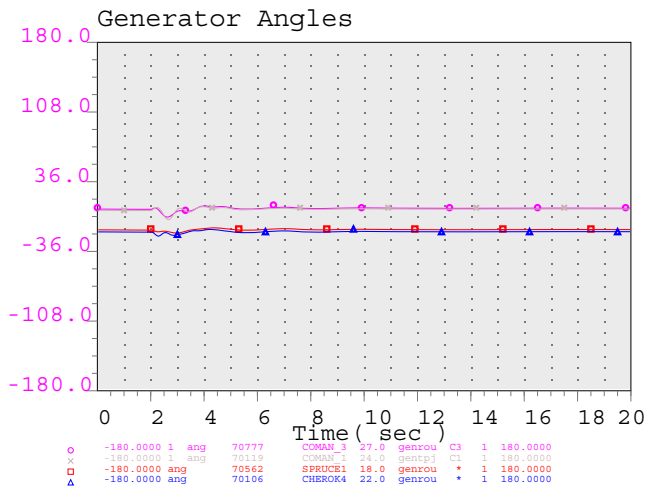

Bus Voltage Magnitude 345 KV
1.20
1.10
1.00
0.90
0.80
0.70
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
0.7000 vbus 70654 COMANCHE 345.0 vmeta * 1 1.2000
0.7000 vbus 70601 DANIELPK 345.0 vmeta * 1 1.2000
0.7000 vbus 70465 MIDWAYPS 345.0 vmeta * 1 1.2000
0.7000 vbus 70466 WATERTON 345.0 vmeta * 1 1.2000

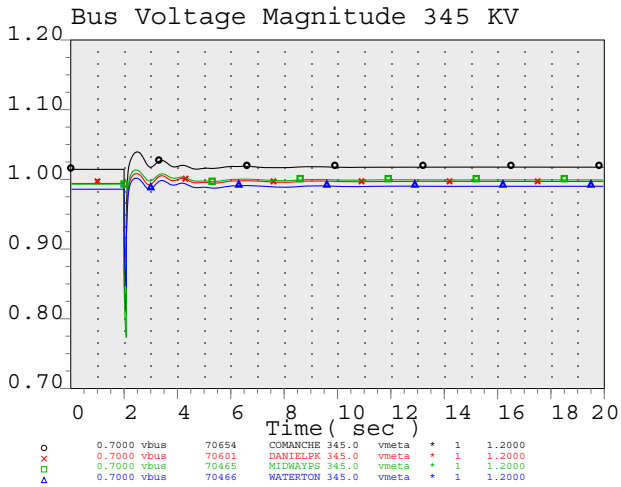

Bus Voltage Magnitude 230 KV
1.20
1.10
1.00
0.90
0.80
0.70
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
0.7000 vbus 70122 COMANCHE 230.0 vmeta * 1 1.2000
0.7000 vbus 70286 MIDWAYPS 230.0 vmeta * 1 1.2000
0.7000 vbus 70061 BOONE 230.0 vmeta * 1 1.2000
0.7000 vbus 70459 WALSENBG 230.0 vmeta * 1 1.2000

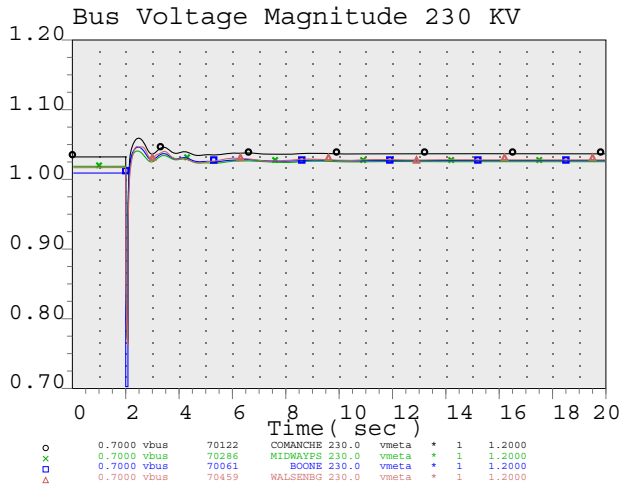

Bus frequency
61.00
60.60
60.20
59.80
59.40
59.00
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
59.0000 fbus 70654 COMANCHE 345.0 fmeta * 1 61.0000
59.0000 fbus 70601 DANIELPK 345.0 fmeta * 1 61.0000
59.0000 fbus 70465 MIDWAYPS 345.0 fmeta * 1 61.0000
59.0000 fbus 70466 WATERTON 345.0 fmeta * 1 61.0000
59.0000 fbus 70061 BOONE 230.0 fmeta * 1 61.0000
59.0000 fbus 70122 COMANCHE 230.0 fmeta * 1 61.0000

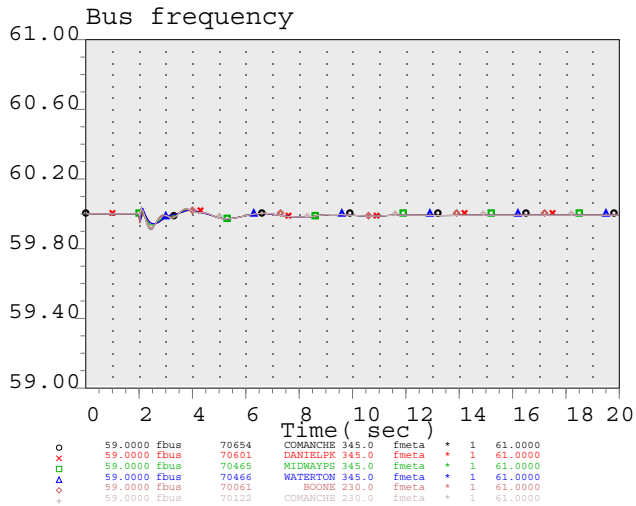

Generator Pgen
1050.00
810.00
570.00
330.00
90.00
-150.00
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
-150.0000 1 pg 70777 COMAN_3 27.0 genrou C3 1 1050.0000
-150.0000 1 pg 70119 COMAN_1 24.0 gentpj C1 1 1050.0000
-150.0000 1 pg 70120 COMAN_2 24.0 gentpj C2 1 1050.0000

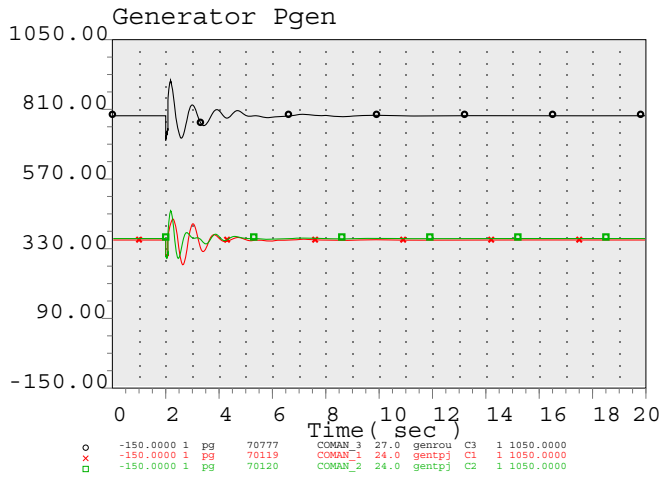

Generator Pgen
450.0
330.0
210.0
90.0
-30.0
-150.0
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
-150.0000 pg 97015 LV PV1 0.6 regc_a * 1 450.0000
-150.0000 pg 97016 LV PV2 0.6 regc_a * 1 450.0000
-150.0000 pg 500 NEPT_PV 0.7 regc_a * 1 450.0000
-150.0000 pg 350 NEPT_BATT 0.5 regc_a * 1 450.0000

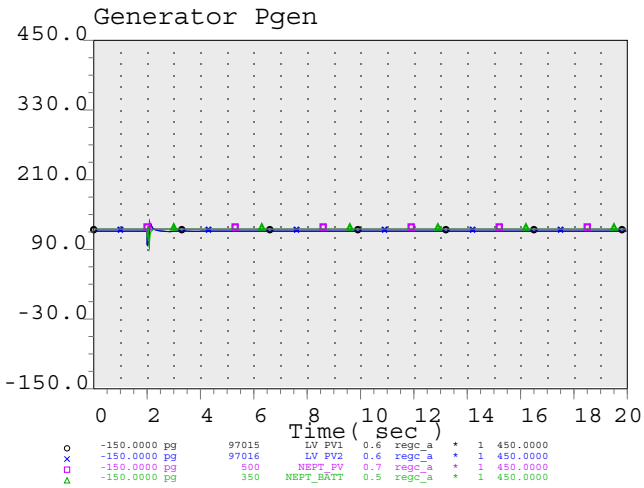

Generator Angles
180.0
108.0
36.0
-36.0
-108.0
-180.0
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
-180.0000 1 ang 70777 COMAN_3 27.0 genrou C3 1 180.0000
-180.0000 1 ang 70119 COMAN_1 24.0 gentpj C1 1 180.0000
-180.0000 ang 70562 SPRUCE1 18.0 genrou * 1 180.0000
-180.0000 ang 70106 CHEROK4 22.0 genrou * 1 180.0000

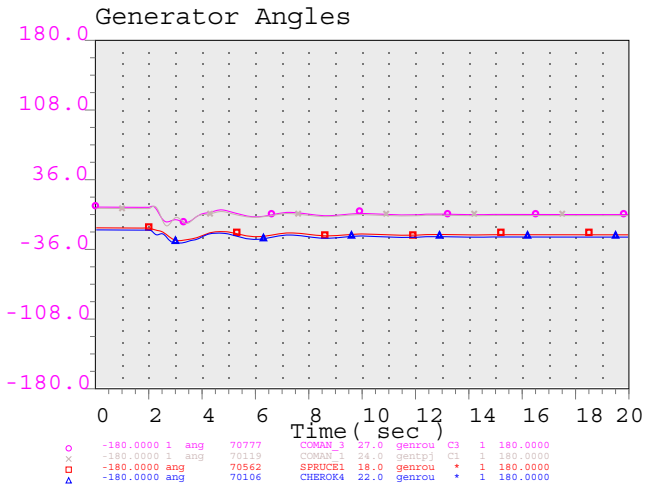




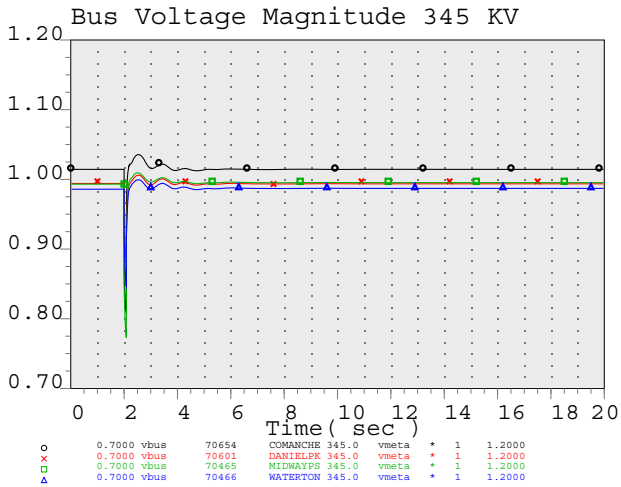


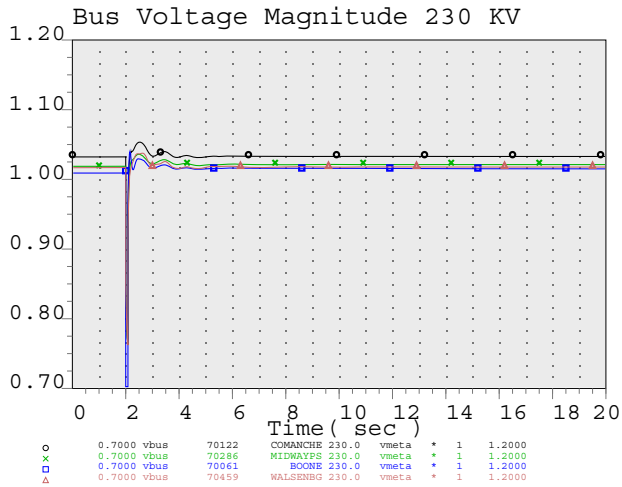


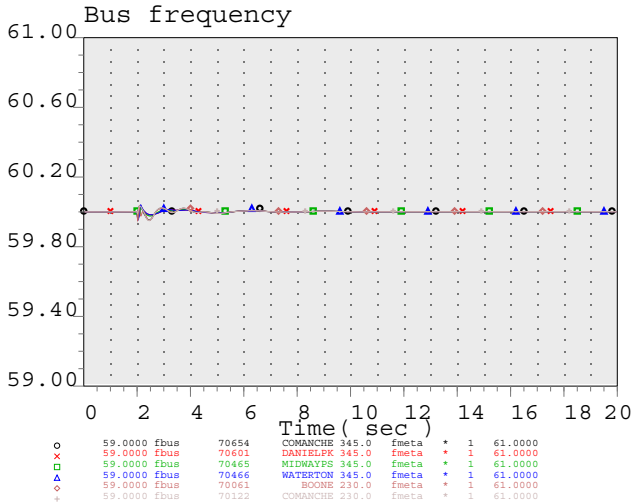


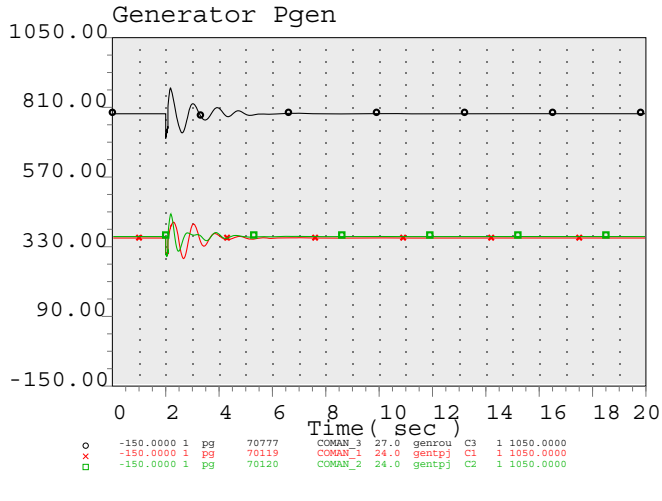


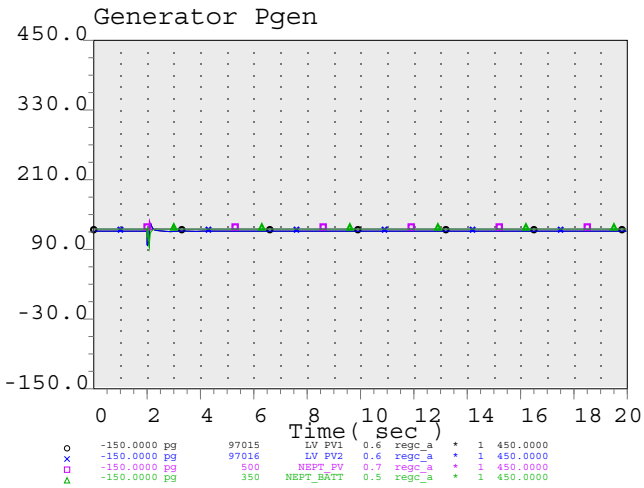
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Lamar 230 KV line and Lamar gen

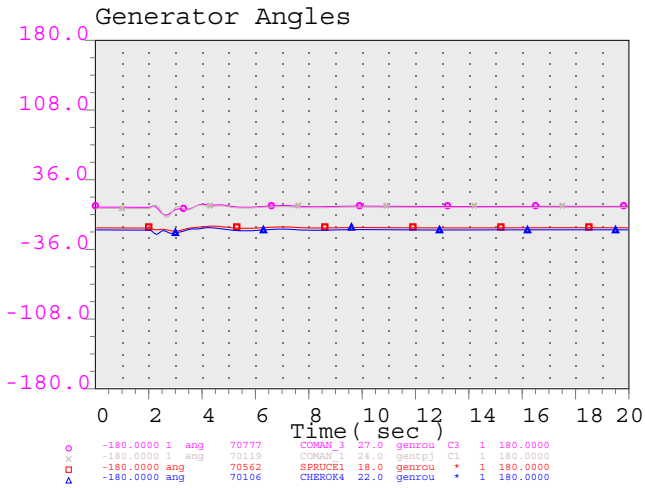




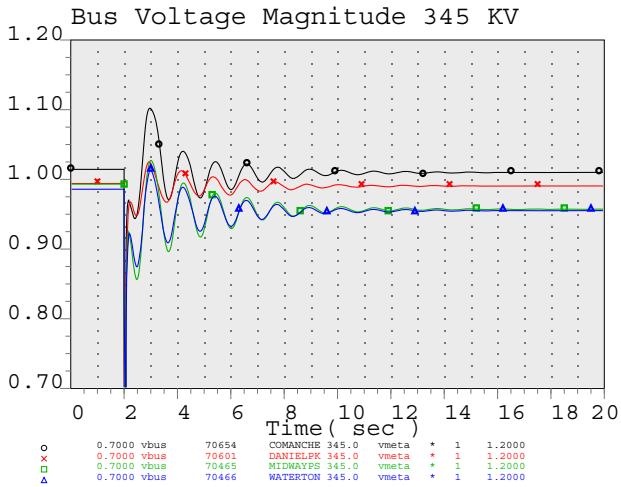


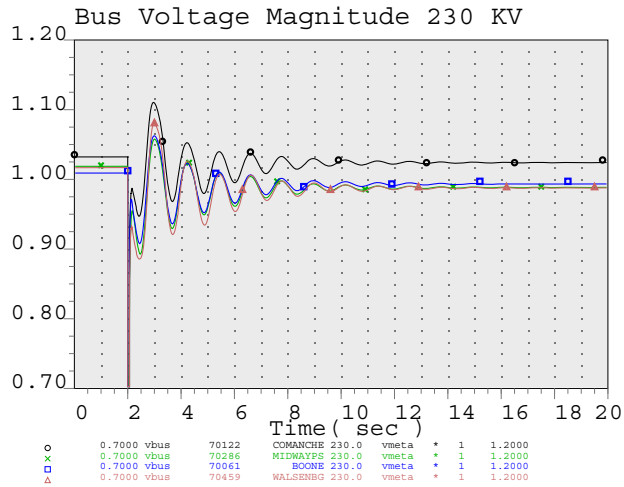


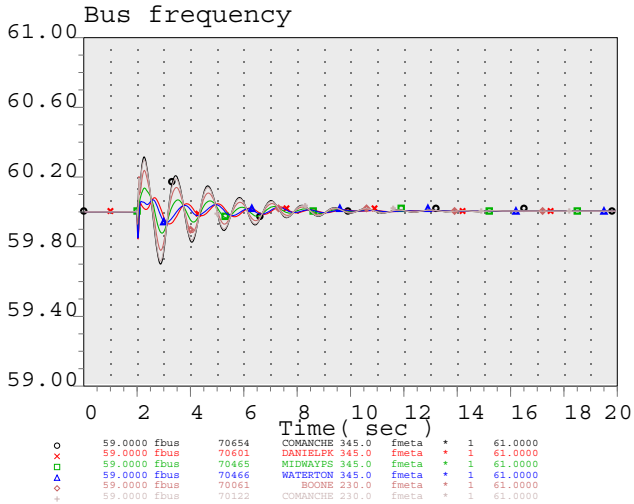


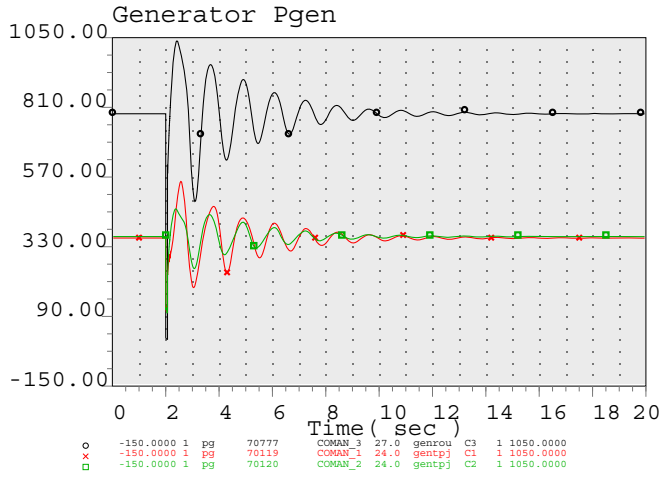


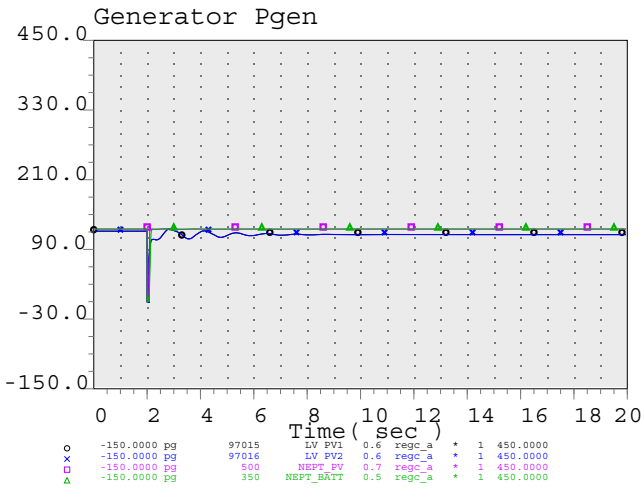
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Midway 230 KV line

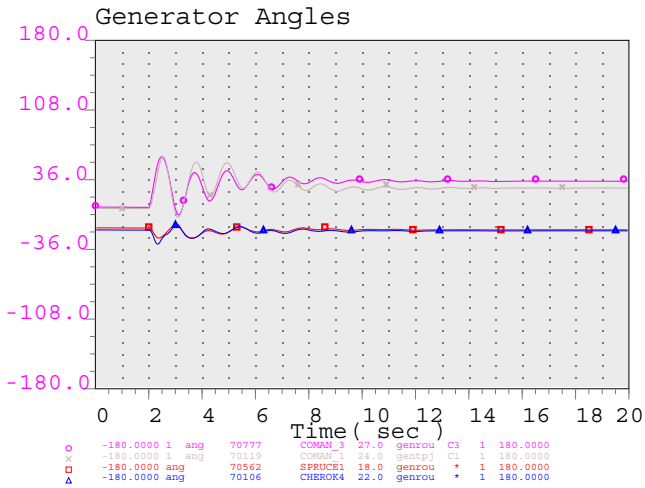




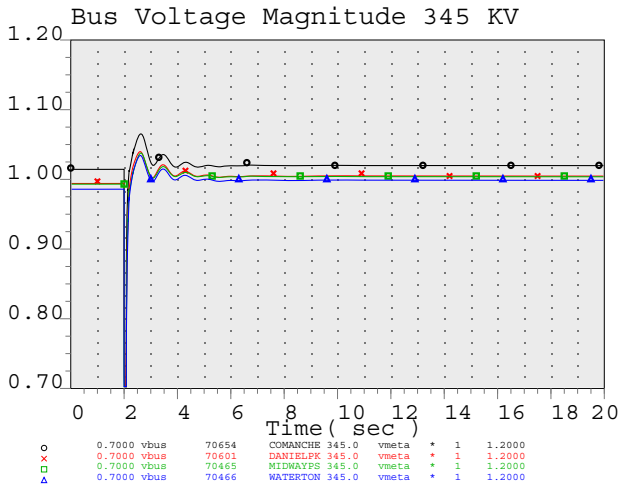


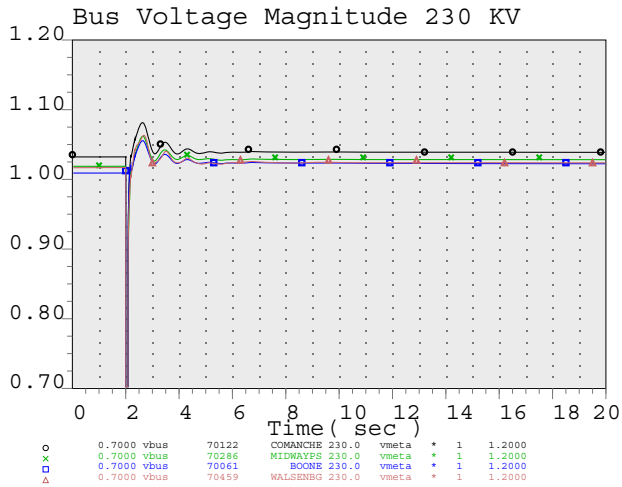


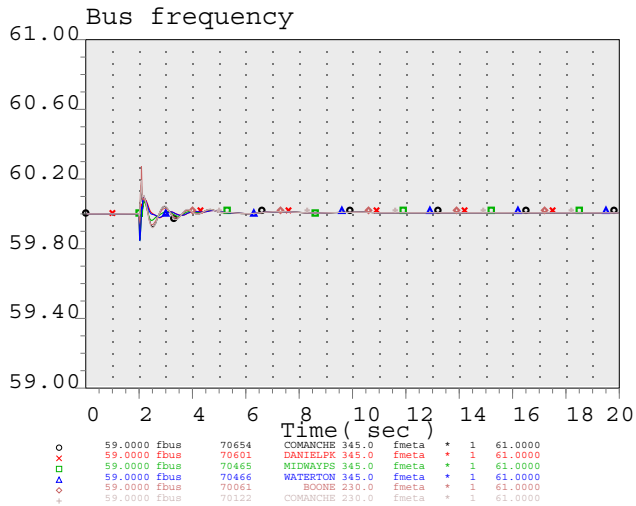


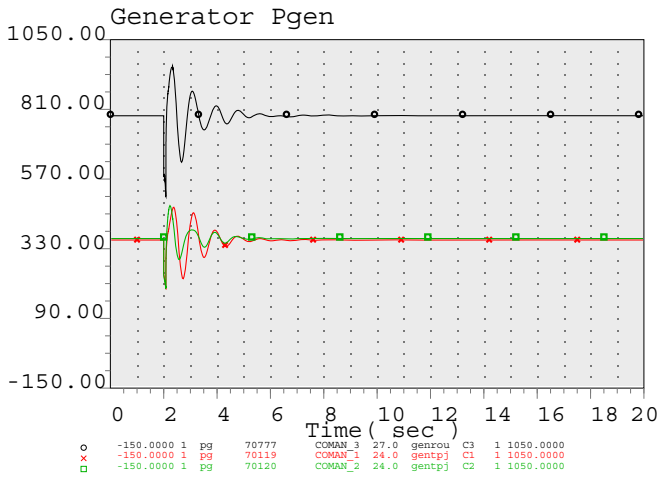


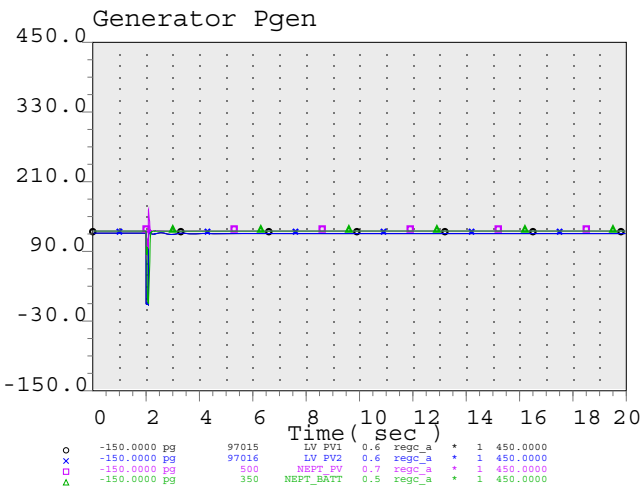
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
outage: lose Comanche - Daniels Park 345 KV
and lose Comanche - Tundra 345 KV line

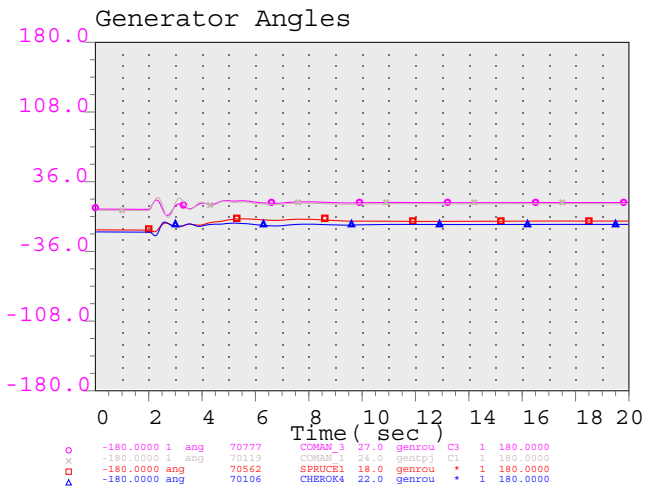




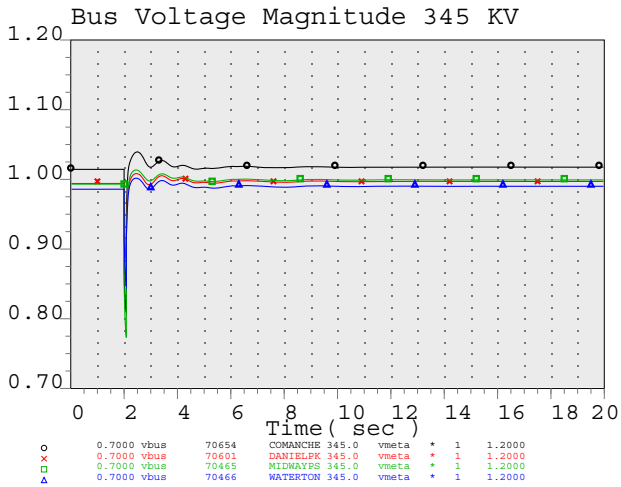


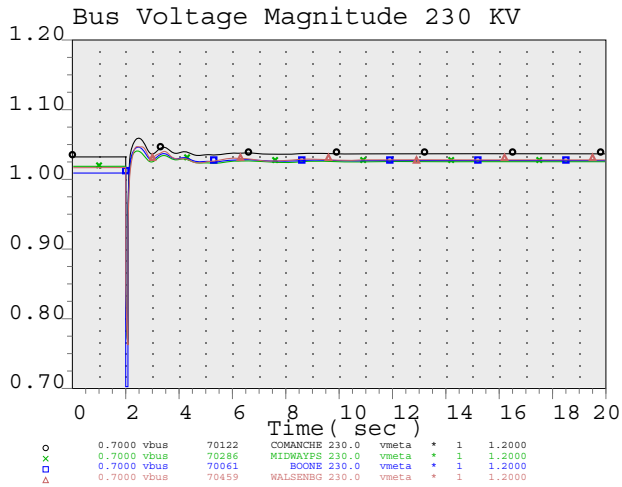


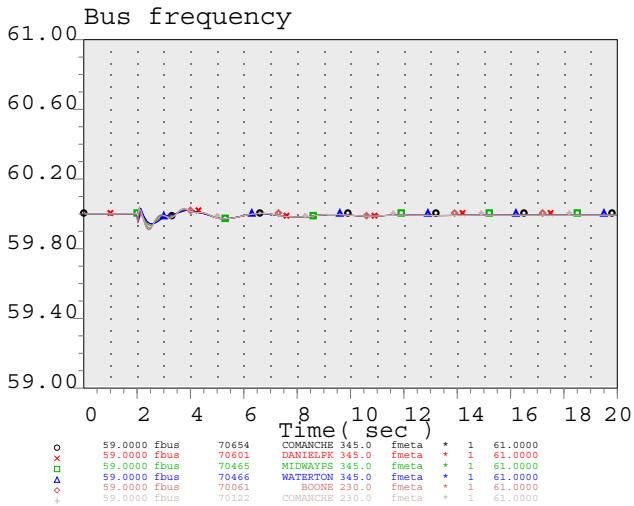


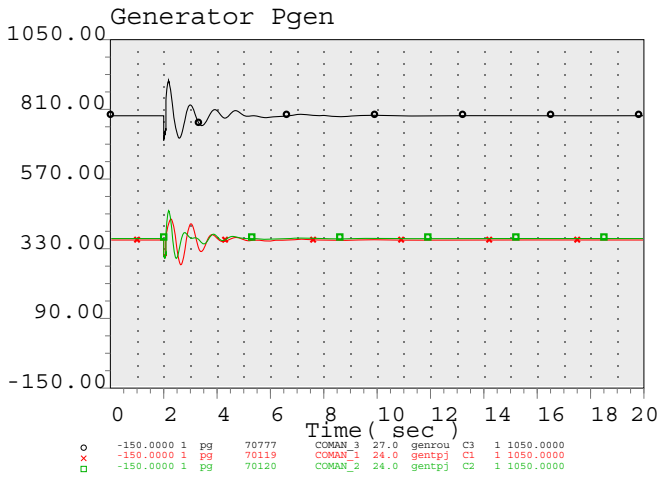


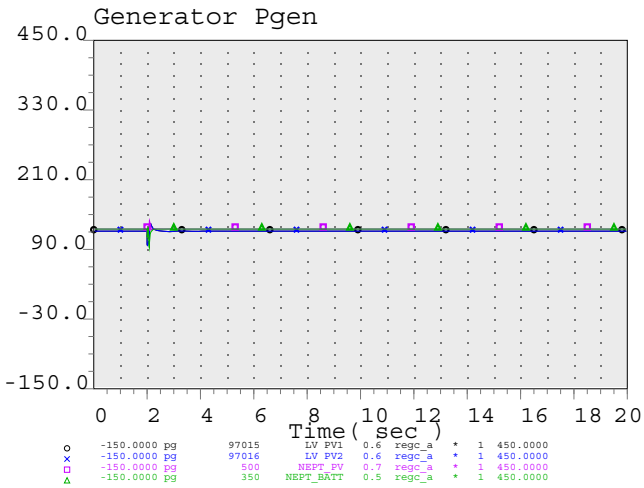
Fault: MIDWAYPS 230 KV 5 cycle 3-ph bus fault
Outage: lose Fountain Valley gen

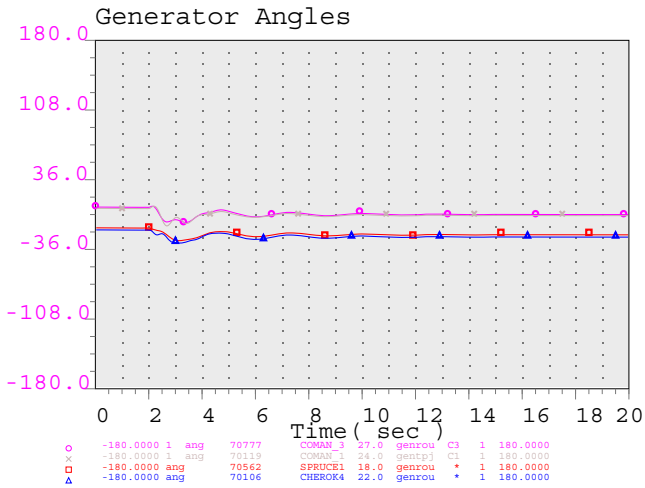




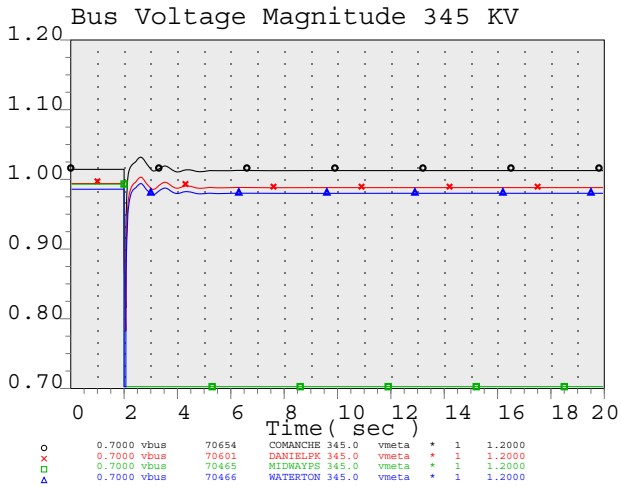


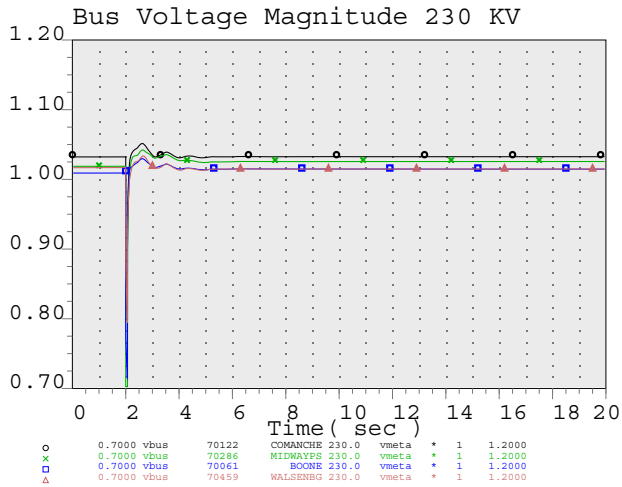


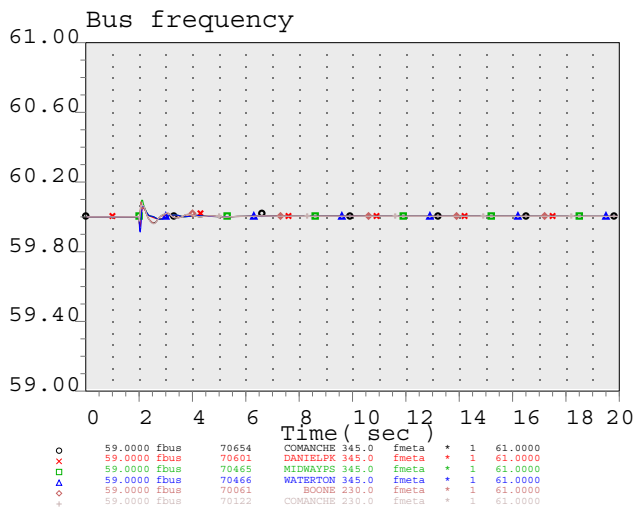


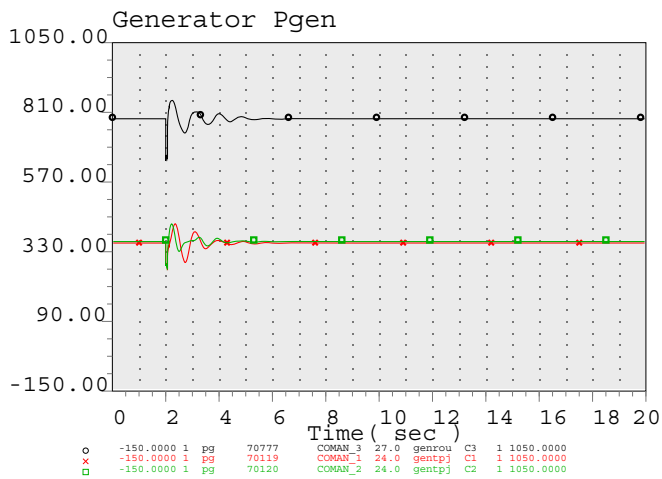


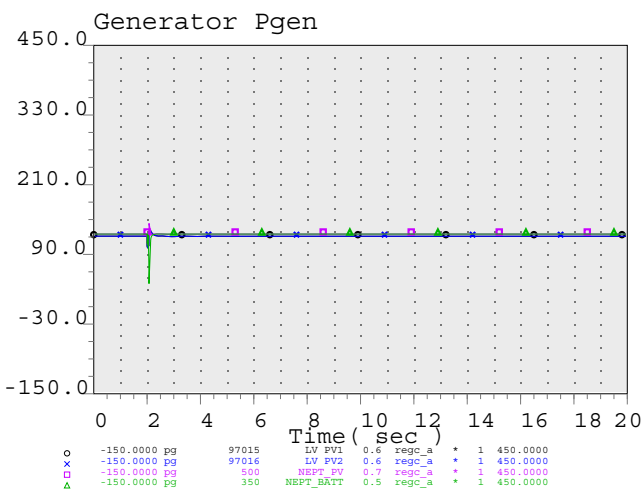
FAULT:Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone-Lamar 230kV and Lama gen

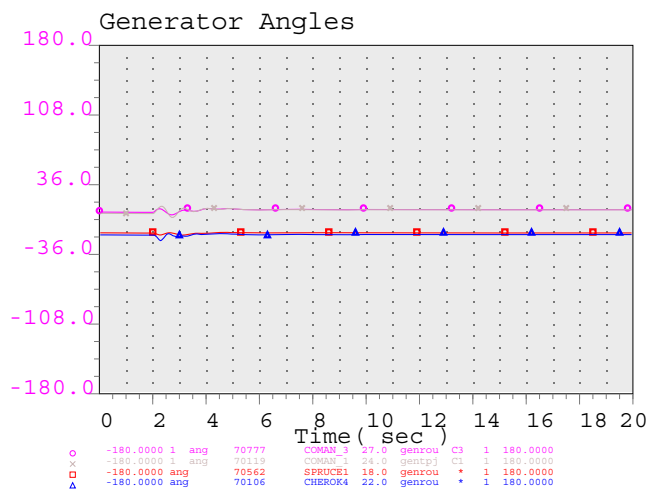




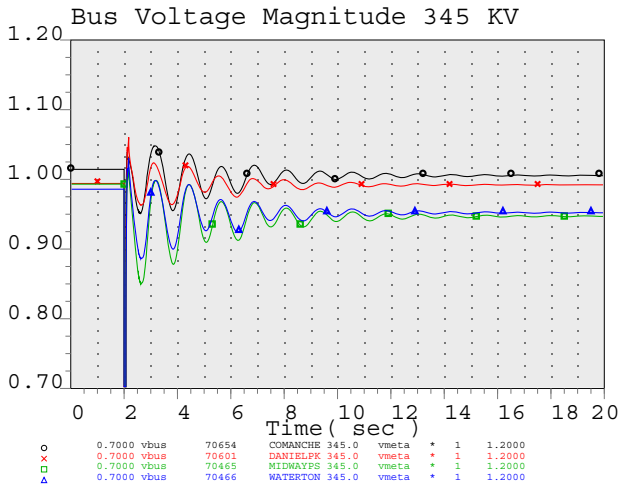


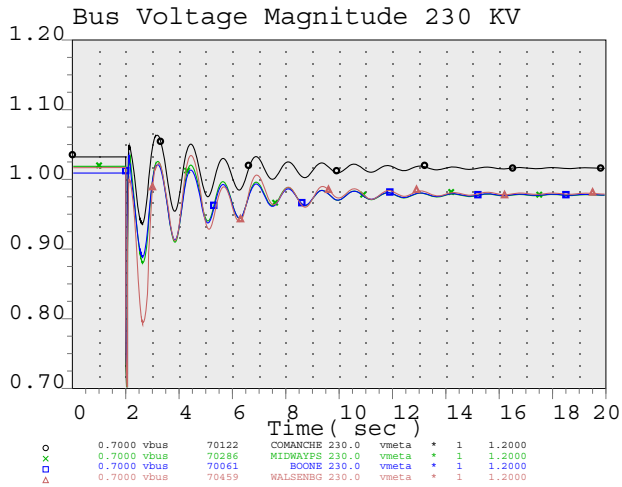


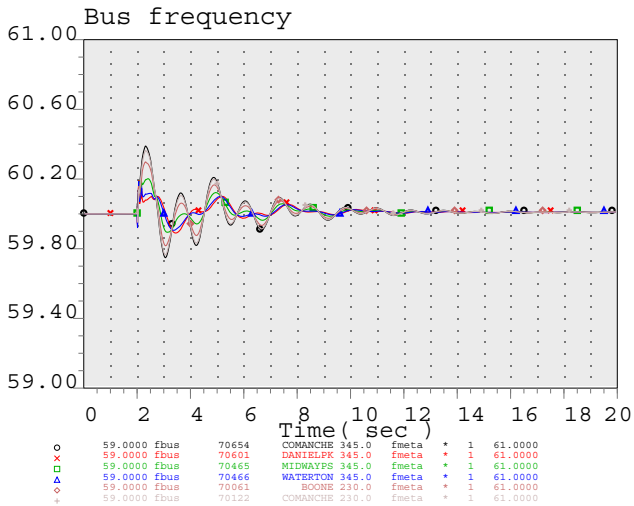


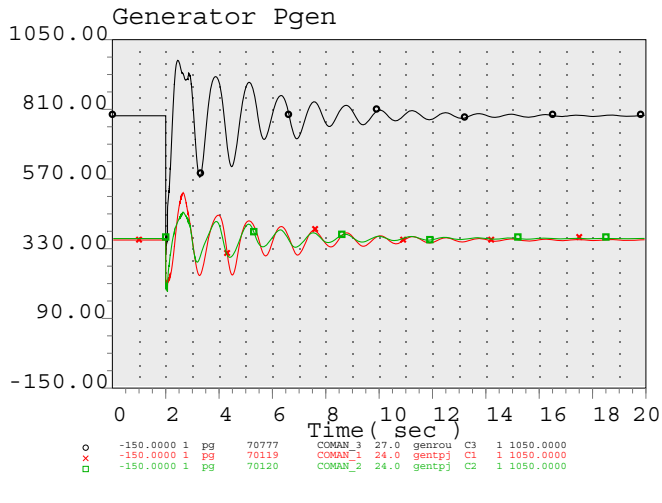


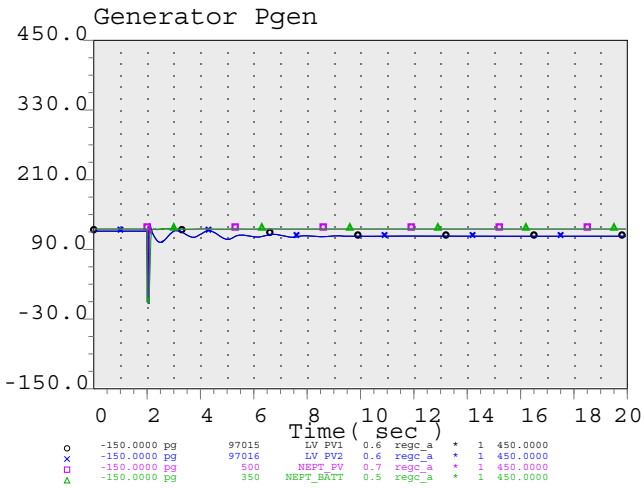
Fault: MIDWAYPS 345 KV 4 cycle 3-ph bus fault
Outage: lose MidwayPS 345/230 KV and MidwayPS - Waterton 345 KV line

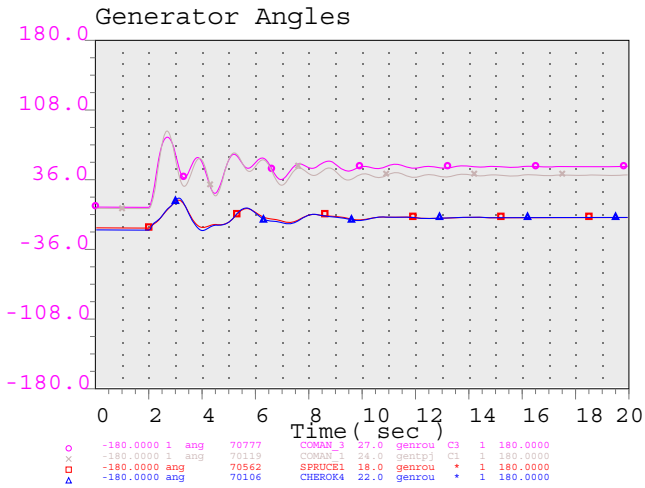








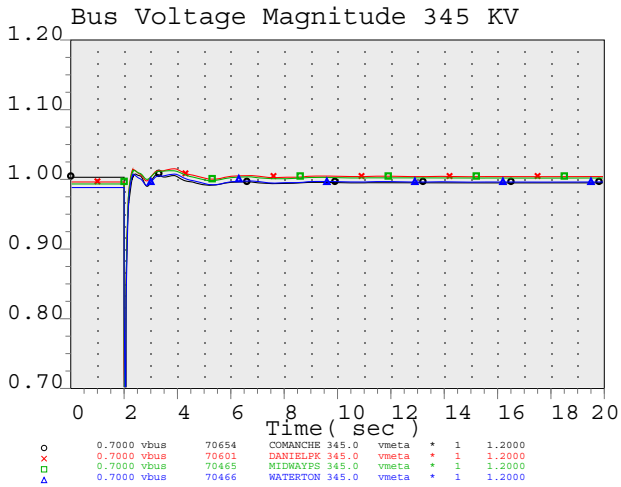


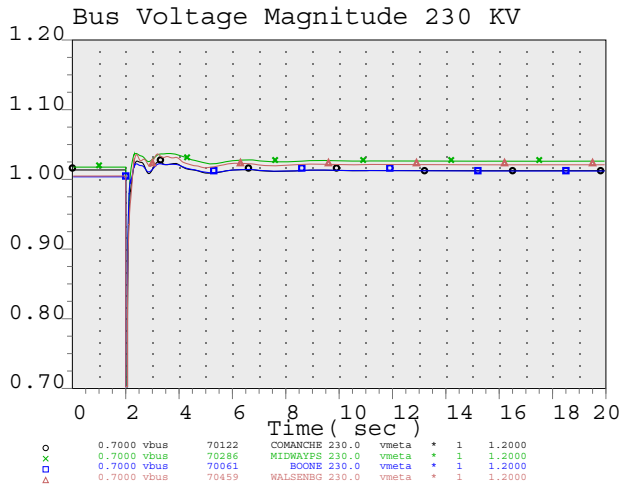


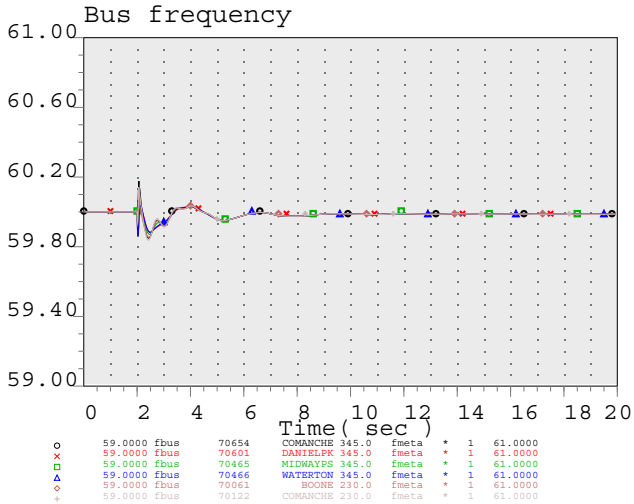
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
outage: lose Comanche - Daniels Park 345 KV and
lose Tundra - Daniels Park 345 KV line

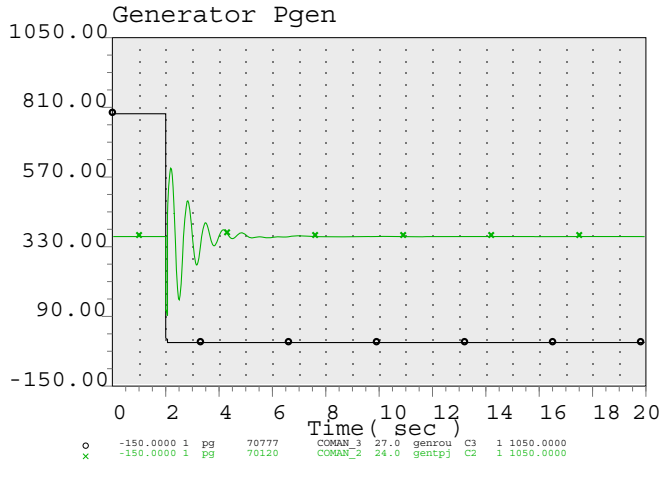
Transient Stability Plot with GI-2018-24

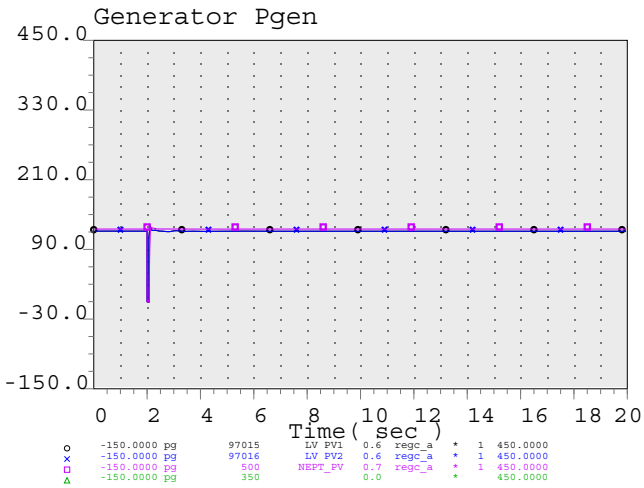
PV only Operation

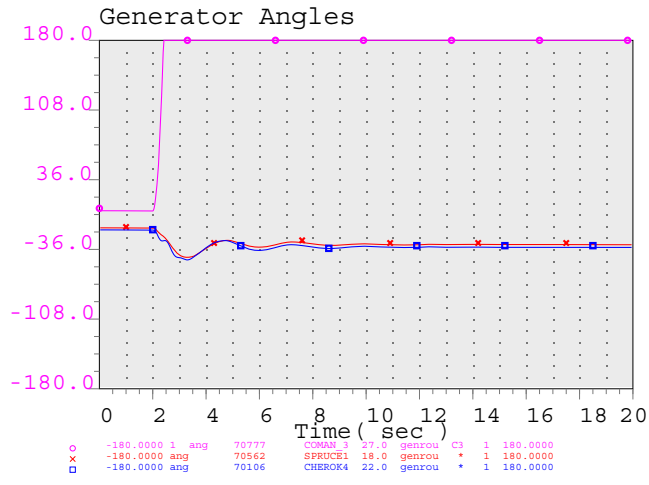




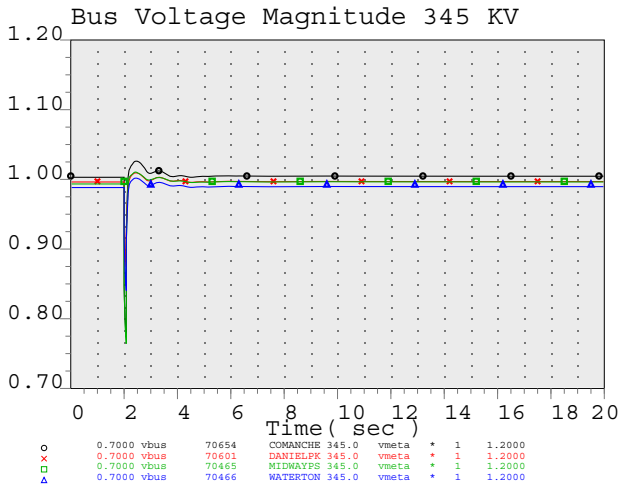


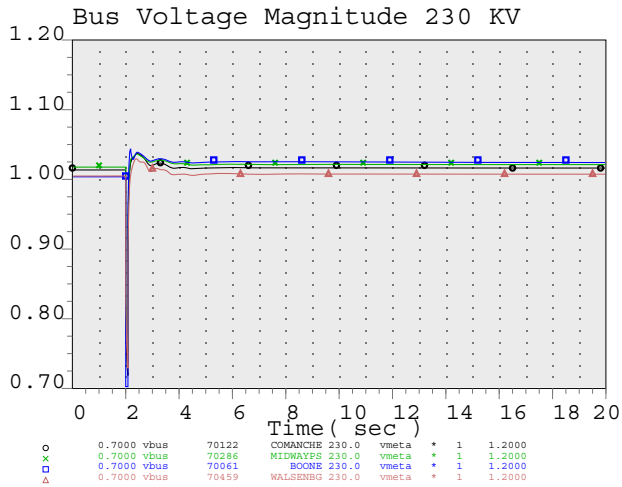


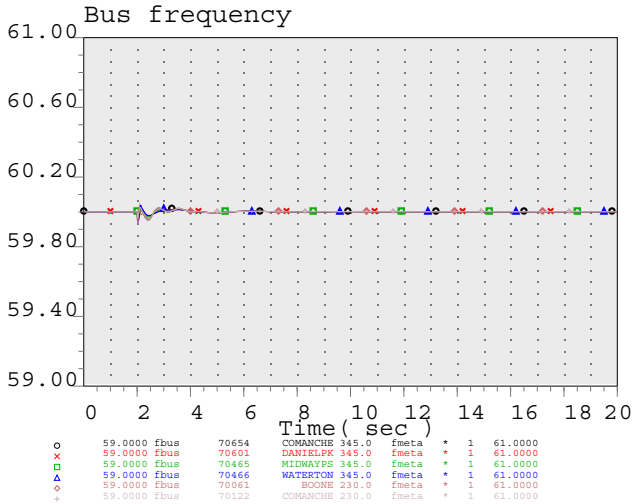


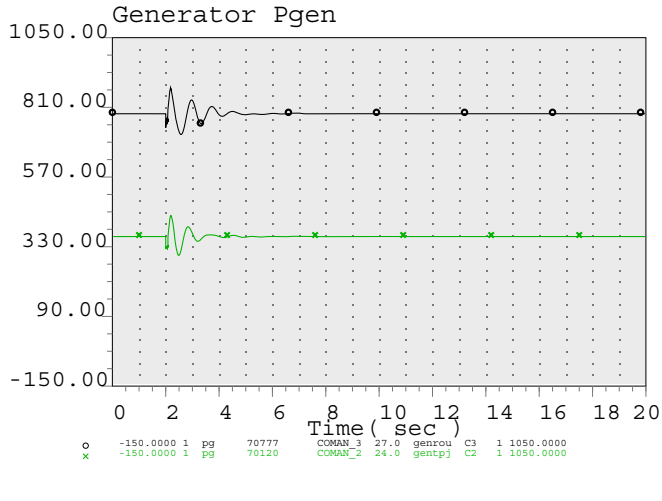


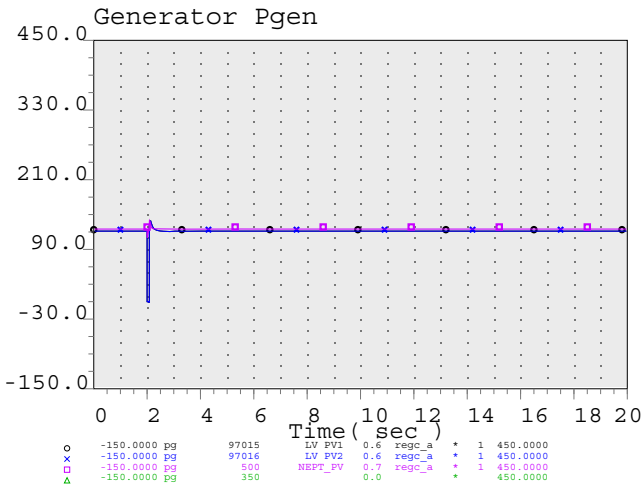
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: Comanche unit 3

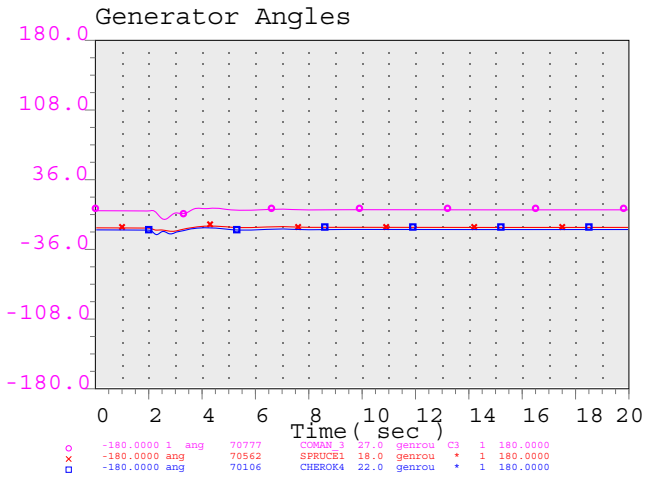




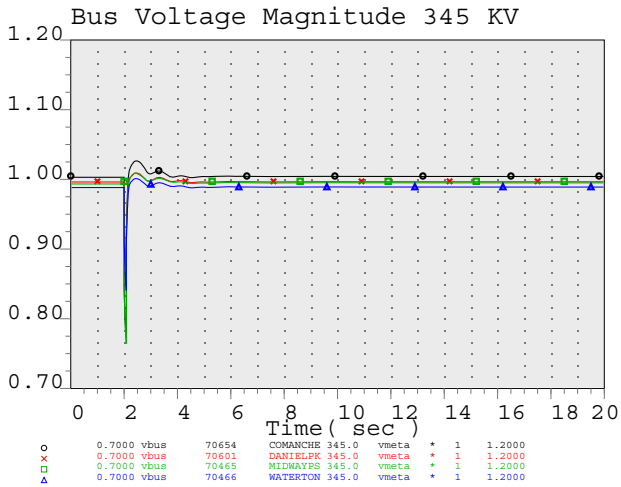


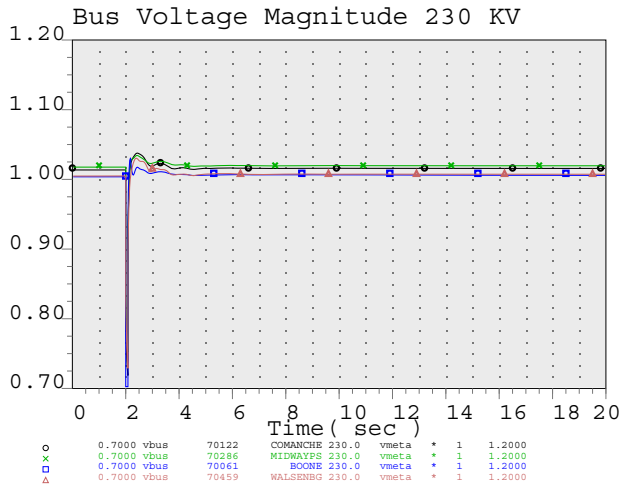


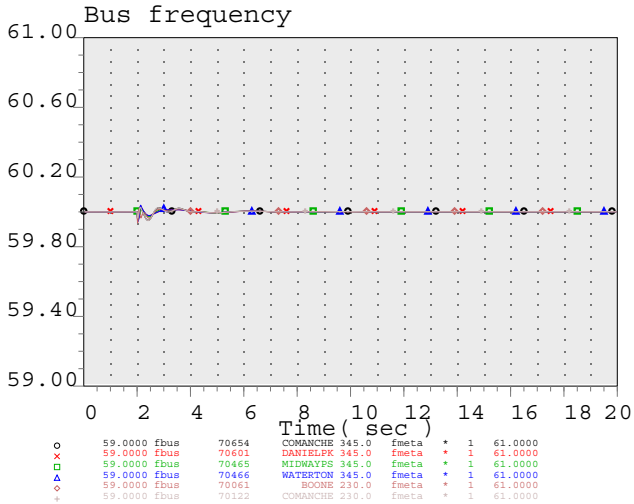


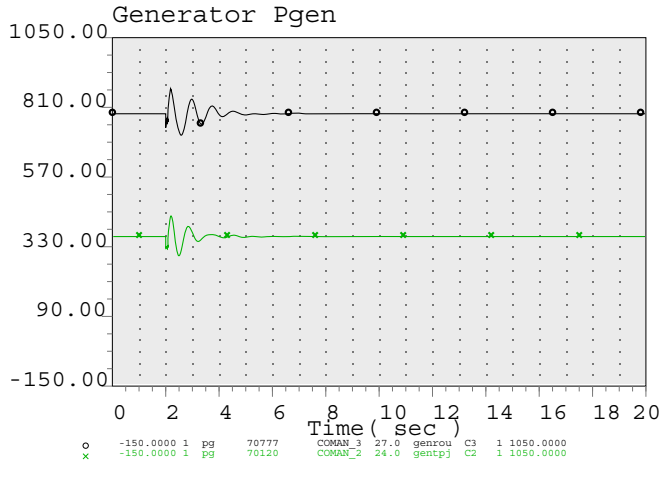


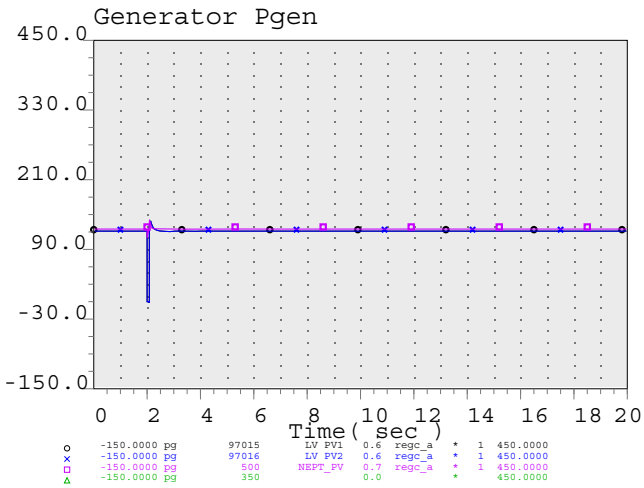
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage:lose Boone 230/115 KV bank

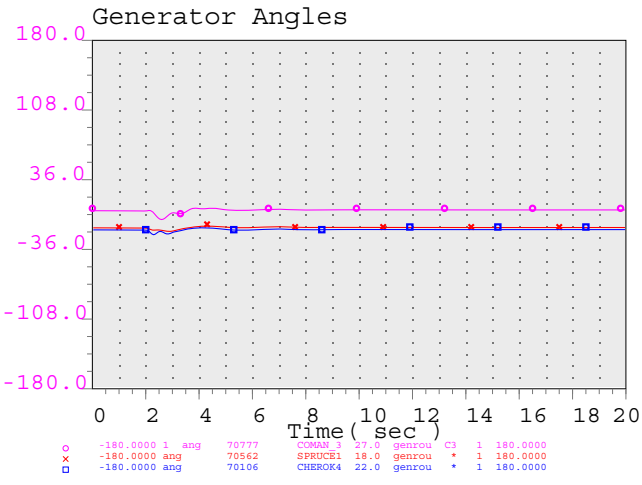




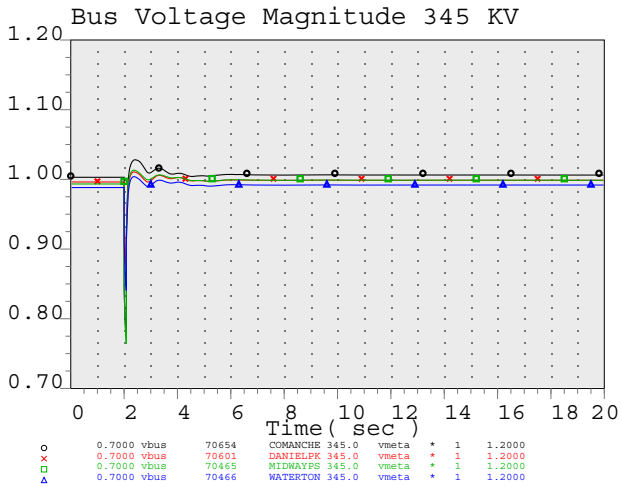


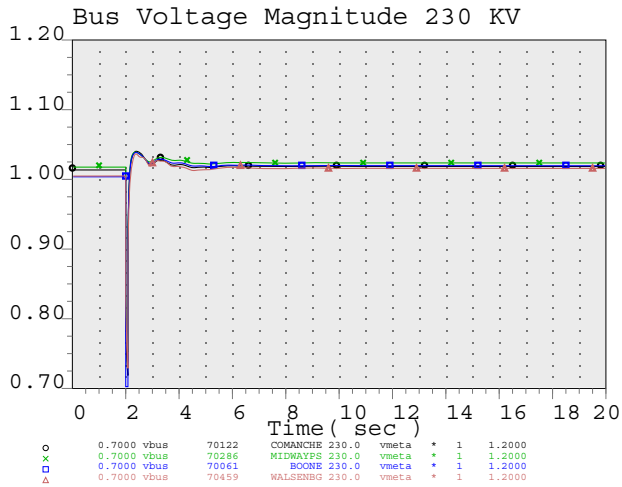


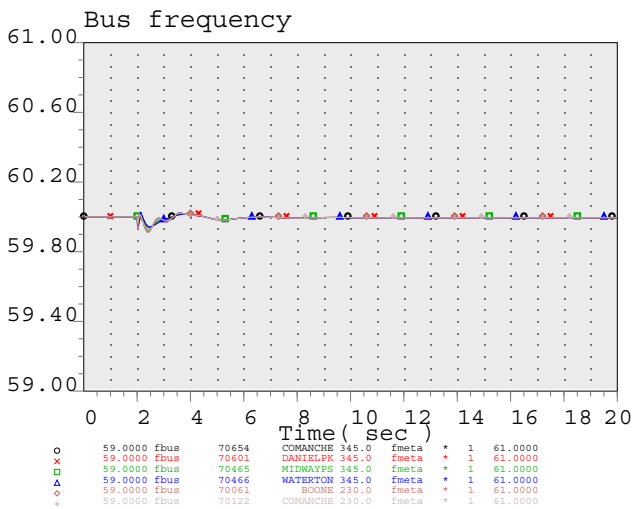


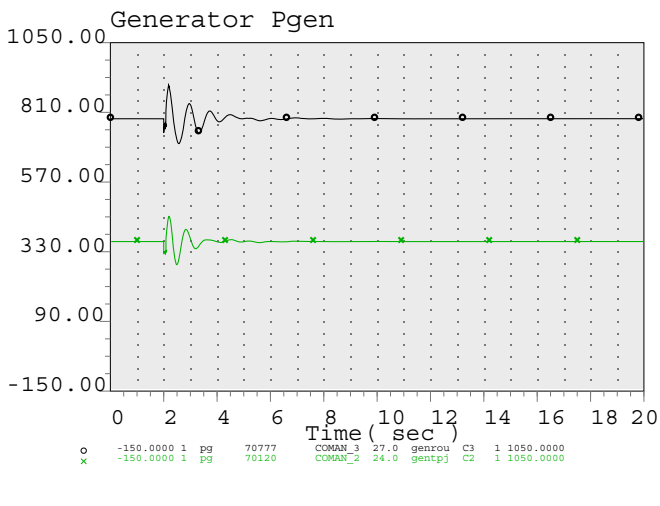


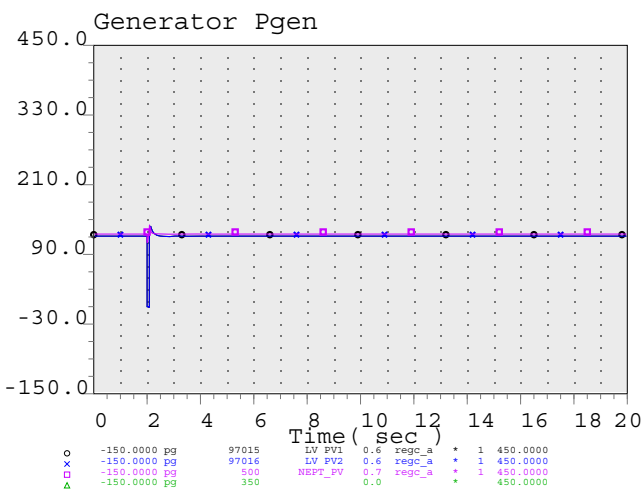
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Comanche 230 KV line

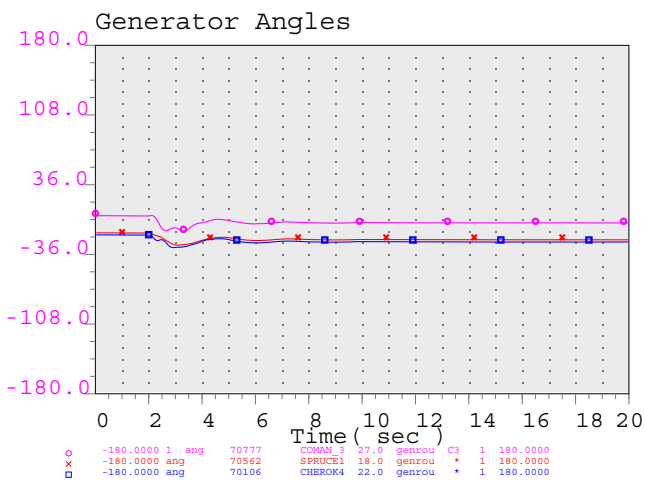




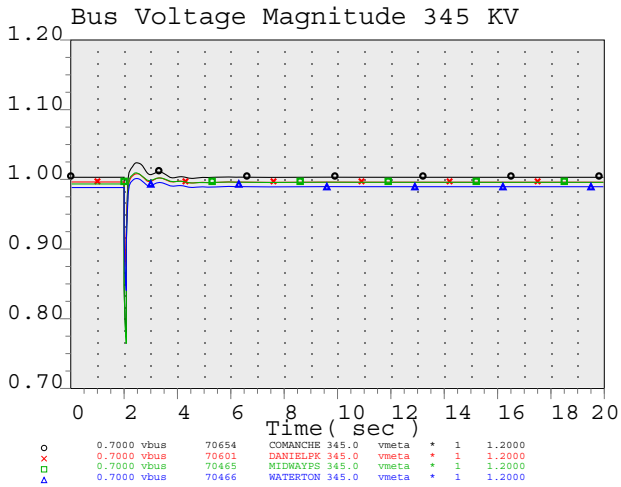


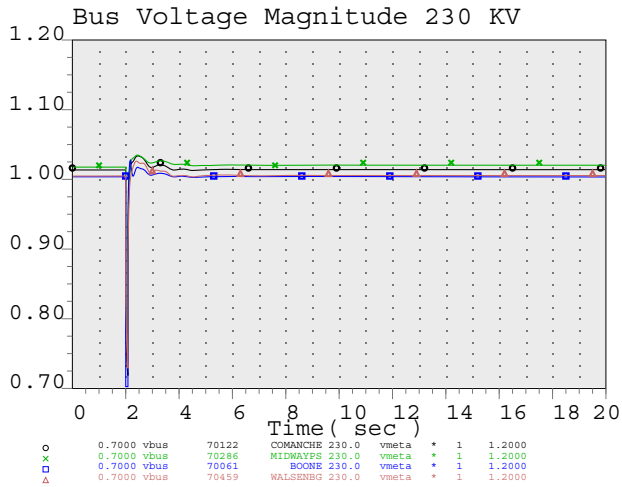


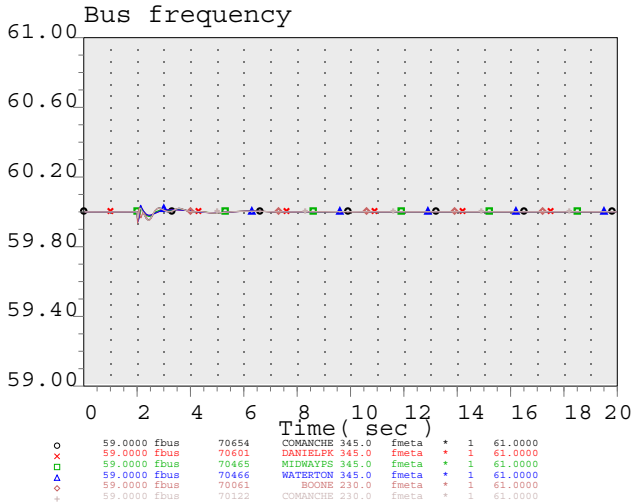


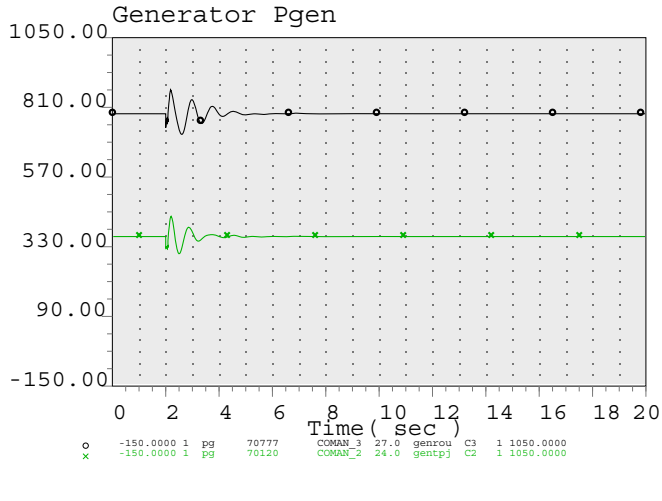


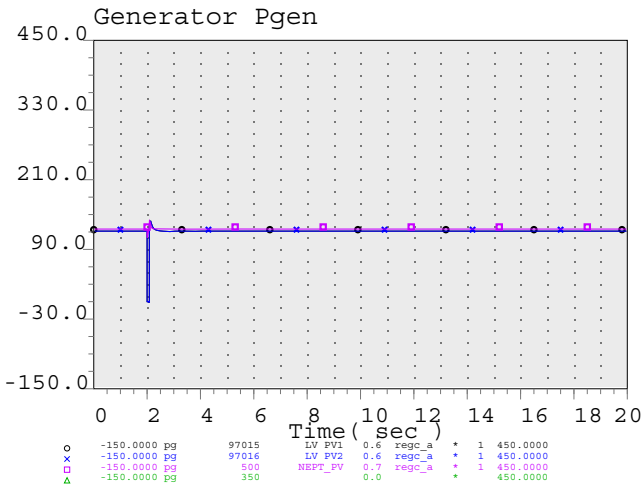
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Lamar 230 KV line and Lamar gen

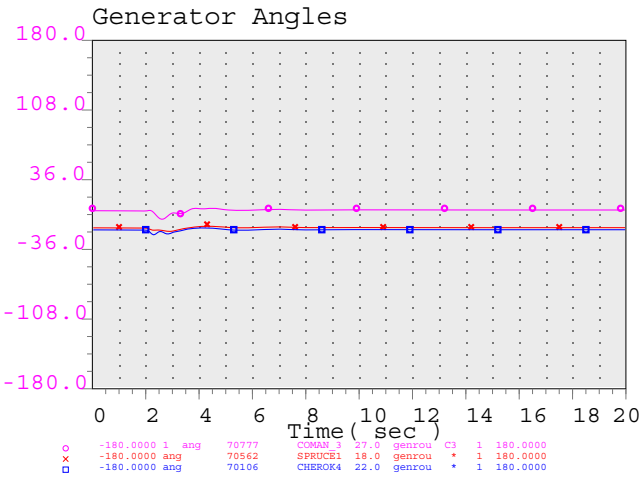




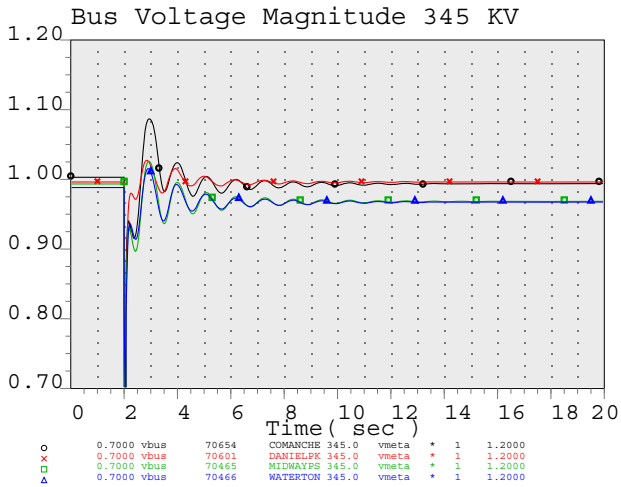


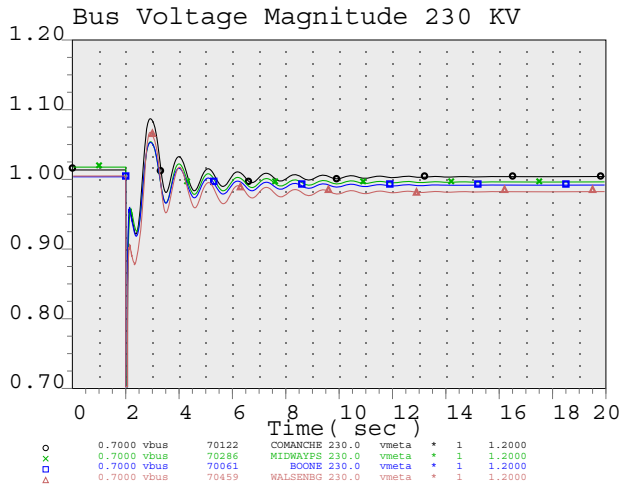


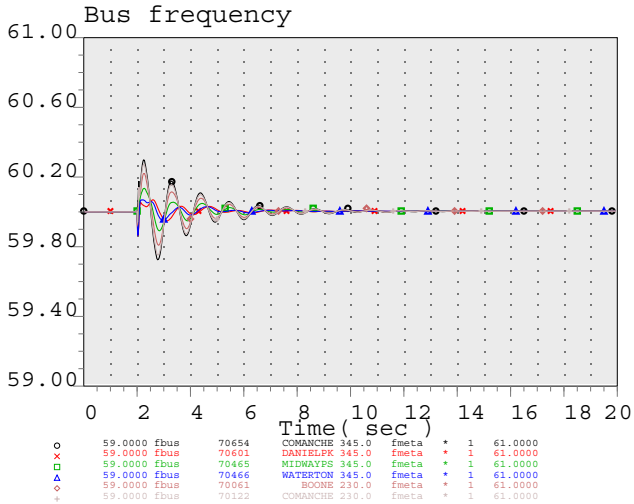


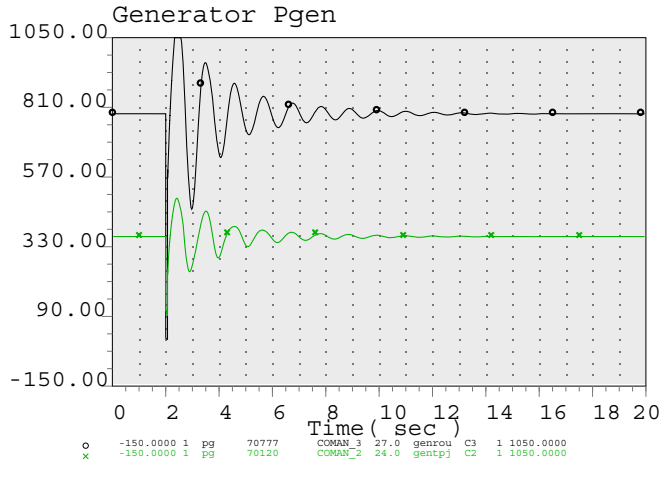


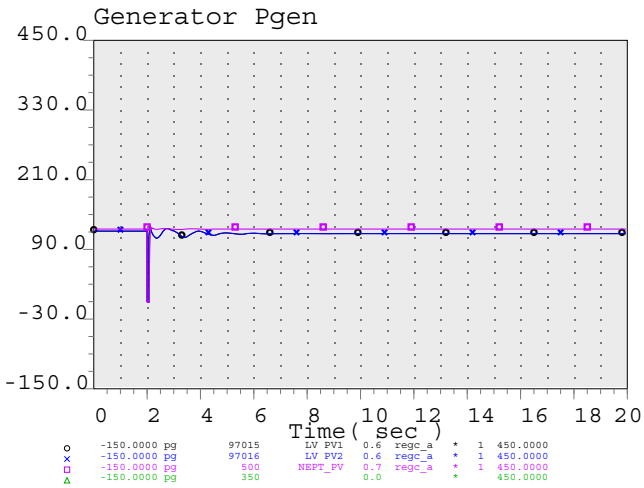
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Midway 230 KV line

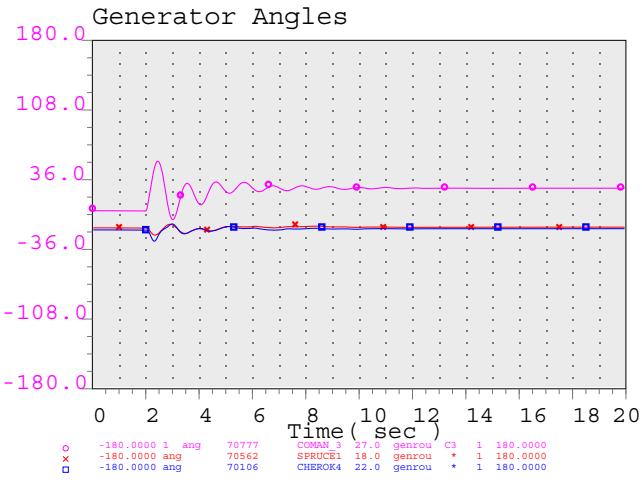




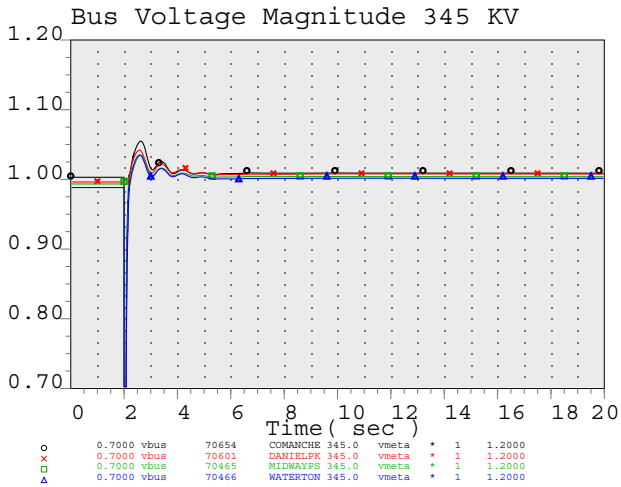


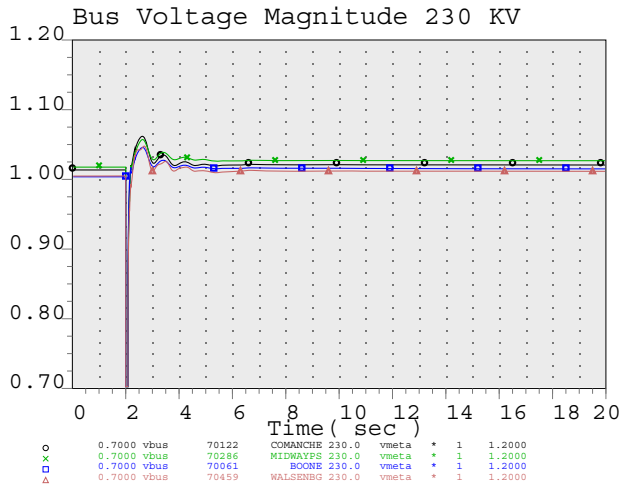


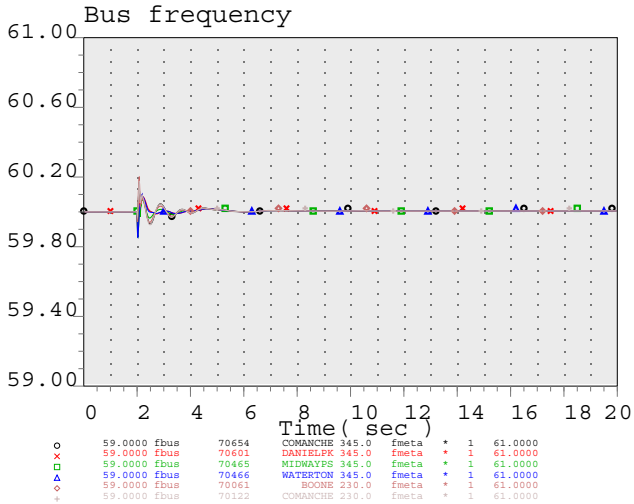


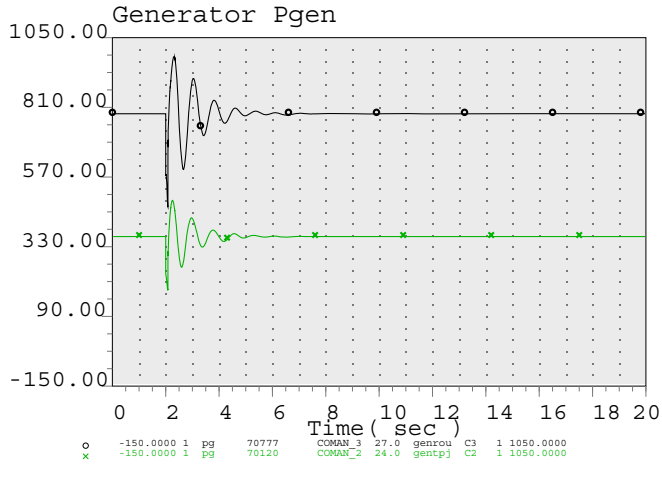


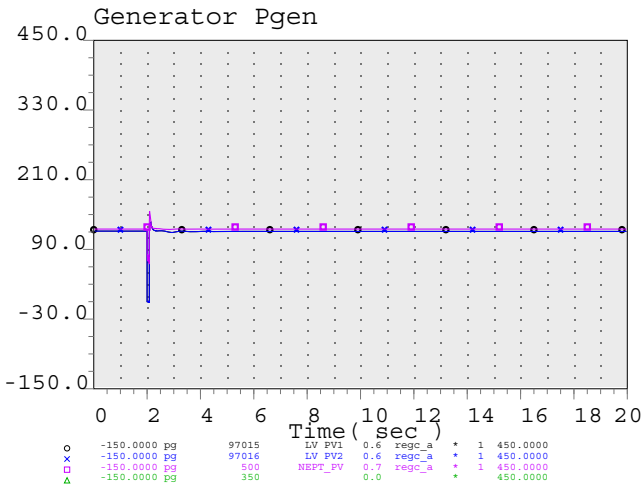
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
outage: lose Comanche - Daniels Park 345 KV
and lose Comanche - Tundra 345 KV line

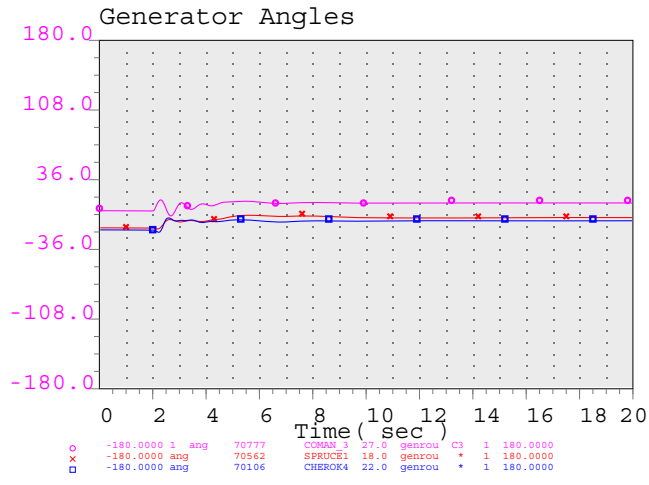




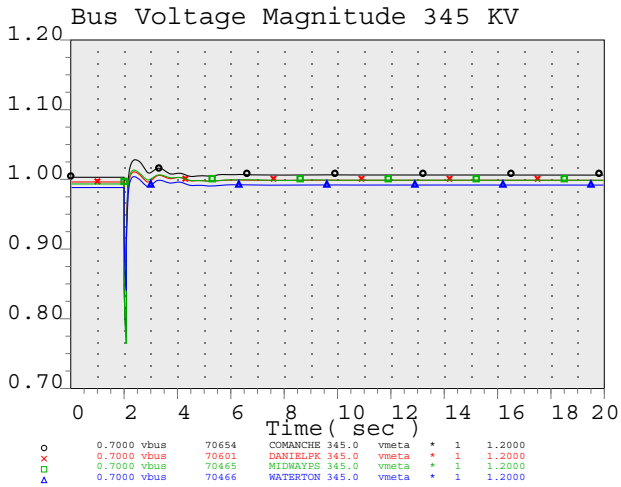


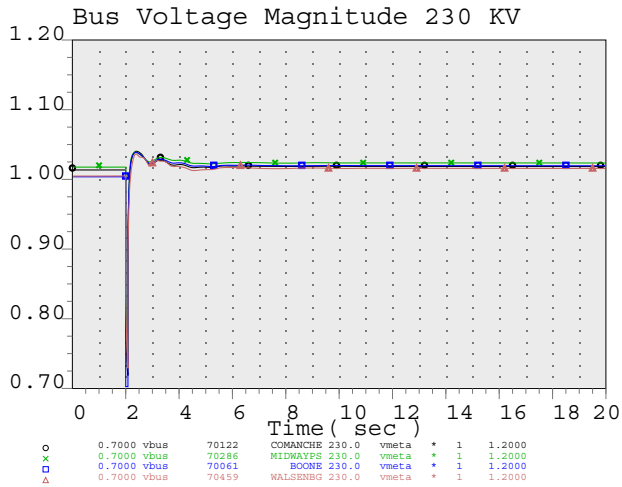


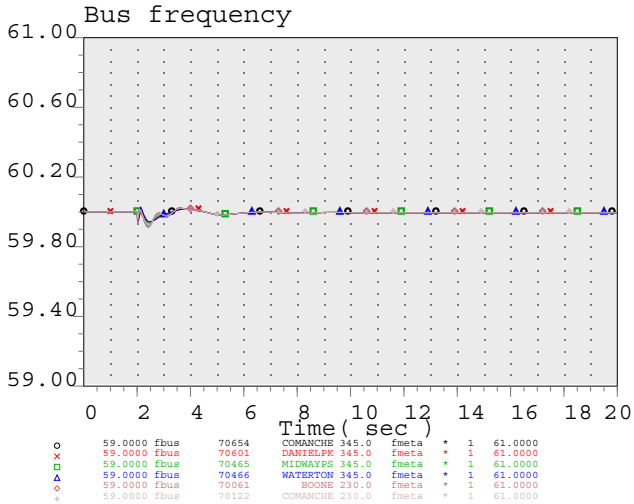


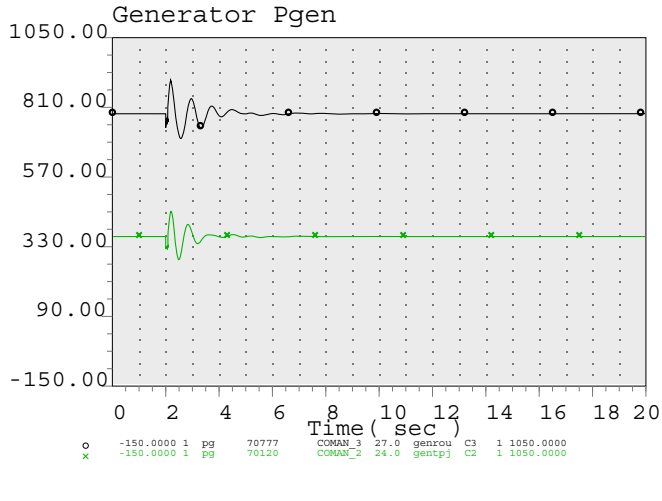


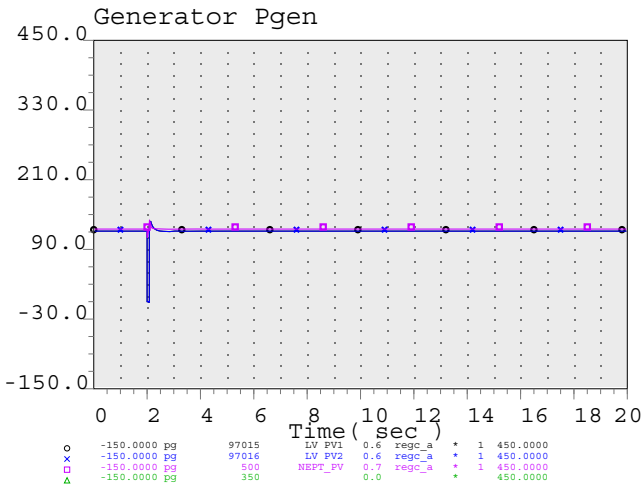
Fault: MIDWAYPS 230 KV 5 cycle 3-ph bus fault
Outage: lose Fountain Valley gen

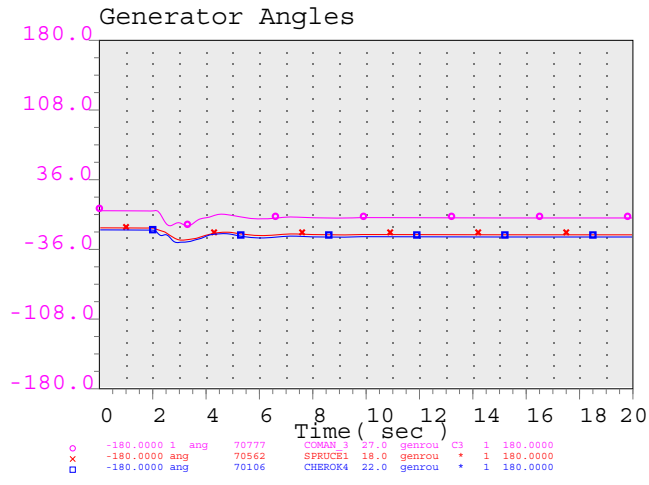

Bus Voltage Magnitude 345 KV
1.20
1.10
1.00
0.90
0.80
0.70
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
0.7000 vbus 70654 COMANCHE 345.0 vmeta * 1 1.2000
0.7000 vbus 70601 DANIELPK 345.0 vmeta * 1 1.2000
0.7000 vbus 70465 MIDWAYPS 345.0 vmeta * 1 1.2000
0.7000 vbus 70466 WATERTON 345.0 vmeta * 1 1.2000

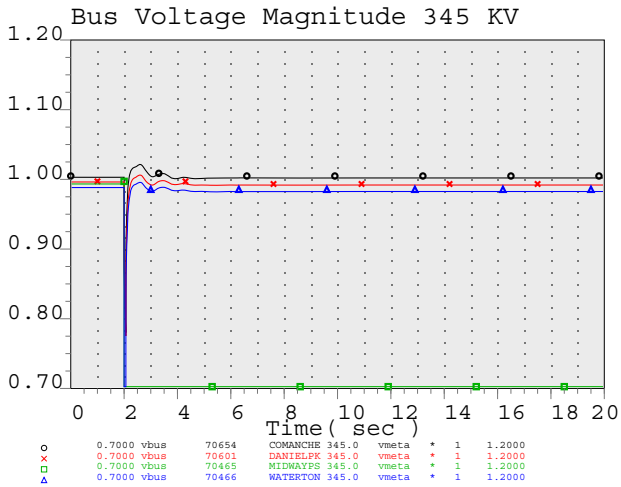

Bus Voltage Magnitude 230 KV
1.20
1.10
1.00
0.90
0.80
0.70
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
0.7000 vbus 70122 COMANCHE 230.0 vmeta * 1 1.2000
0.7000 vbus 70286 MIDWAYPS 230.0 vmeta * 1 1.2000
0.7000 vbus 70061 BOONE 230.0 vmeta * 1 1.2000
0.7000 vbus 70459 WALSENBG 230.0 vmeta * 1 1.2000

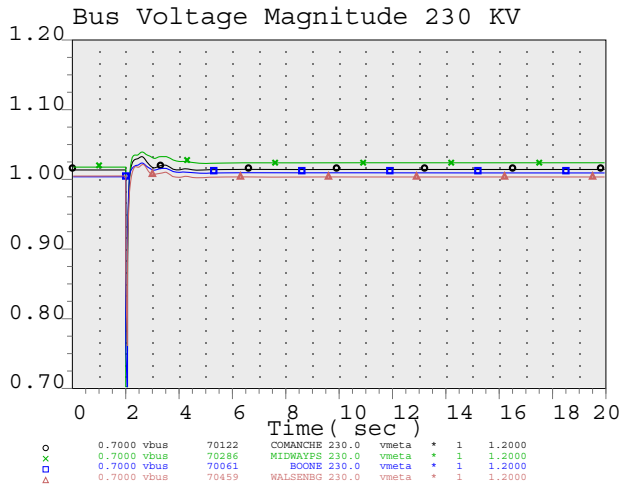

Bus frequency
61.00
60.60
60.20
59.80
59.40
59.00
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
59.0000 fbus 70654 COMANCHE 345.0 fmeta * 1 61.0000
59.0000 fbus 70601 DANIELPK 345.0 fmeta * 1 61.0000
59.0000 fbus 70465 MIDWAYPS 345.0 fmeta * 1 61.0000
59.0000 fbus 70466 WATERTON 345.0 fmeta * 1 61.0000
59.0000 fbus 70061 BOONE 230.0 fmeta * 1 61.0000
59.0000 fbus 70122 COMANCHE 230.0 fmeta * 1 61.0000

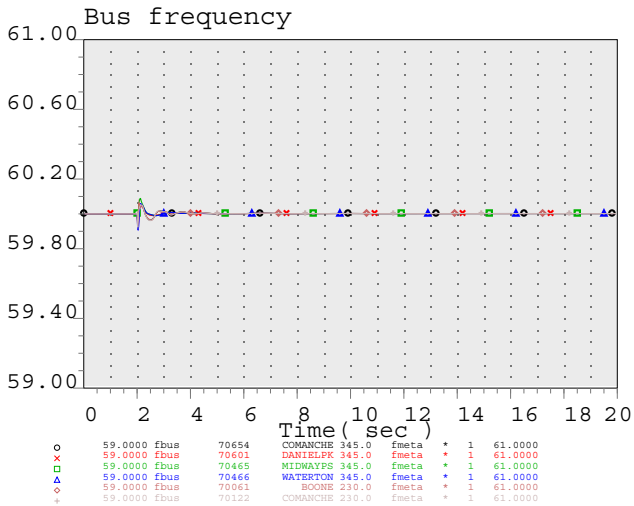

Generator Pgen
1050.00
810.00
570.00
330.00
90.00
-150.00
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
-150.0000 1 pg 70777 COMAN_3 27.0 genrou C3 1 1050.0000
-150.0000 1 pg 70120 COMAN_2 24.0 gentpj C2 1 1050.0000

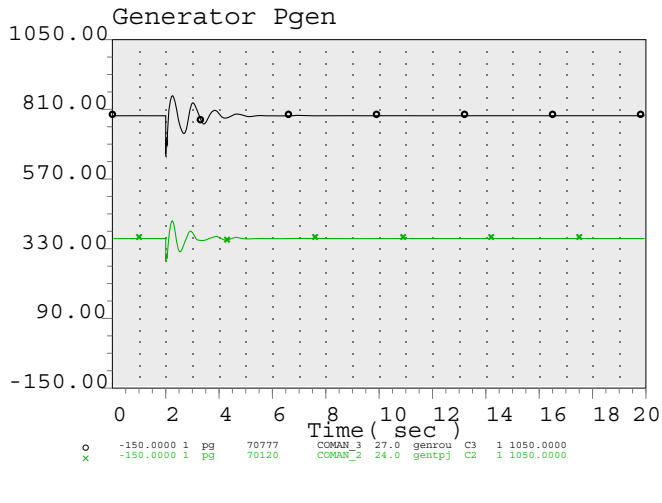

Generator Pgen
450.0
330.0
210.0
90.0
-30.0
-150.0
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
-150.0000 pg 97015 LV PV1 0.6 regc_a * 1 450.0000
-150.0000 pg 97016 LV PV2 0.6 regc_a * 1 450.0000
-150.0000 pg 500 NEPT_PV 0.7 regc_a * 1 450.0000
-150.0000 pg 350 0.0 * 450.0000

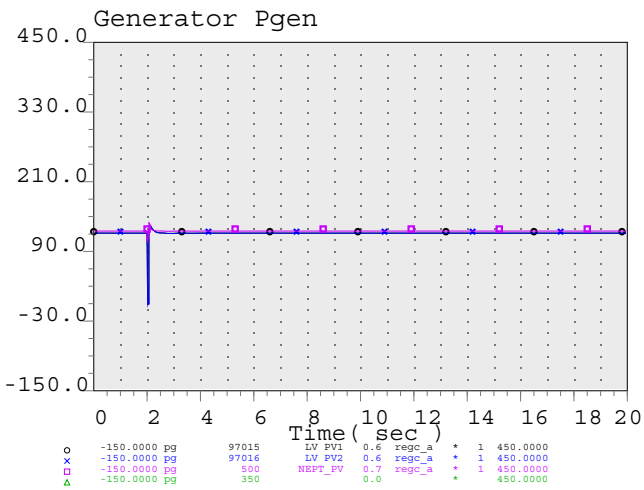

Generator Angles
180.0
108.0
36.0
-36.0
-108.0
-180.0
0 2 4 6 8 10 12 14 16 18 20
Time (sec)
-180.0000 1 ang 70777 COMAN_3 27.0 genrou C3 1 180.0000
-180.0000 ang 70562 SPRUCE1 18.0 genrou * 1 180.0000
-180.0000 ang 70106 CHEROK4 22.0 genrou * 1 180.0000

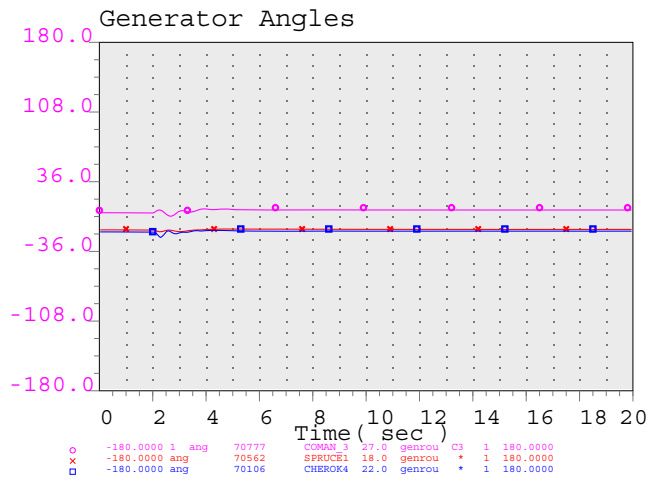




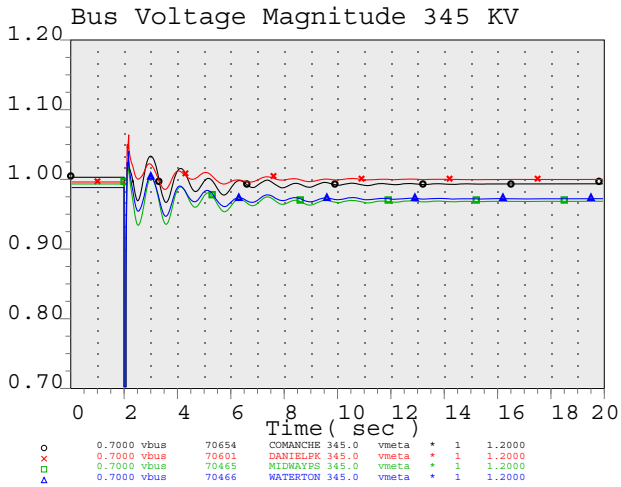


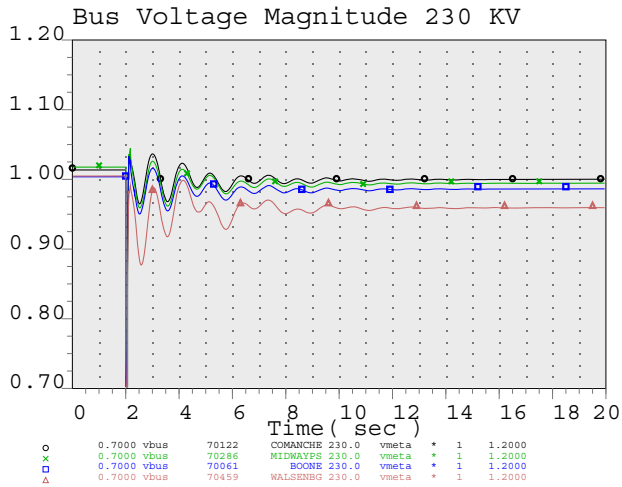


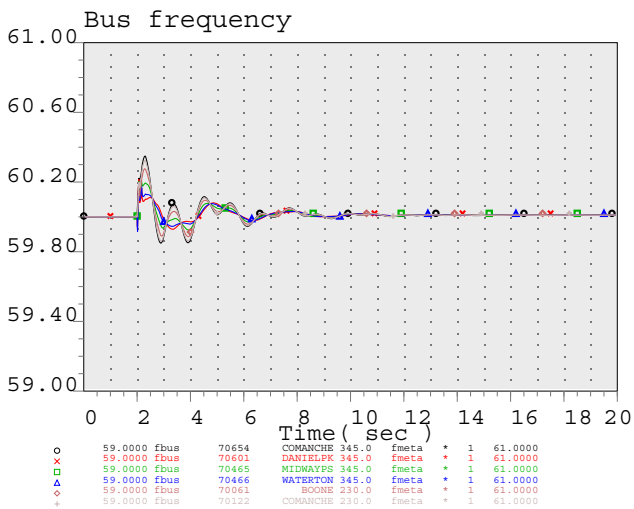


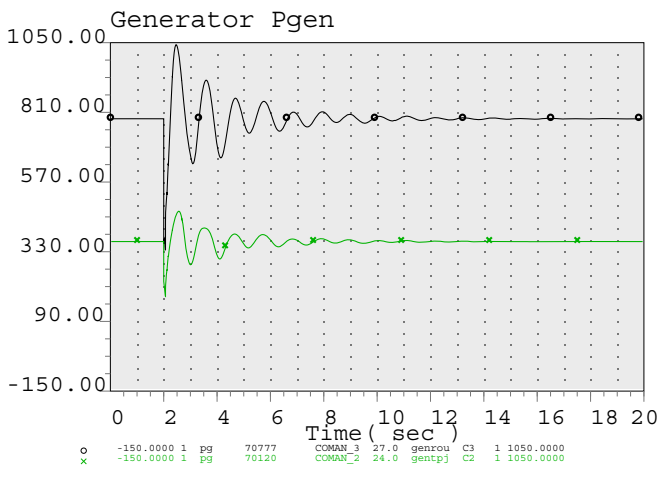


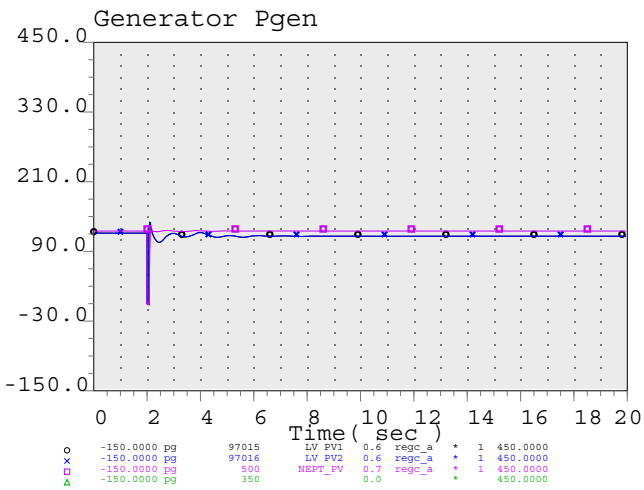
Fault: MIDWAYPS 345 KV 4 cycle 3-ph bus fault
Outage: lose MidwayPS 345/230 KV and MidwayPS - Waterton 345 KV line

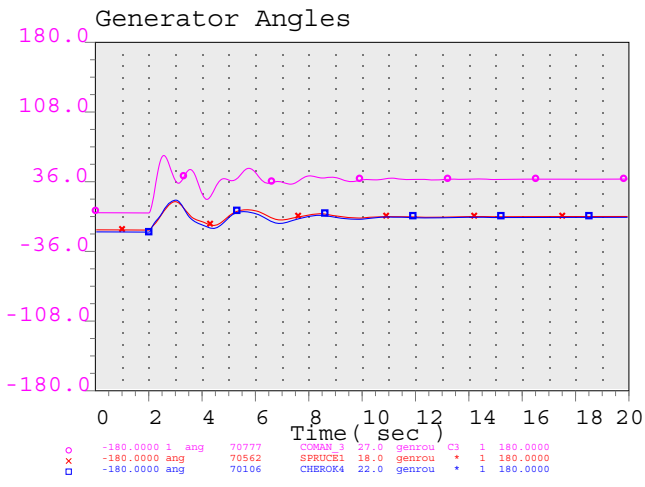








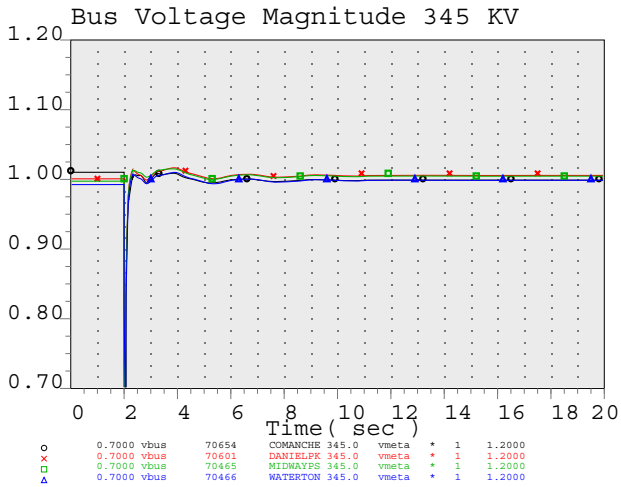


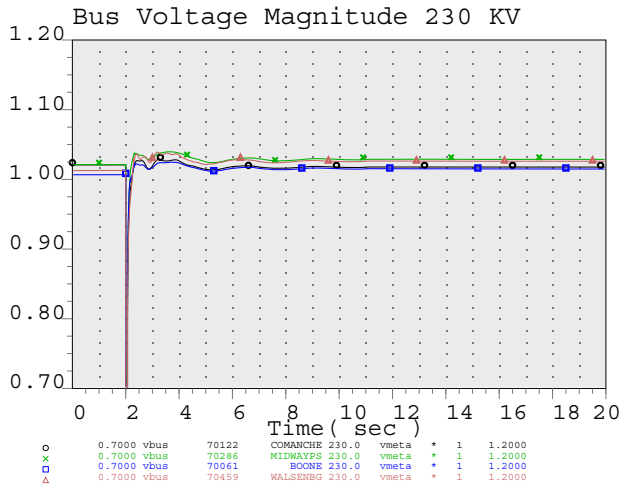


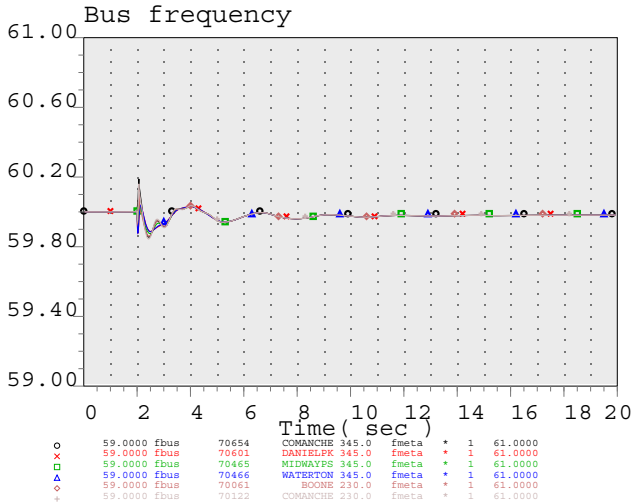
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
outage: lose Comanche - Daniels Park 345 KV and
lose Tundra - Daniels Park 345 KV line

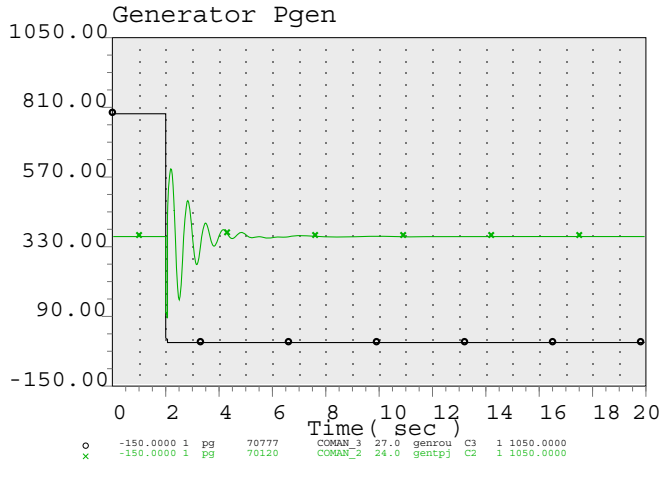
Transient Stability Plot with GI-2018-24

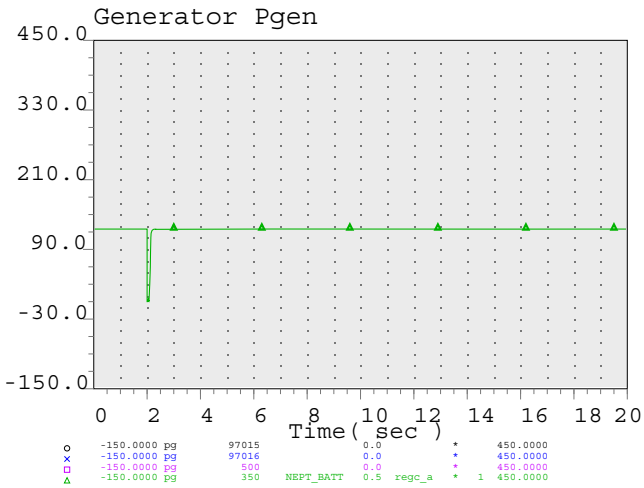
BES only Operation

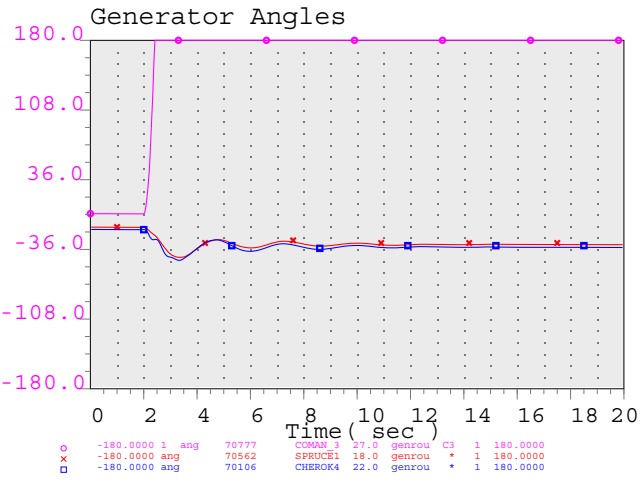




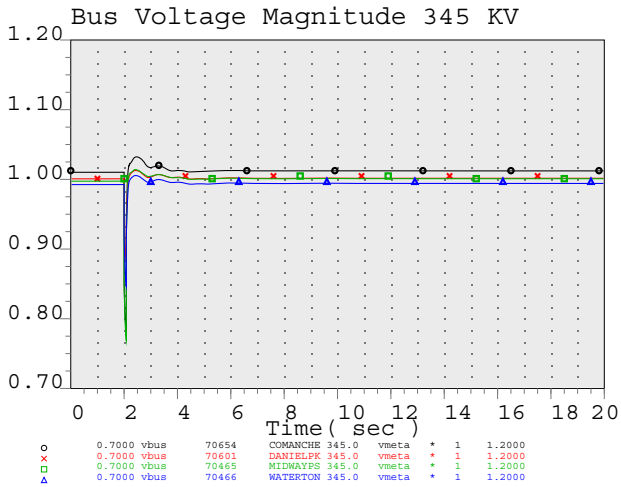


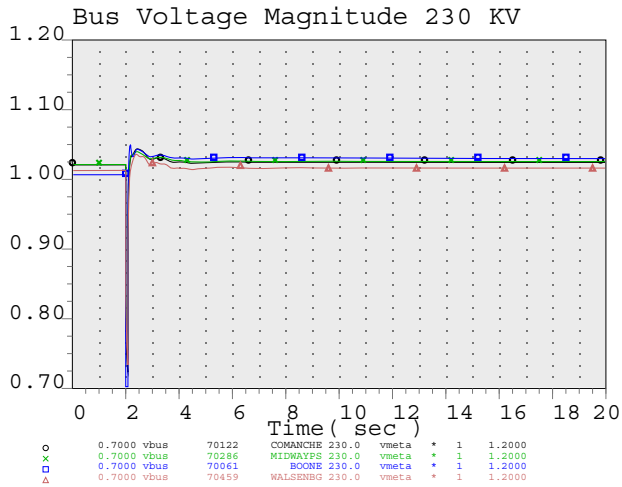


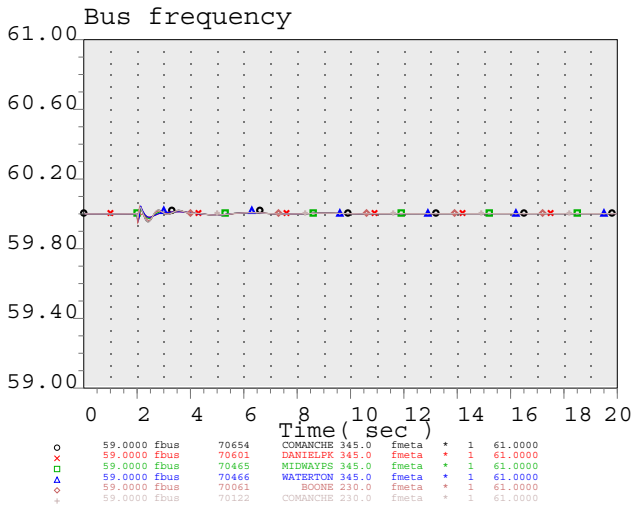


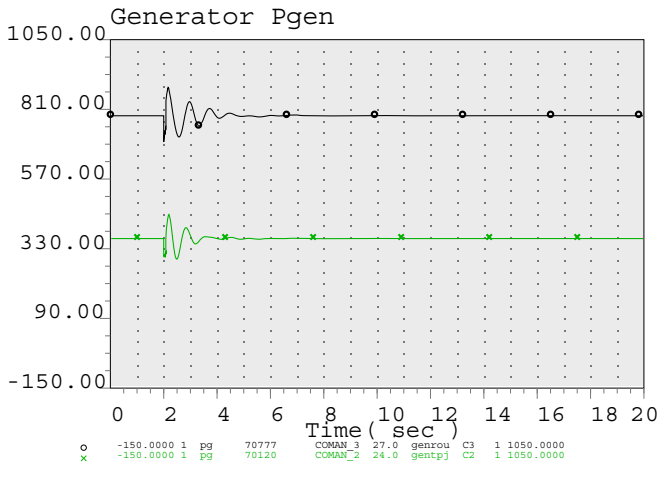


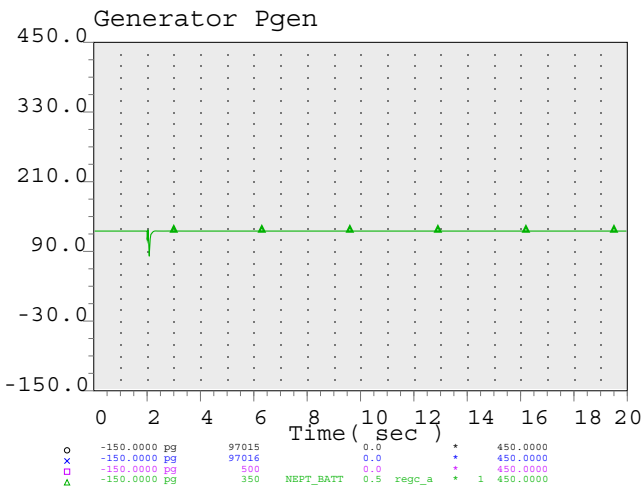
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: Comanche unit 3

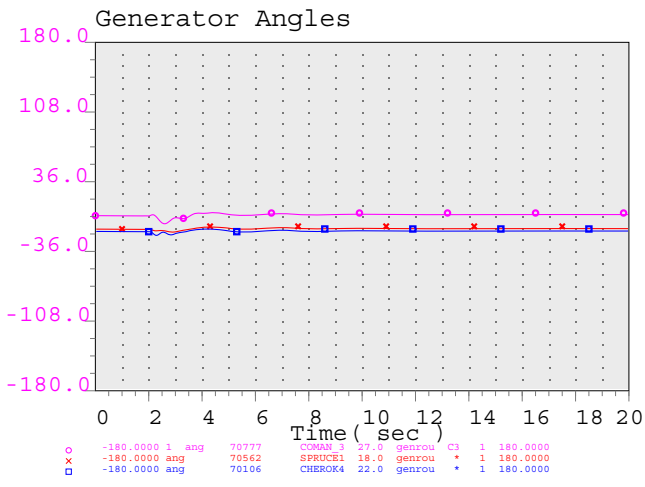




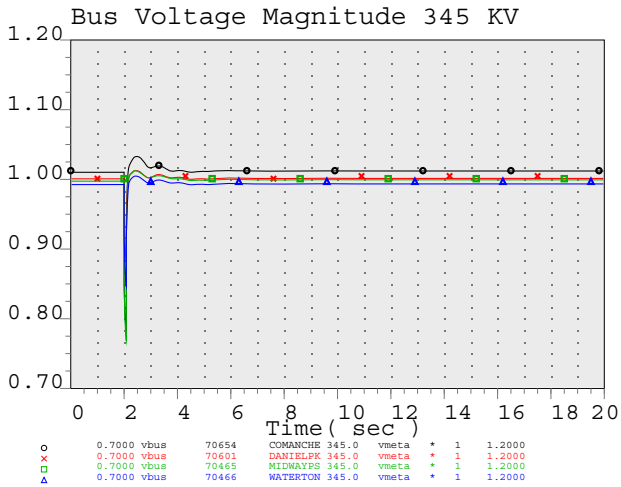


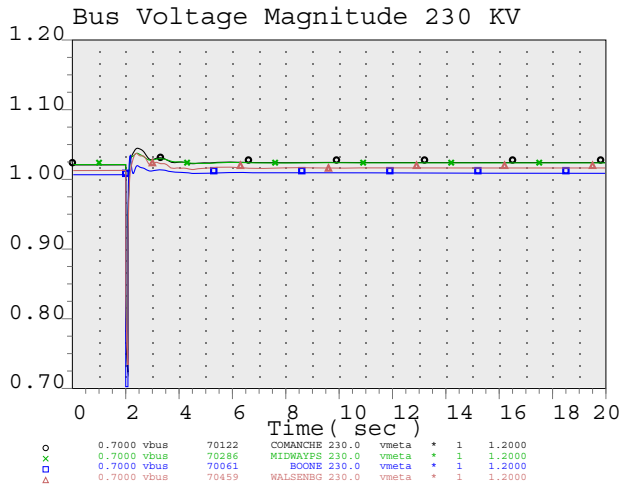


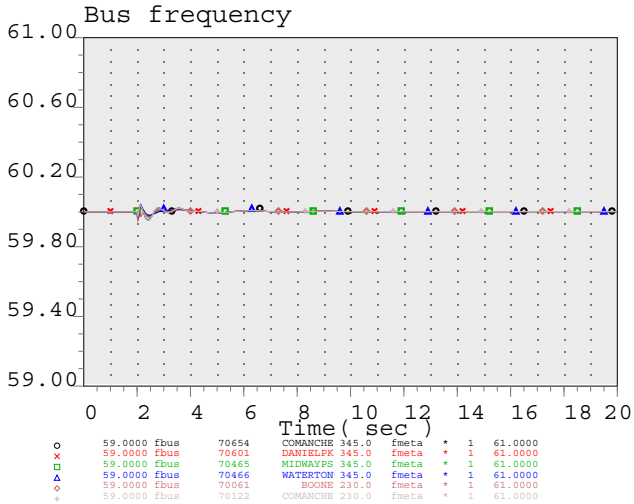


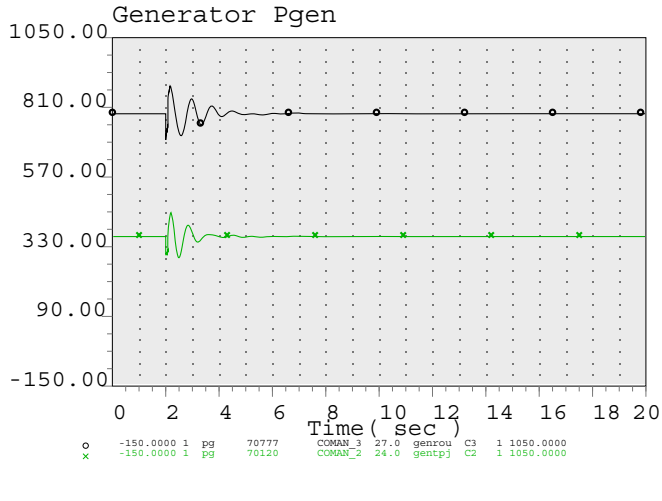


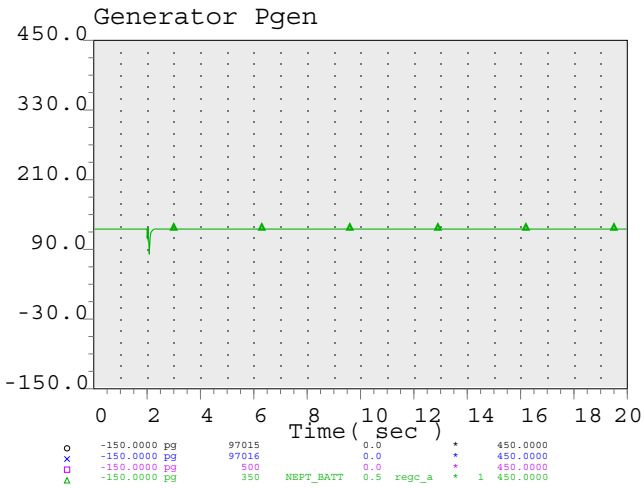
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage:lose Boone 230/115 KV bank

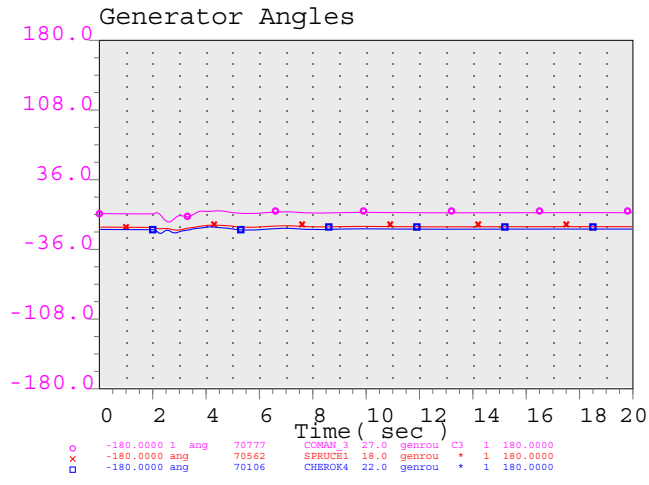




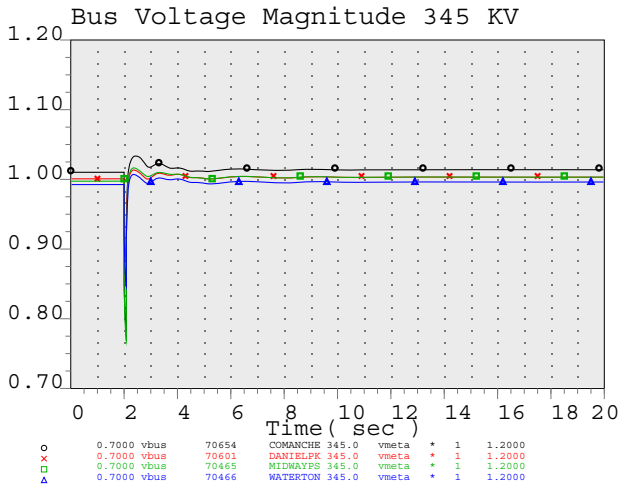


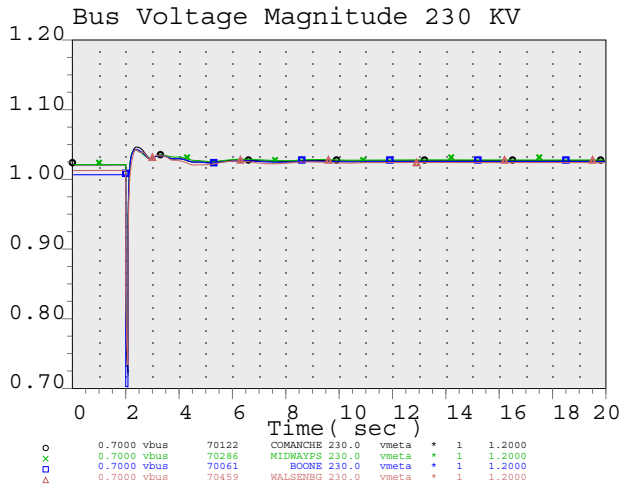


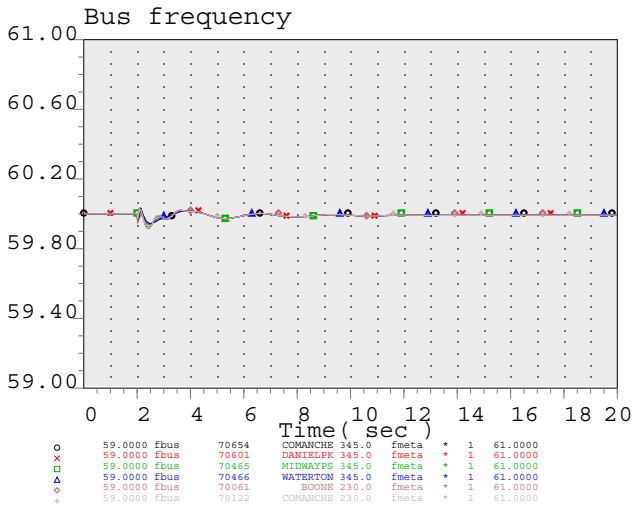


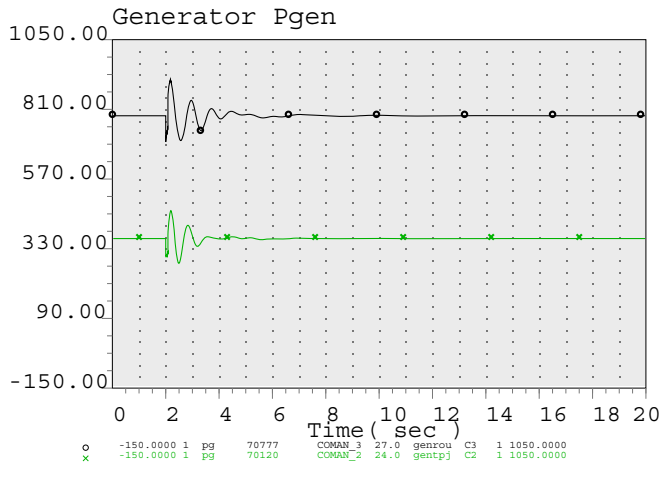


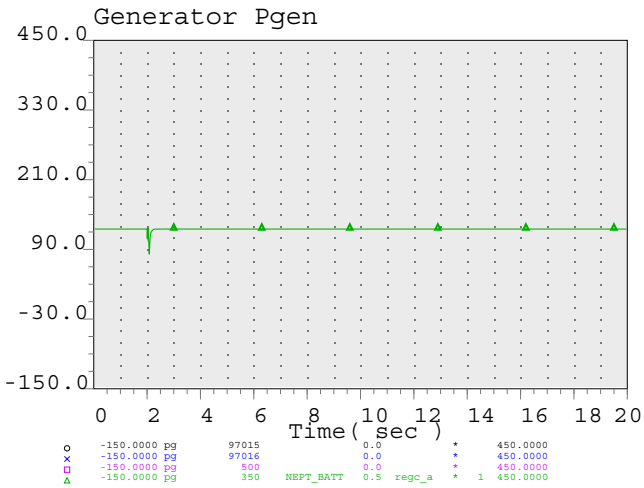
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Comanche 230 KV line

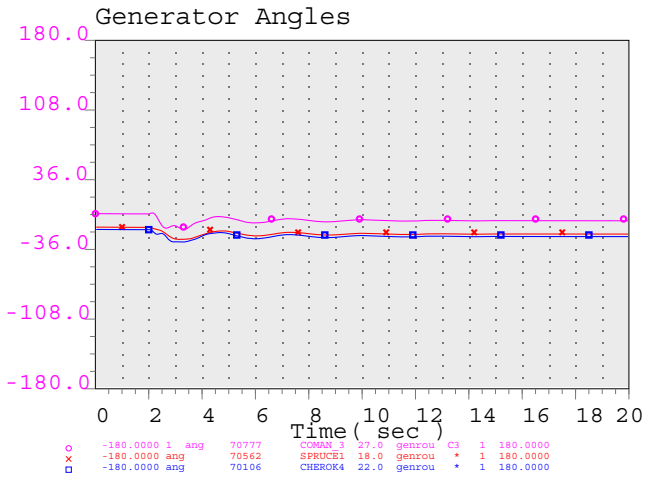




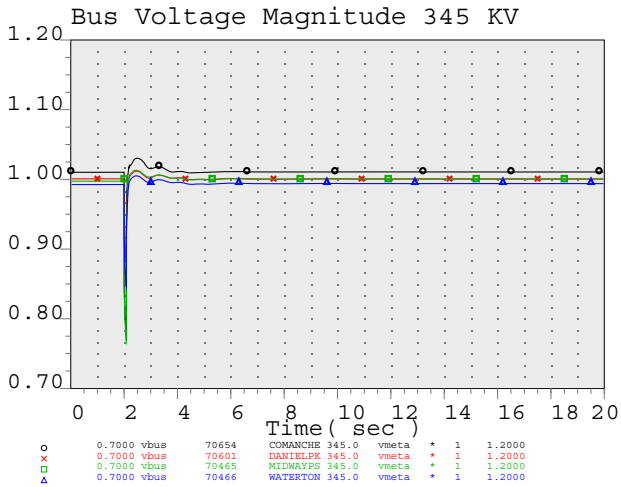


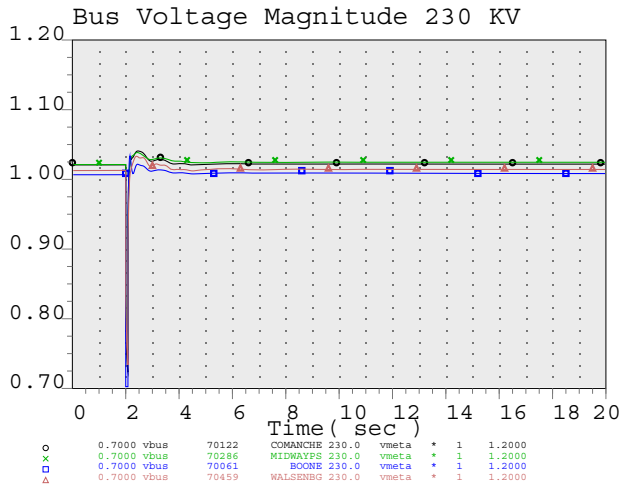


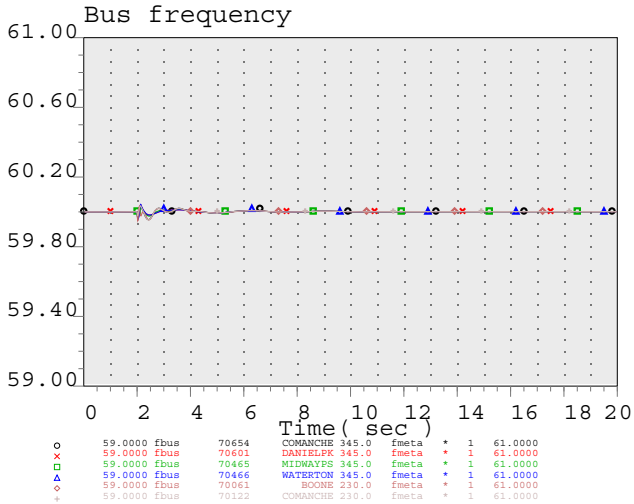


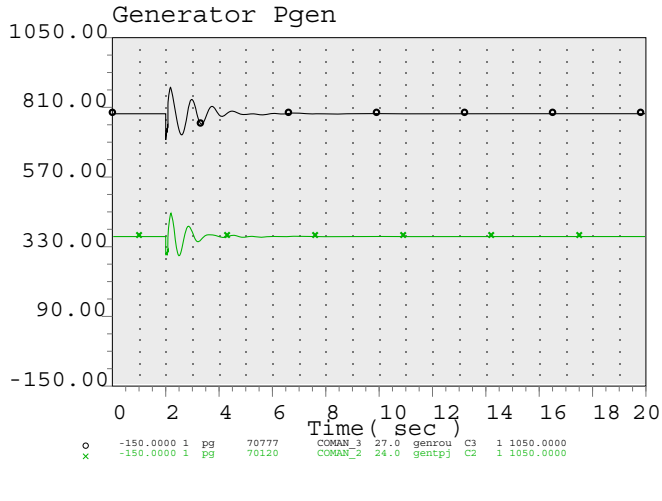


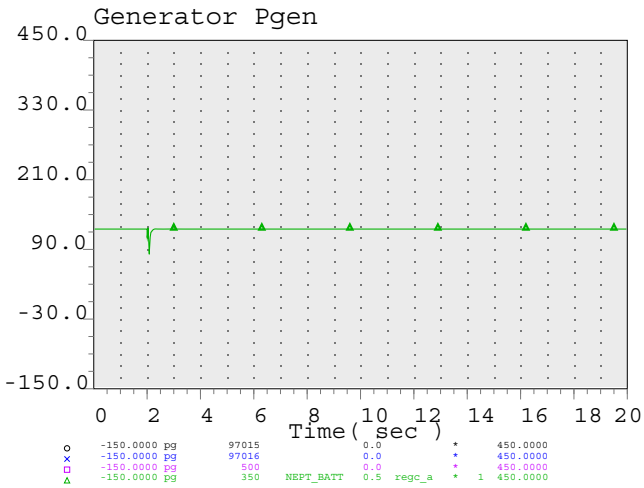
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Lamar 230 KV line and Lamar gen

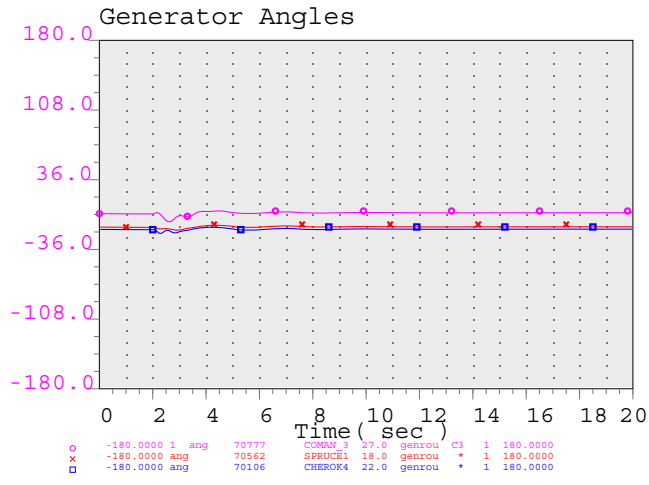




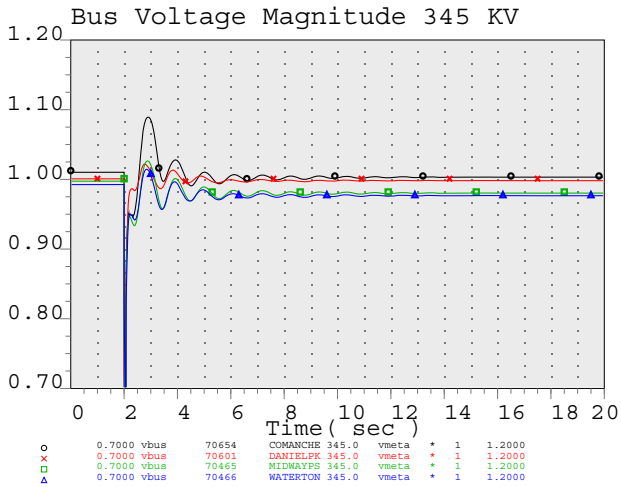


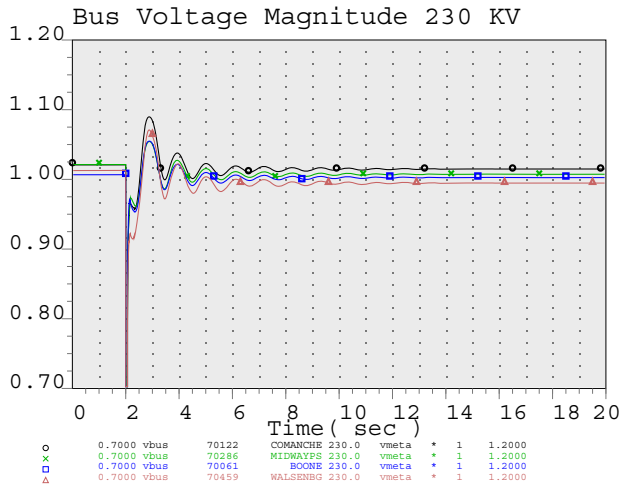


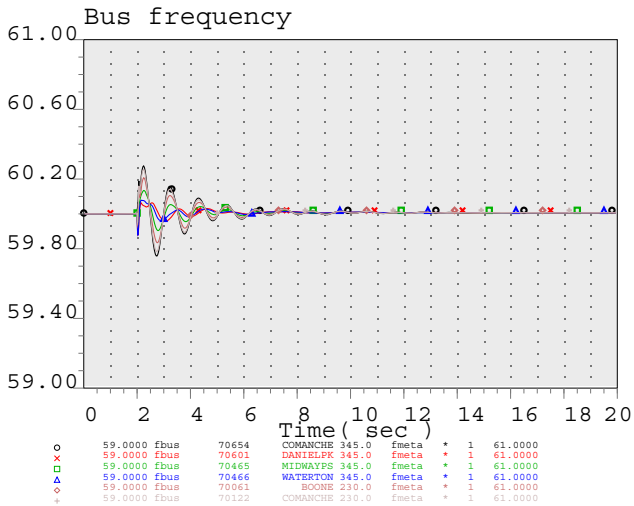


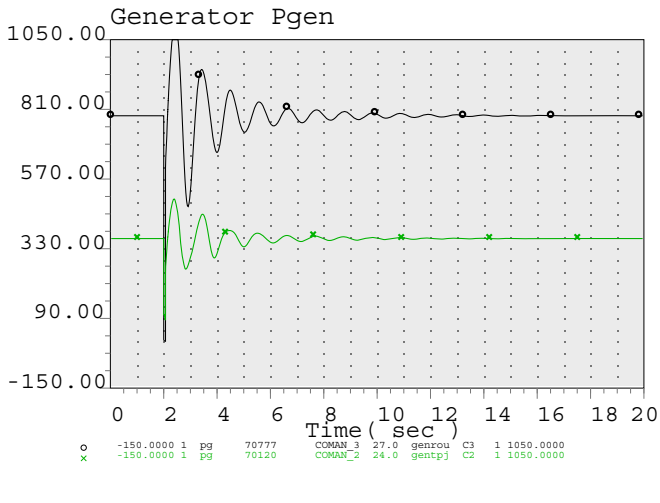


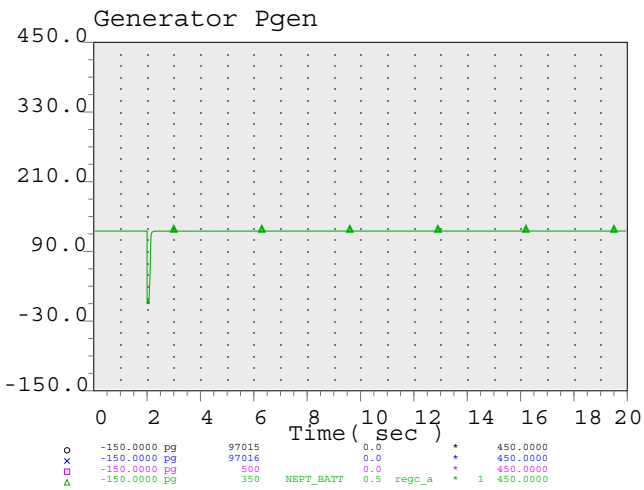
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Midway 230 KV line

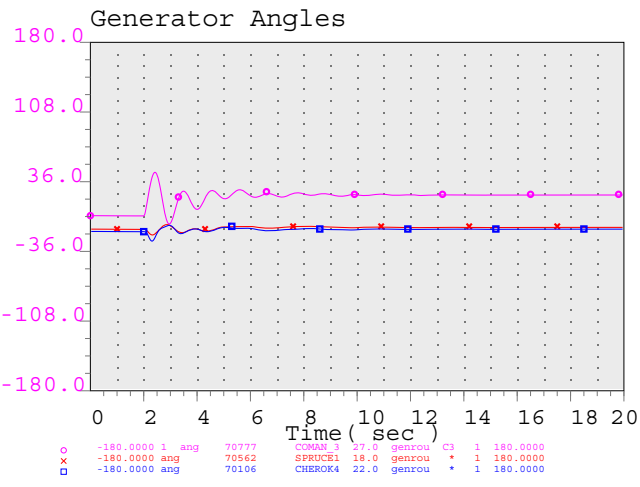




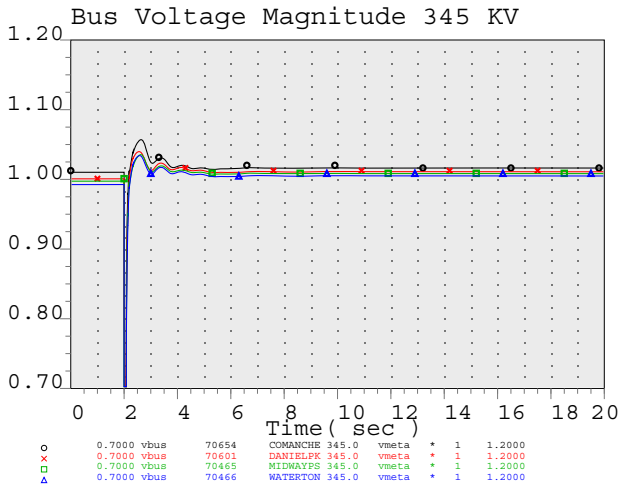


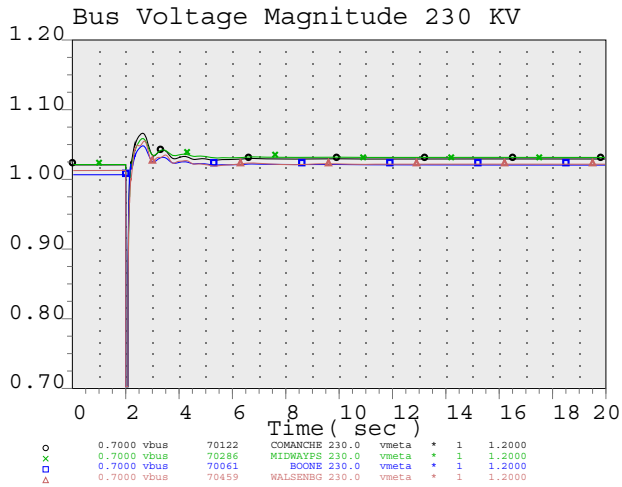


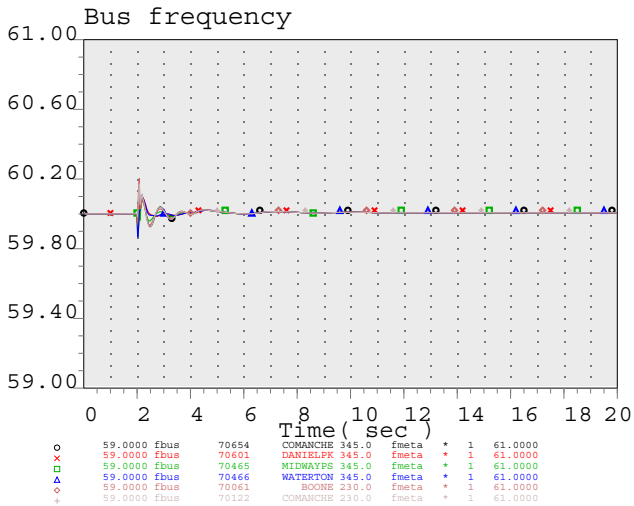


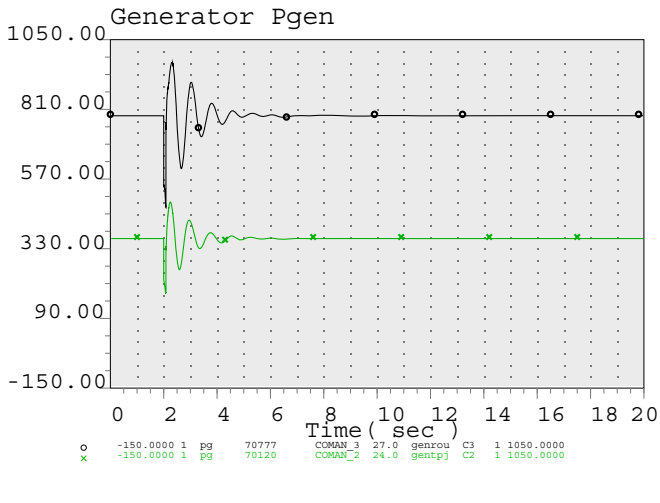


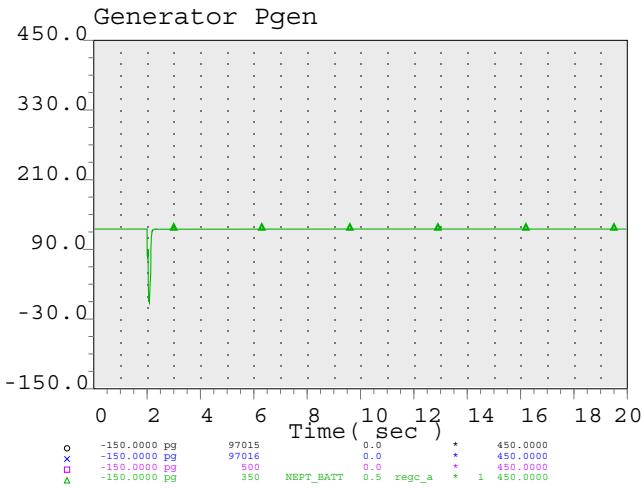
Fault: Comanche 345 KV 4 cycle 3-ph bus fault, outage: lose Comanche - Daniels Park 345 KV and lose Comanche - Tundra 345 KV line

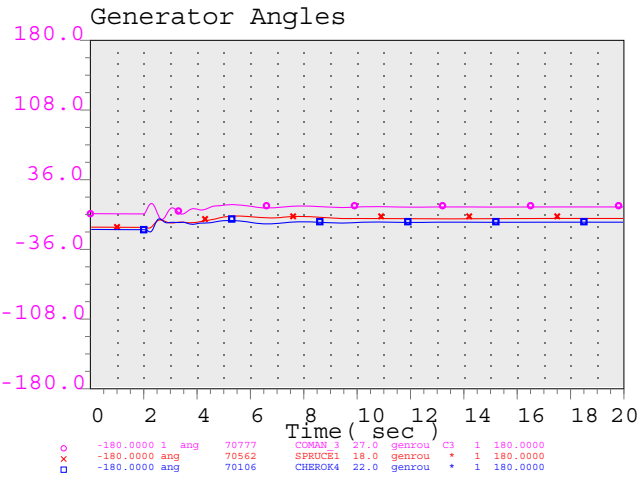




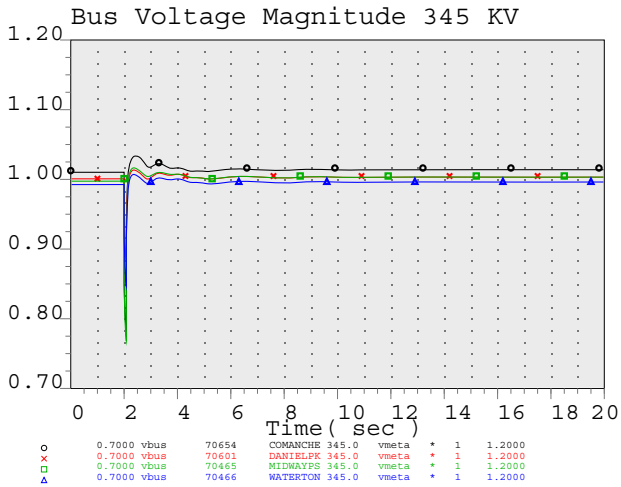


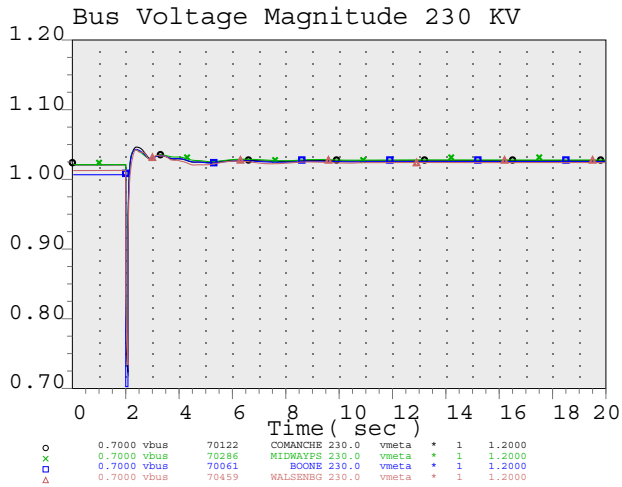


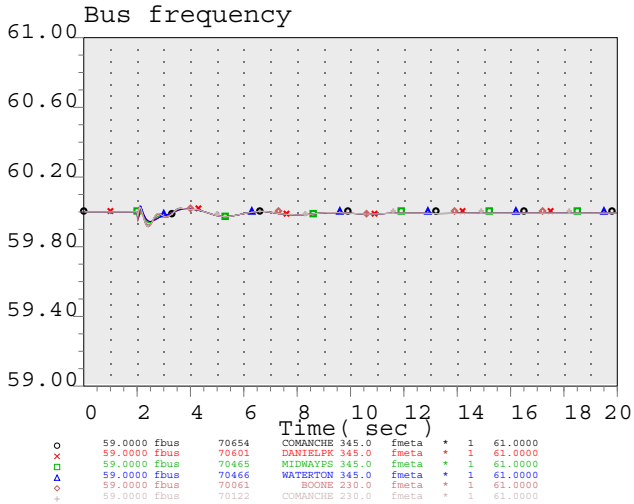


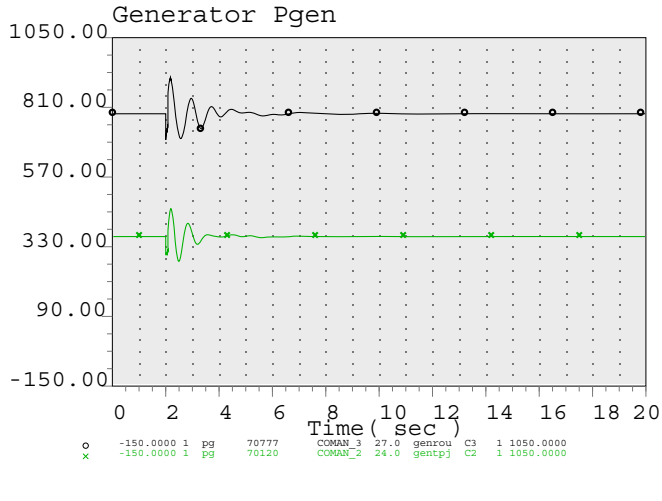


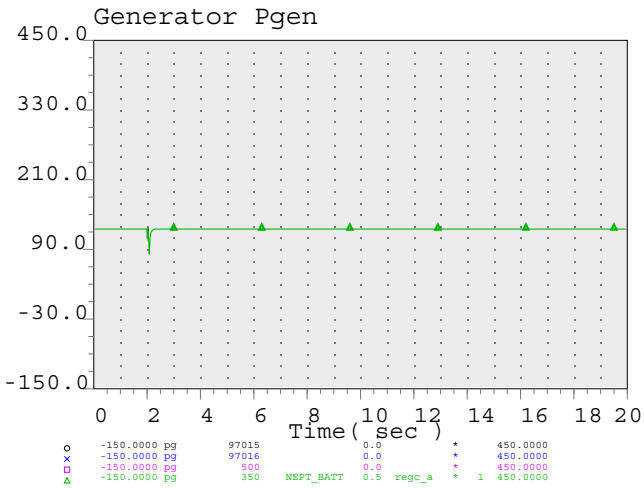
Fault: MIDWAYPS 230 KV 5 cycle 3-ph bus fault
Outage: lose Fountain Valley gen

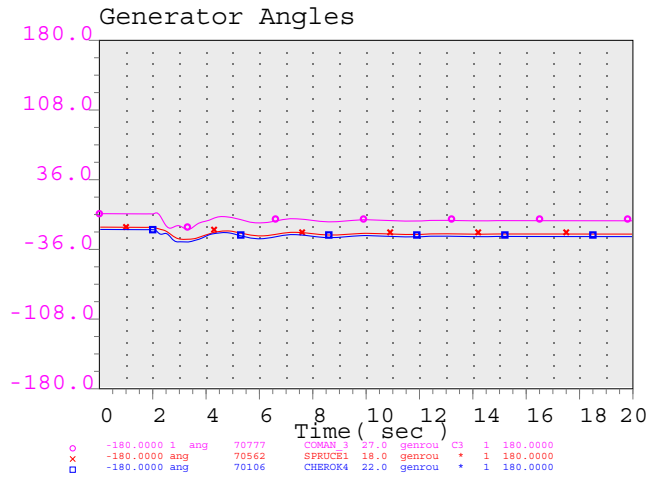




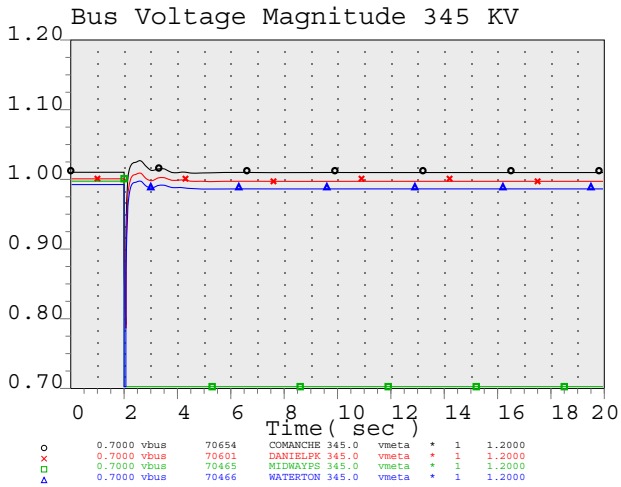


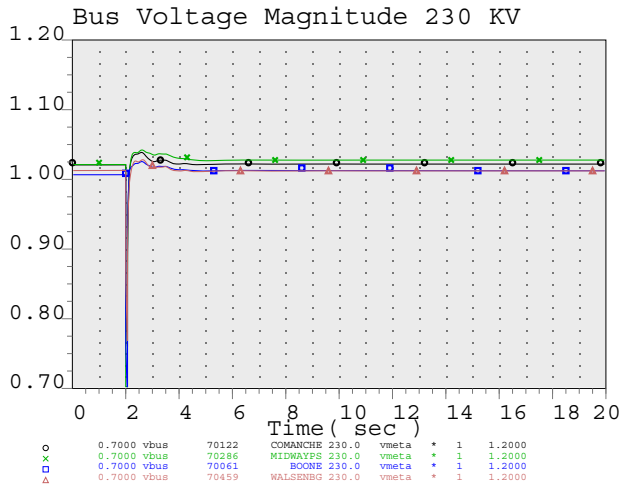


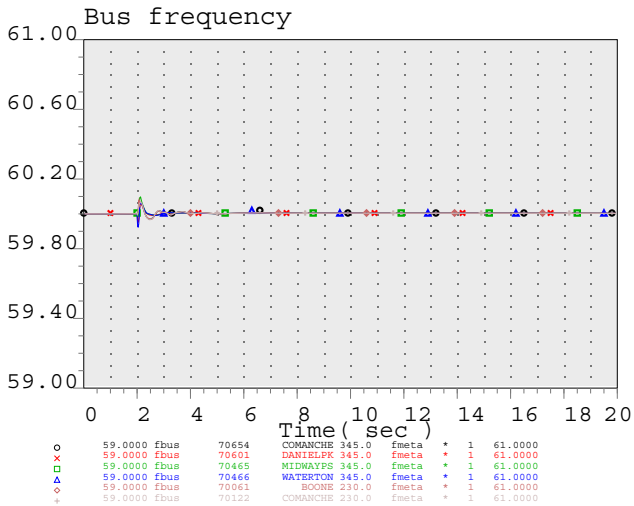


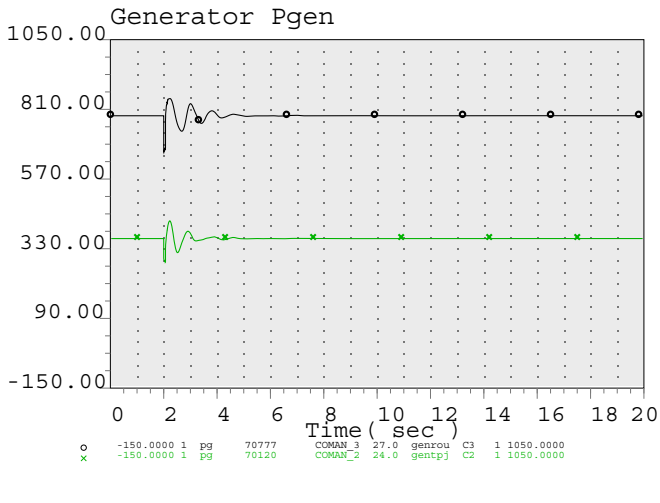


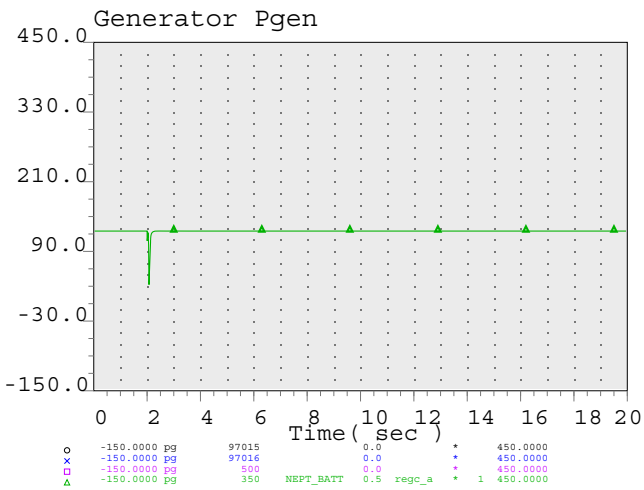
FAULT:Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone-Lamar 230kV and Lama gen

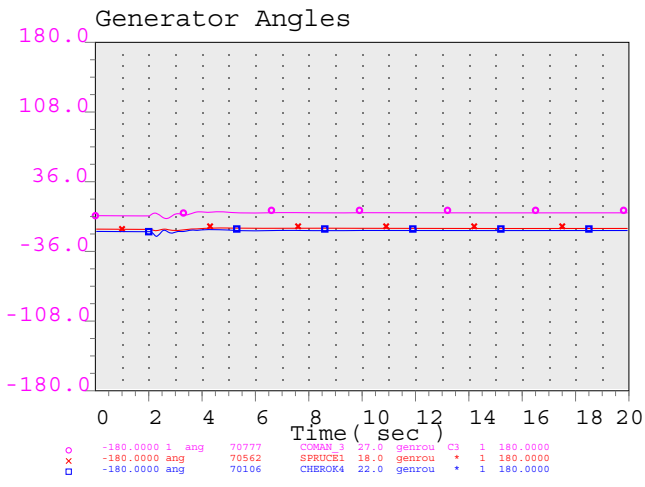




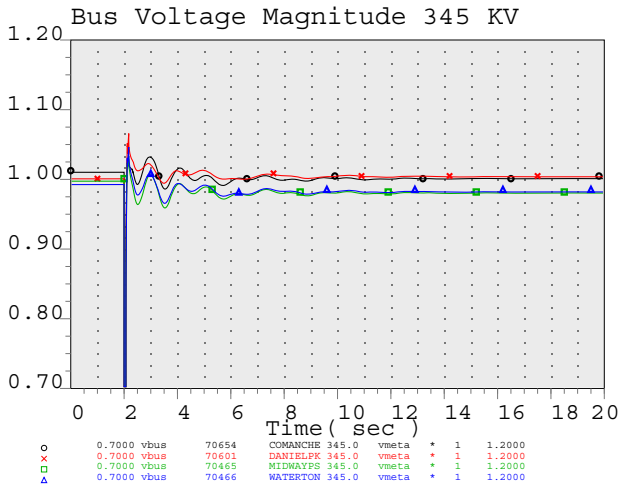


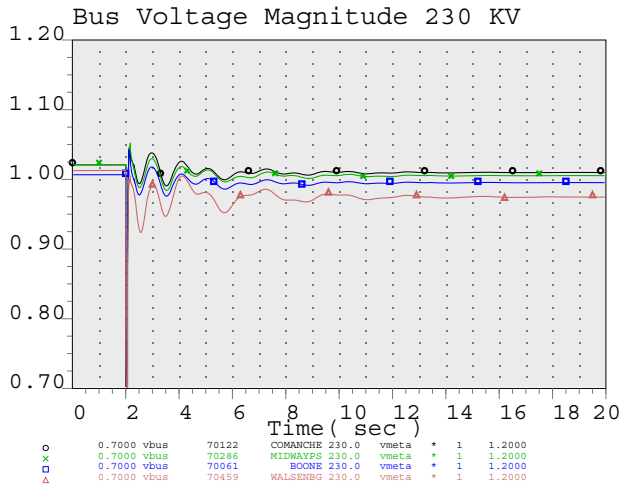


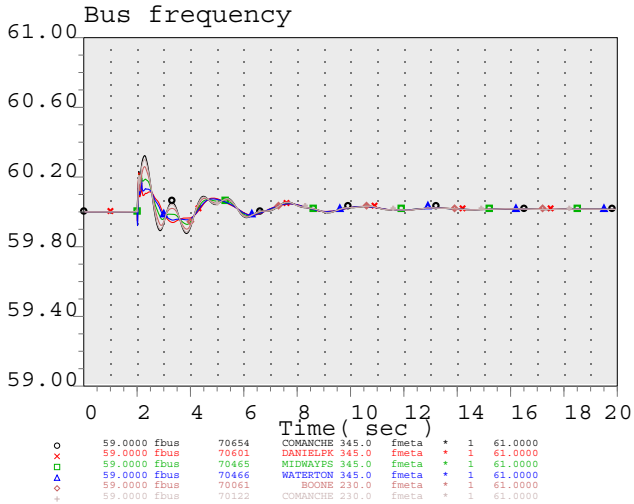


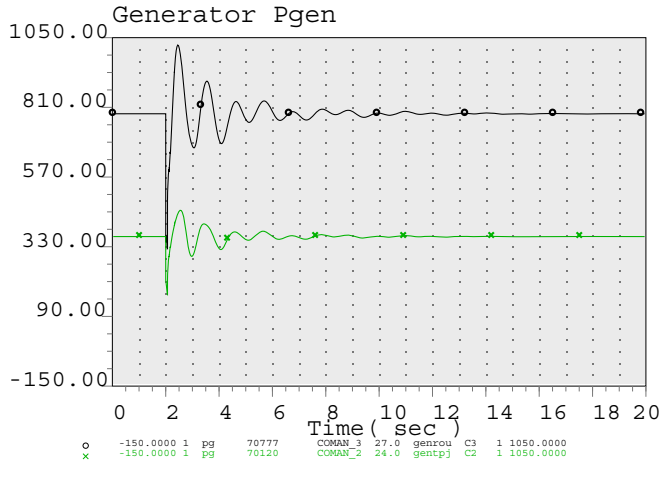


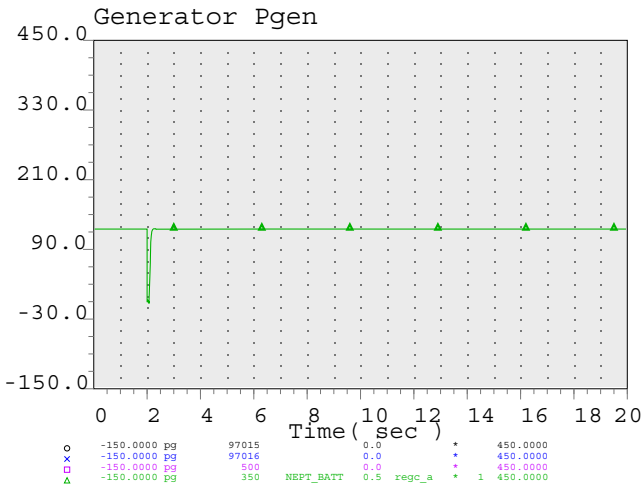
Fault: MIDWAYPS 345 KV 4 cycle 3-ph bus fault
Outage: lose MidwayPS 345/230 KV and MidwayPS - Waterton 345 KV line

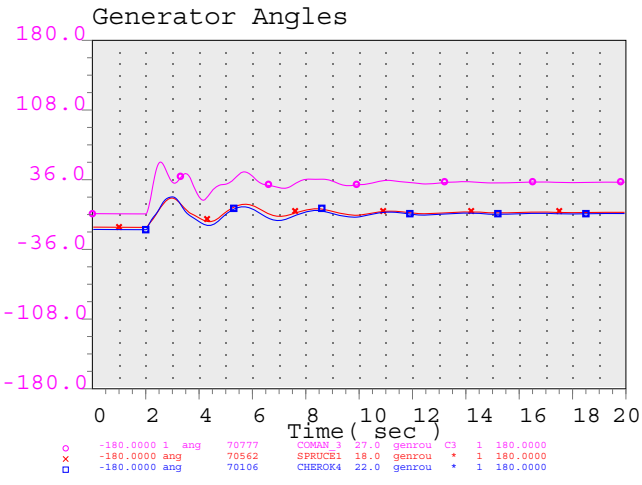








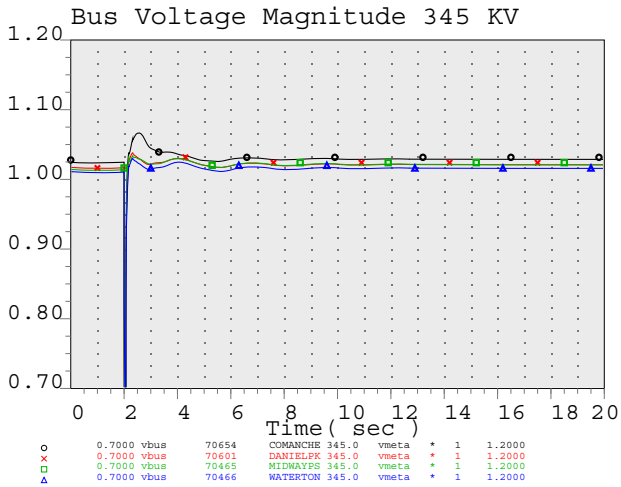


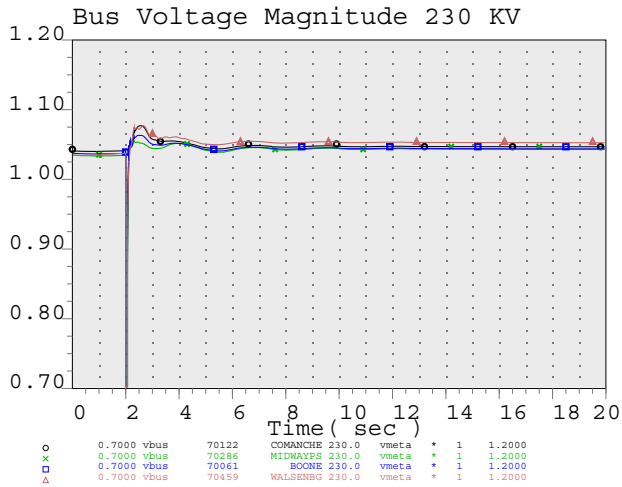


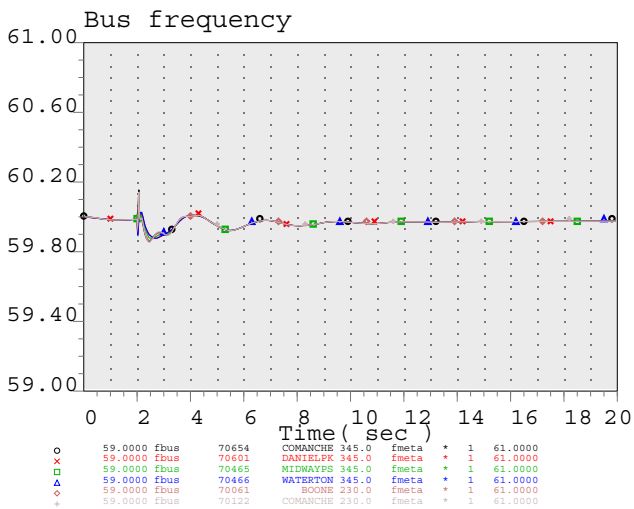
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
outage: lose Comanche - Daniels Park 345 KV and
lose Tundra - Daniels Park 345 KV line

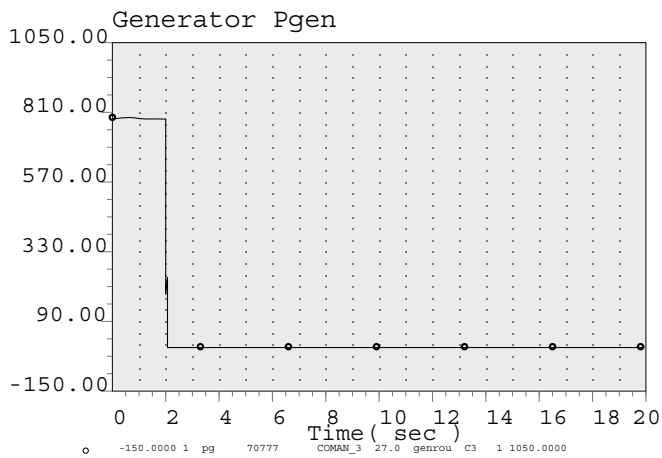
Appendix B

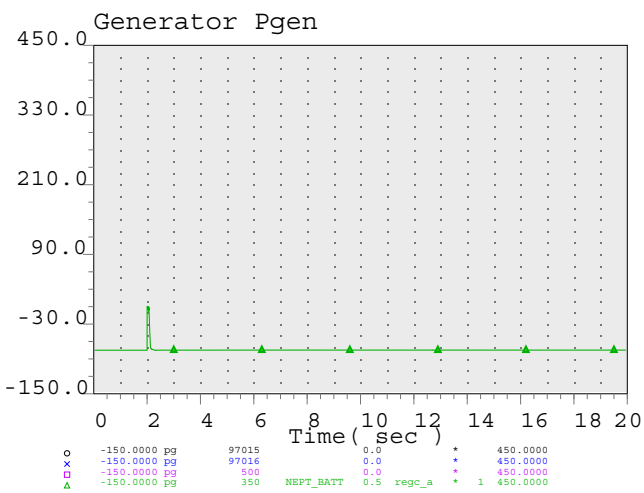
Transient Stability Plot – Grid Charging Service

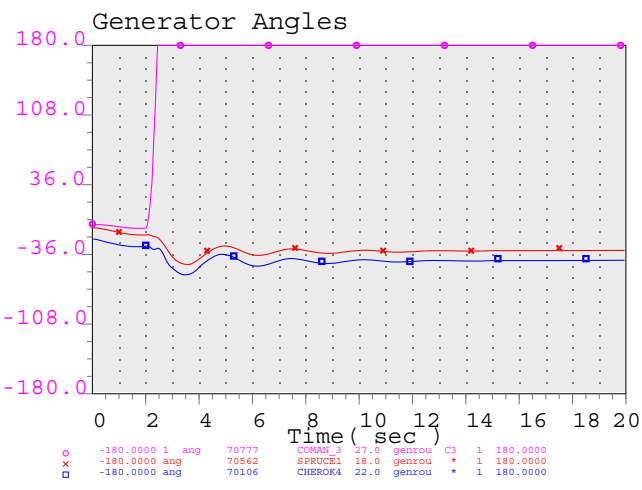




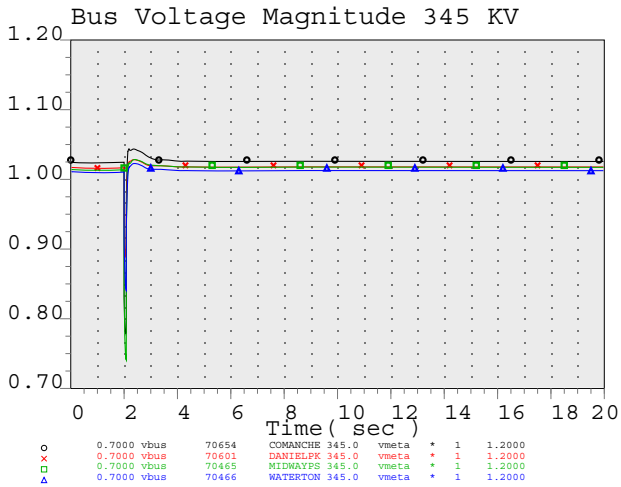


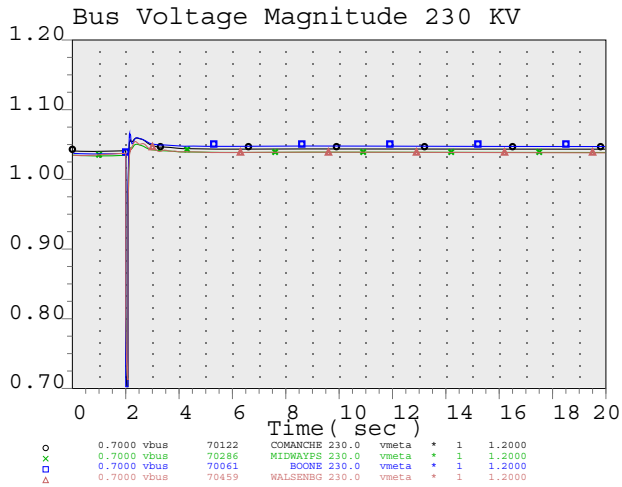


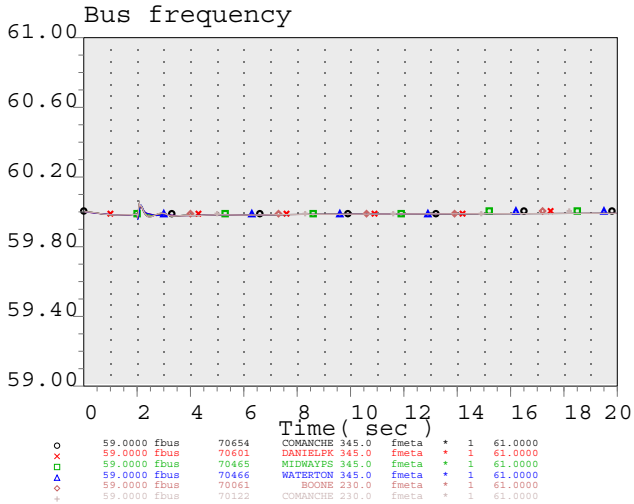


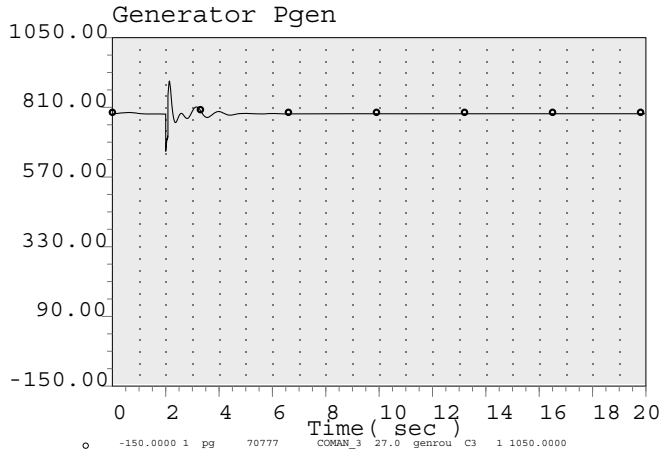


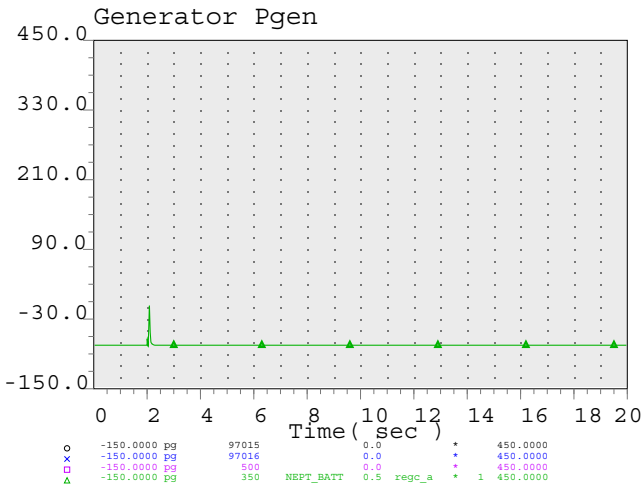
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: Comanche unit 3

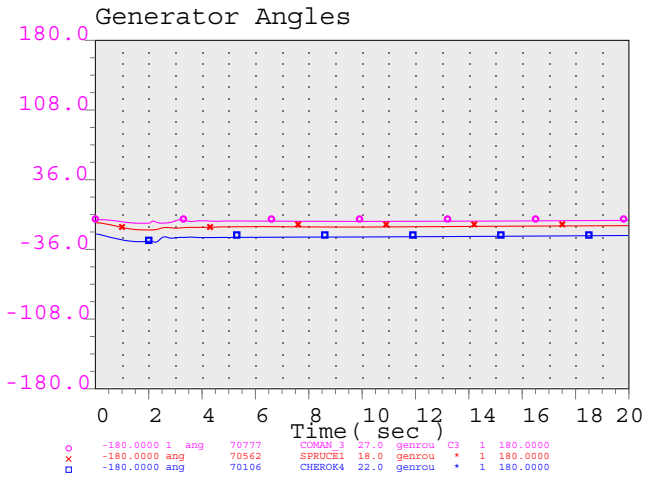




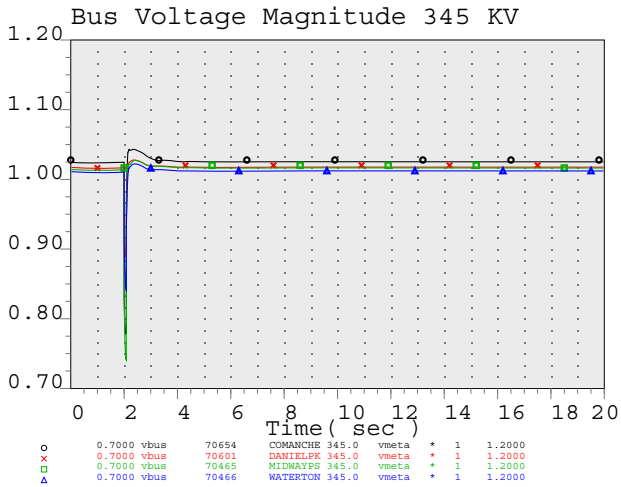


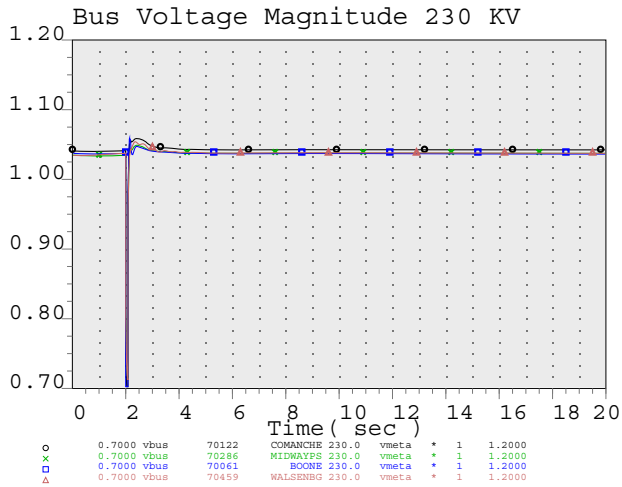


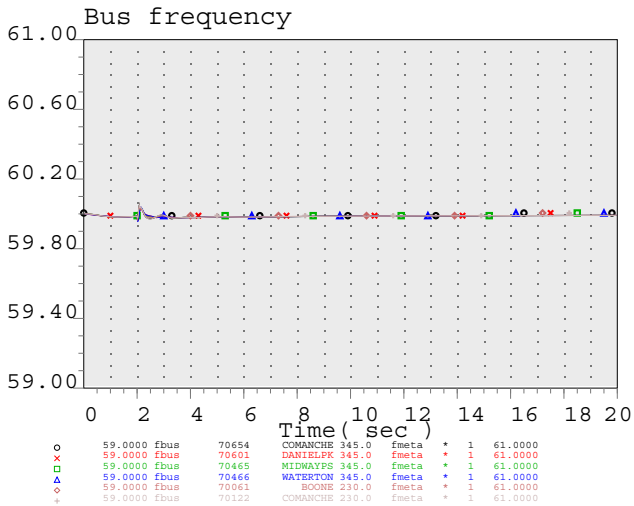


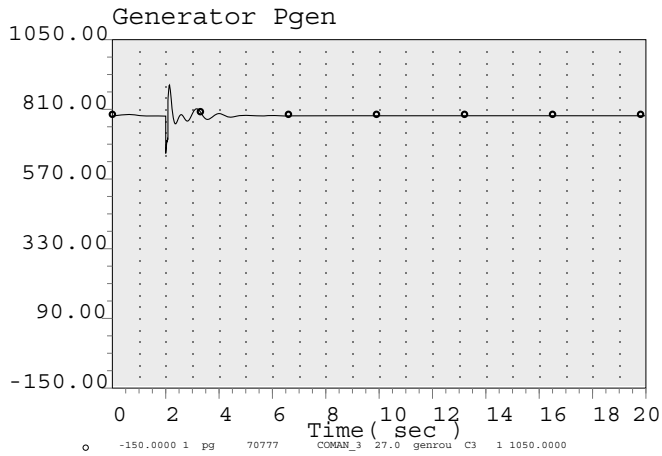


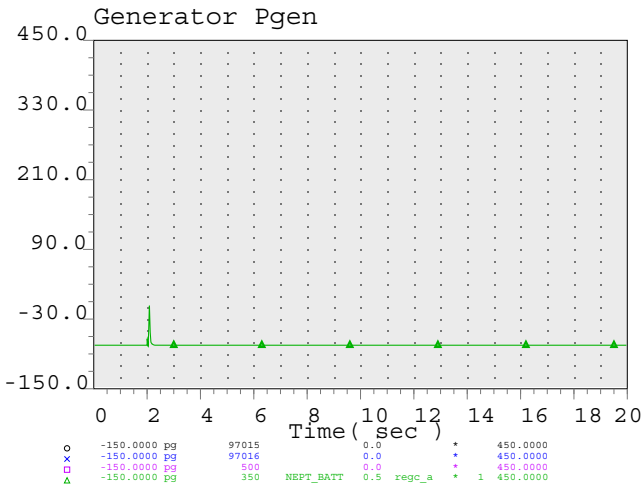
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage:lose Boone 230/115 KV bank

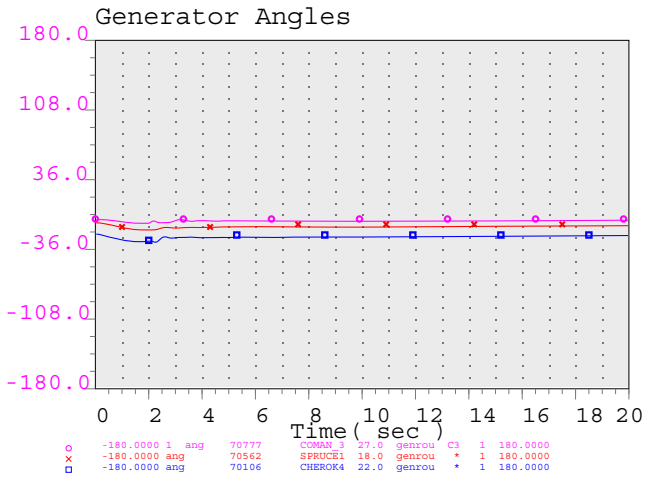




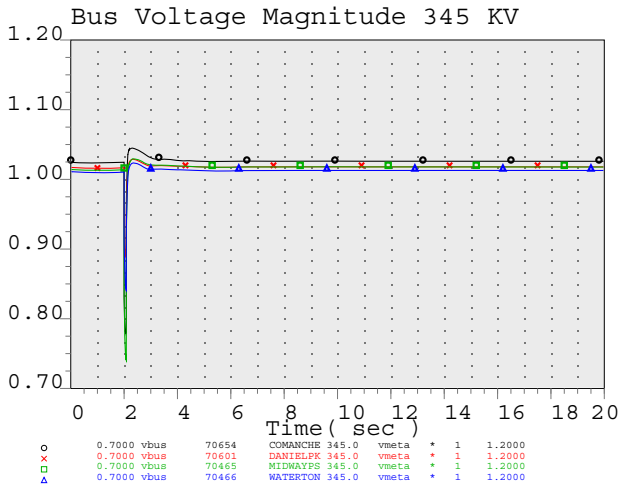


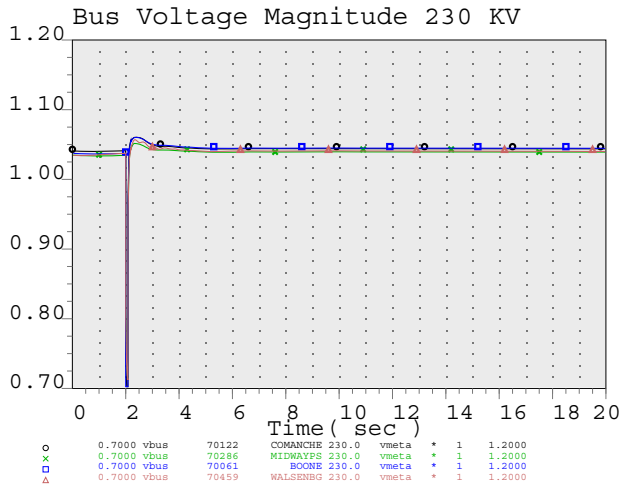


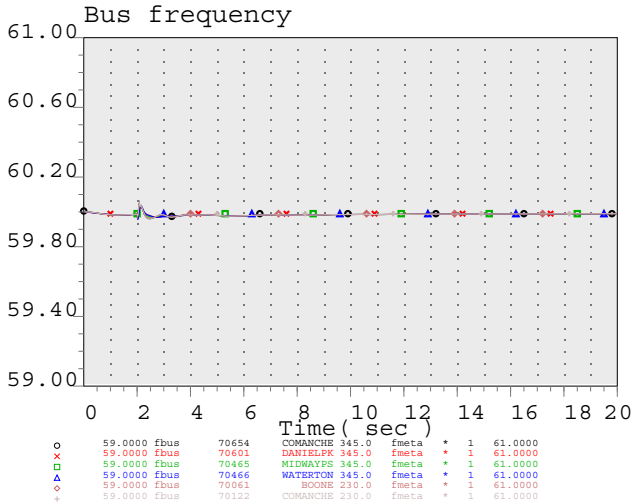


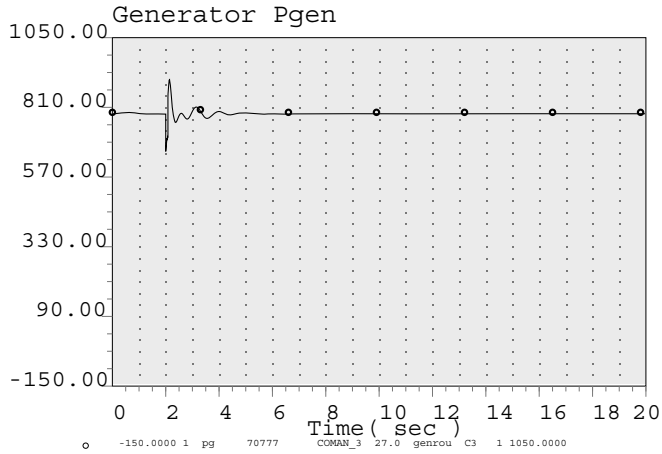


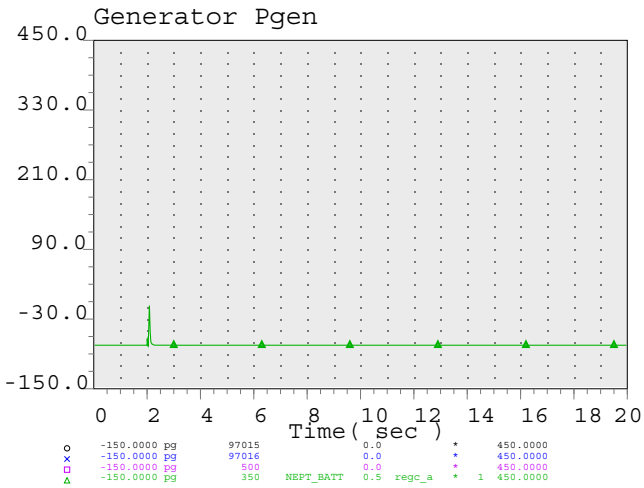
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Comanche 230 KV line

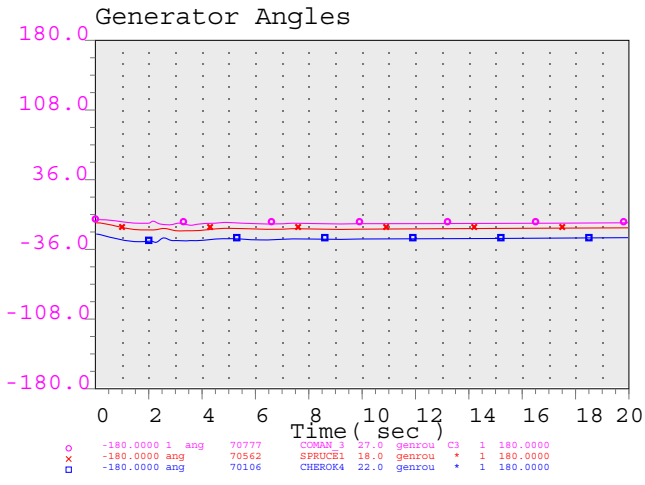




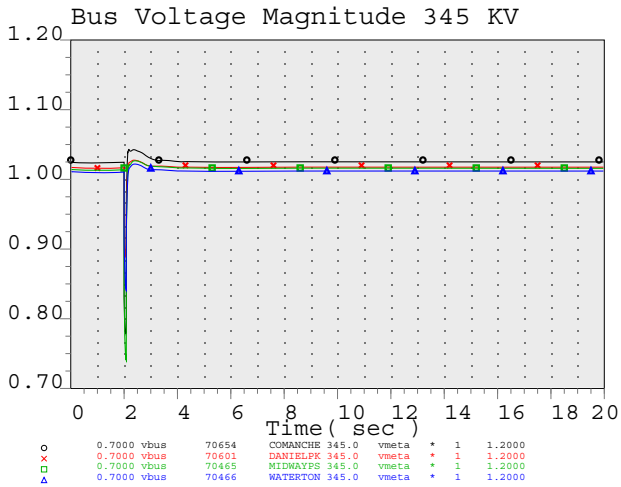


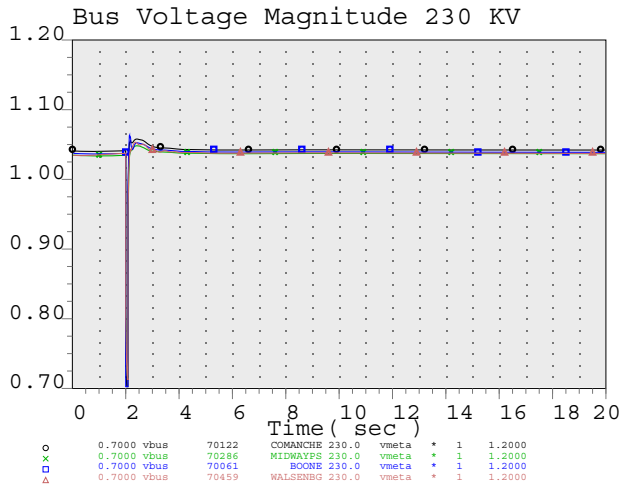


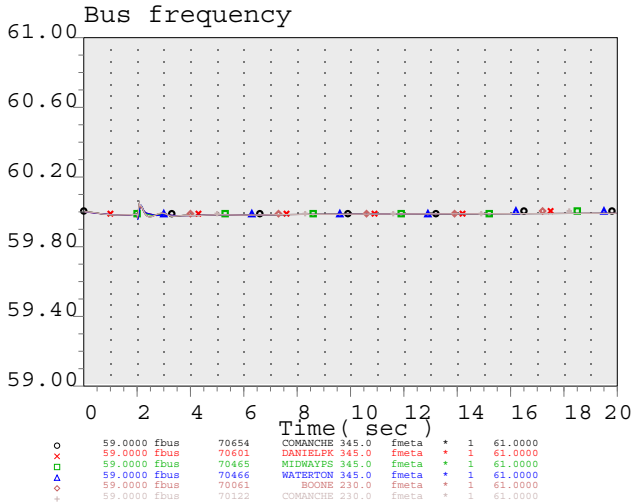


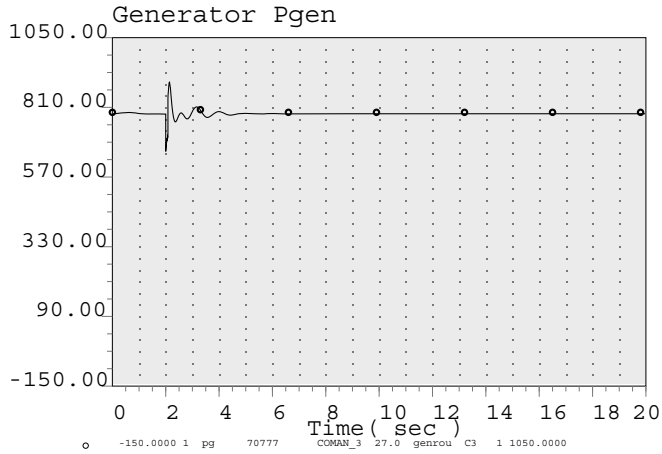


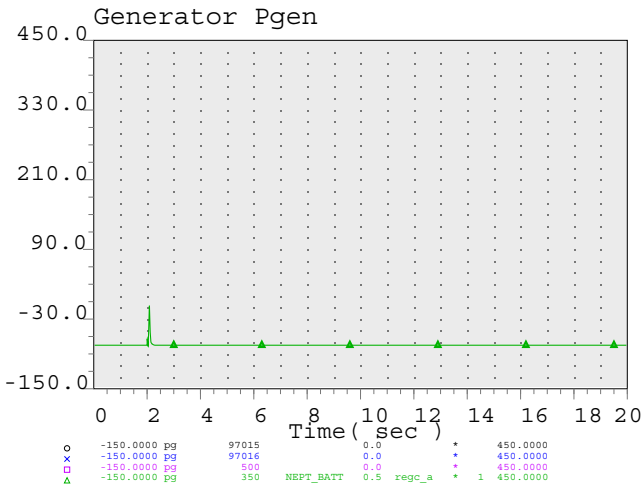
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Lamar 230 KV line and Lamar gen

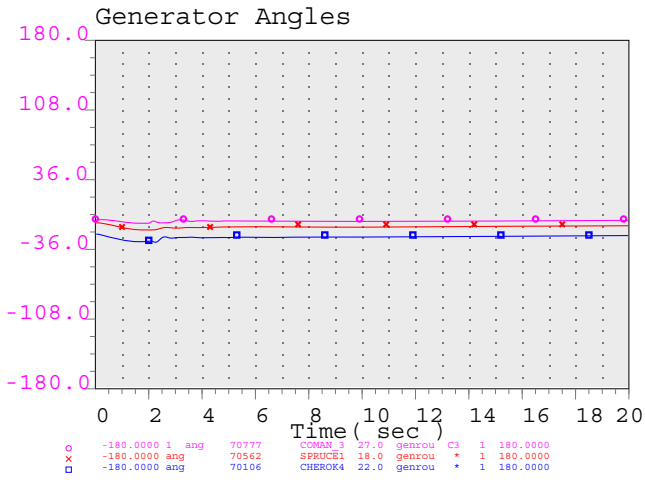




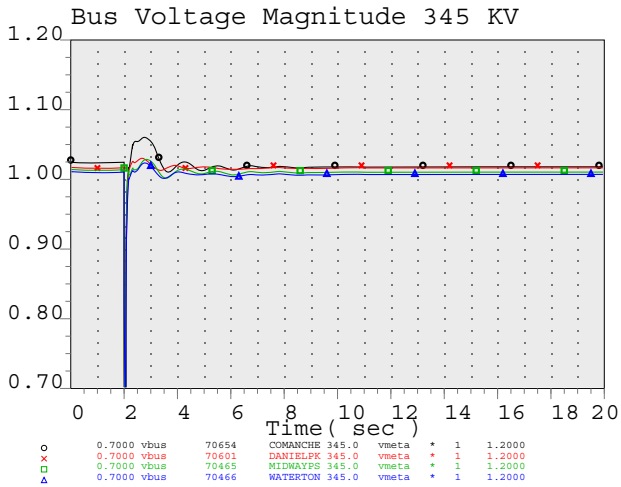


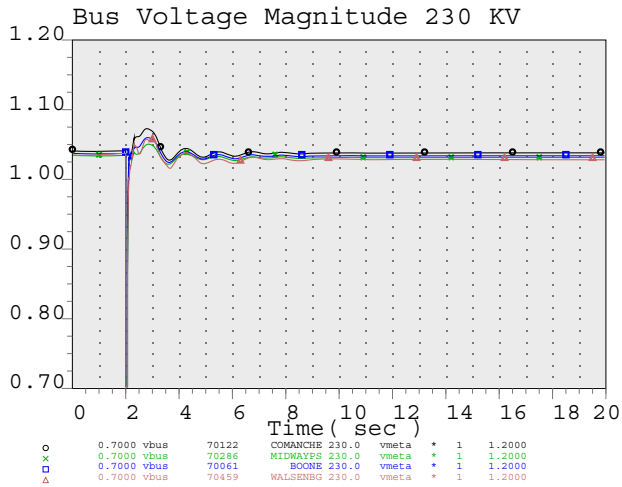


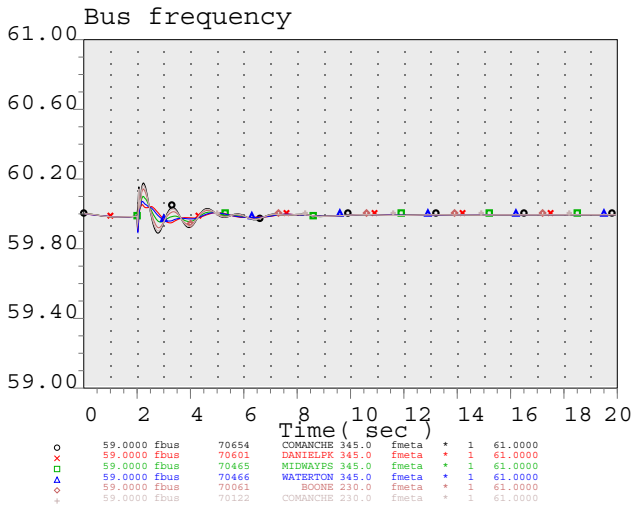


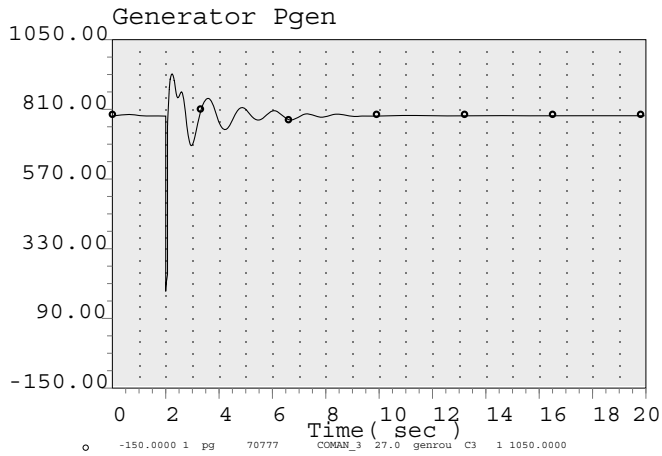


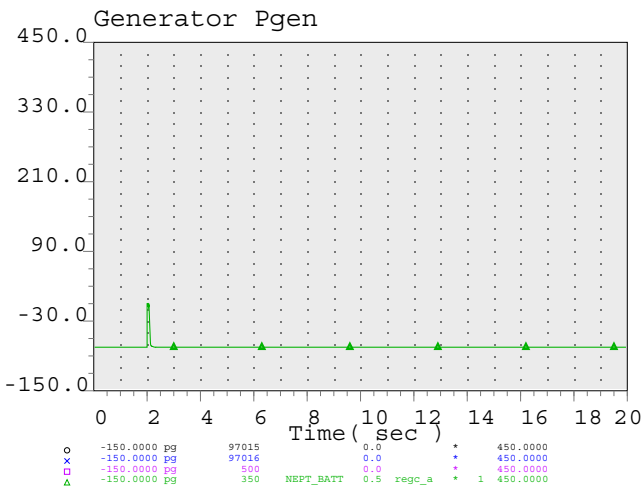
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Midway 230 KV line

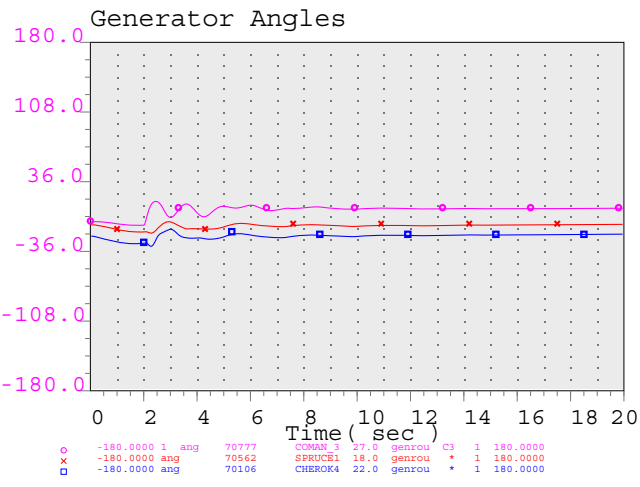




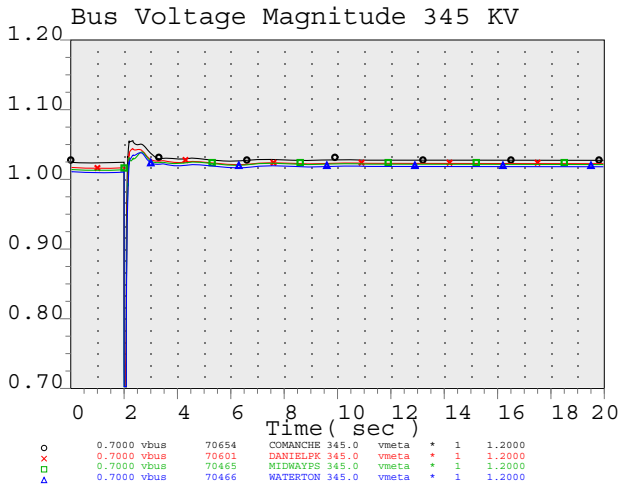


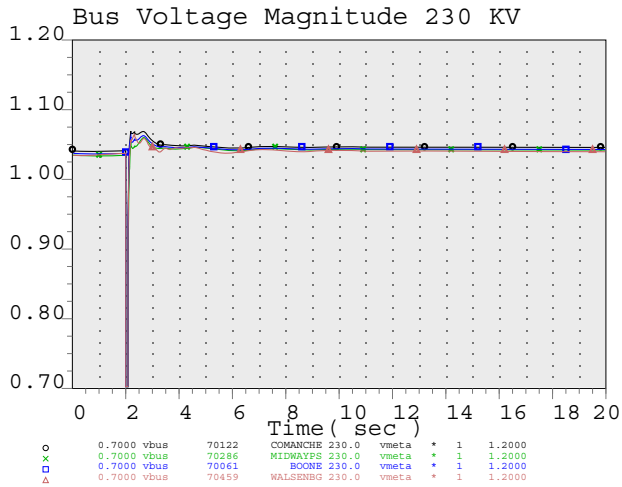


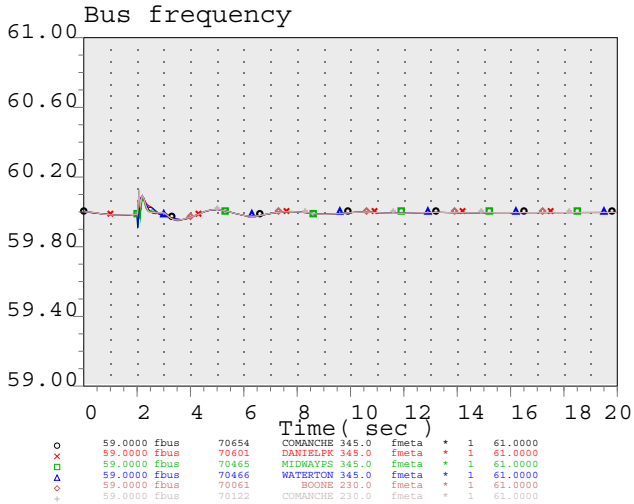


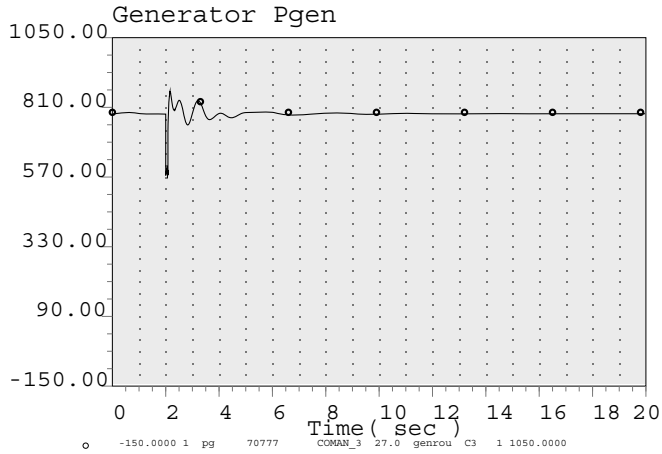


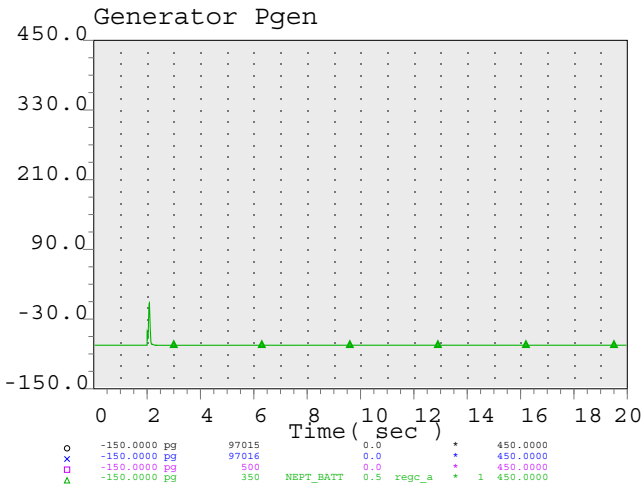
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
outage: lose Comanche - Daniels Park 345 KV
and lose Comanche - Tundra 345 KV line

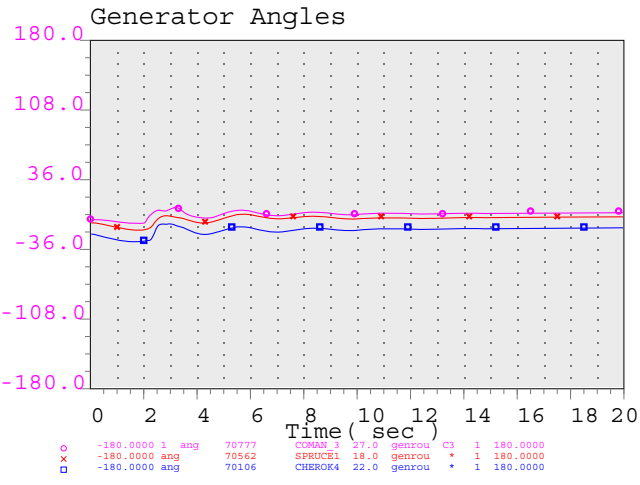




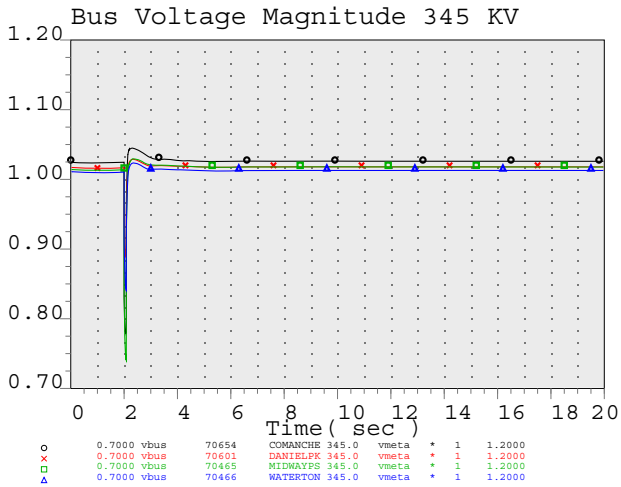


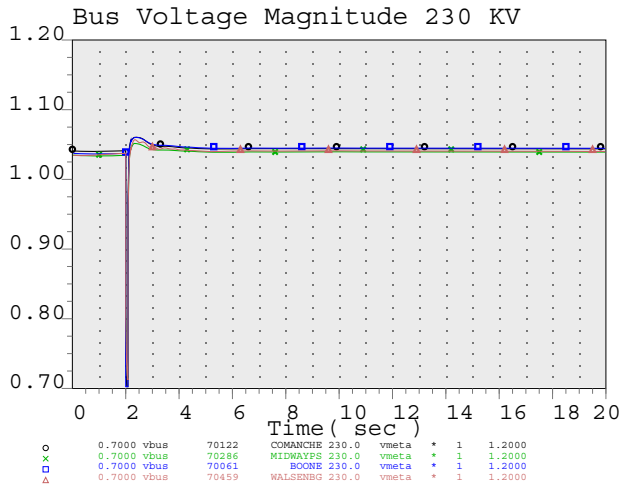


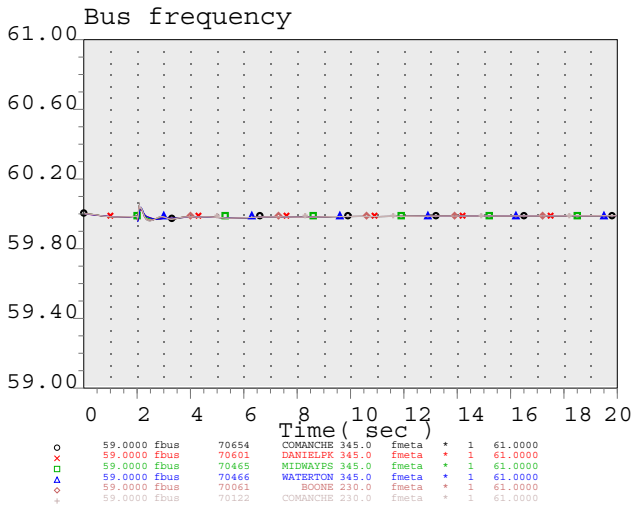


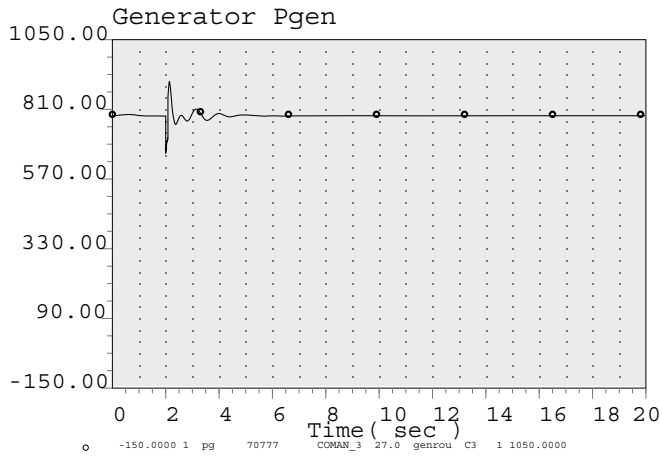


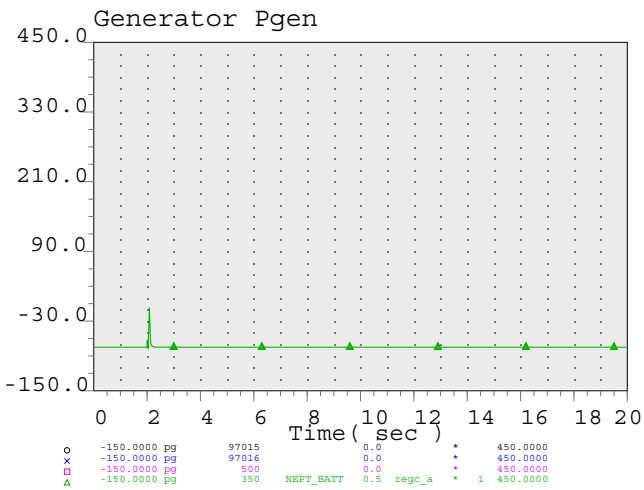
Fault: MIDWAYPS 230 KV 5 cycle 3-ph bus fault
Outage: lose Fountain Valley gen

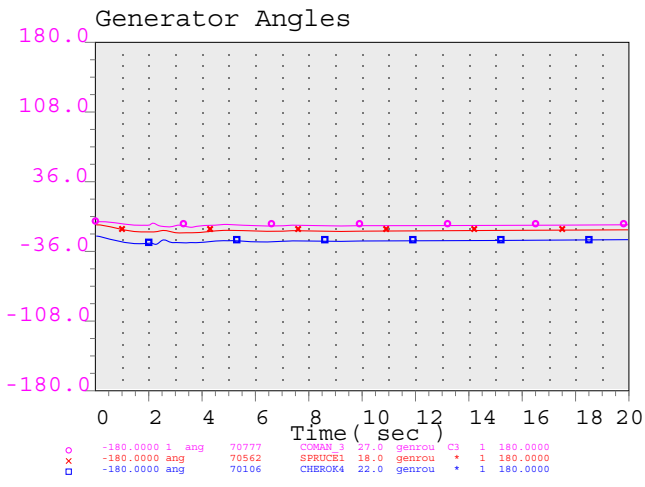




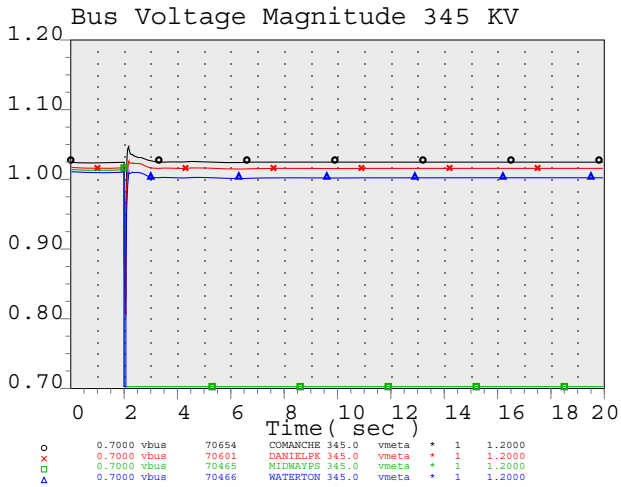


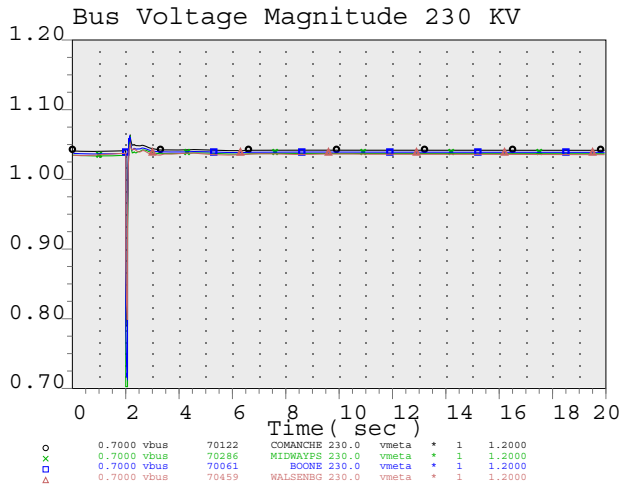


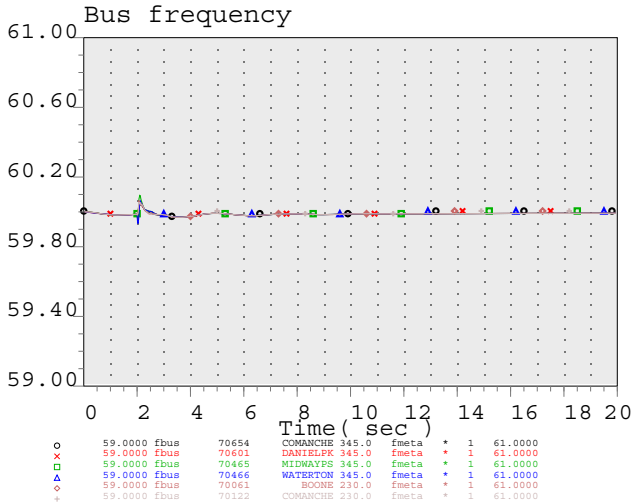


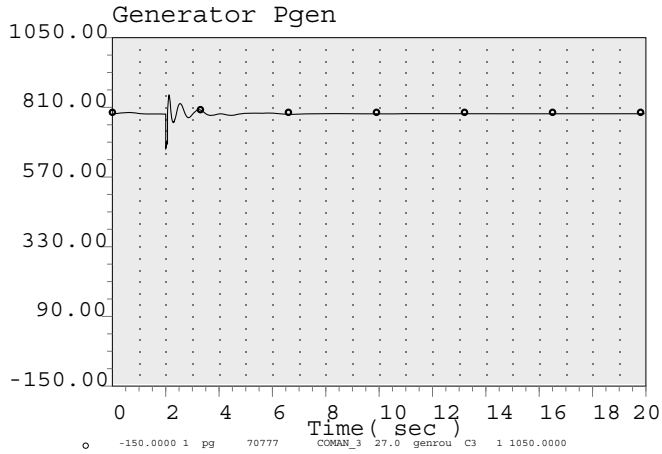


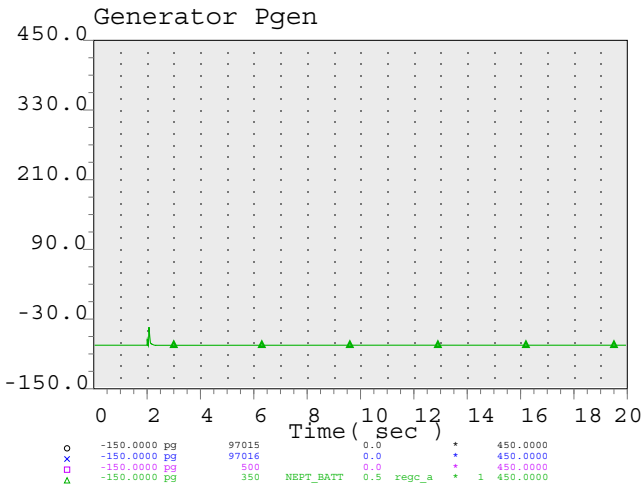
FAULT:Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone-Lamar 230kV and Lama gen

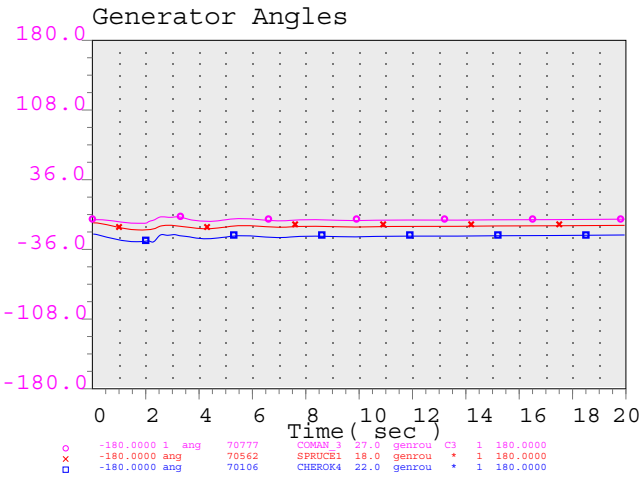




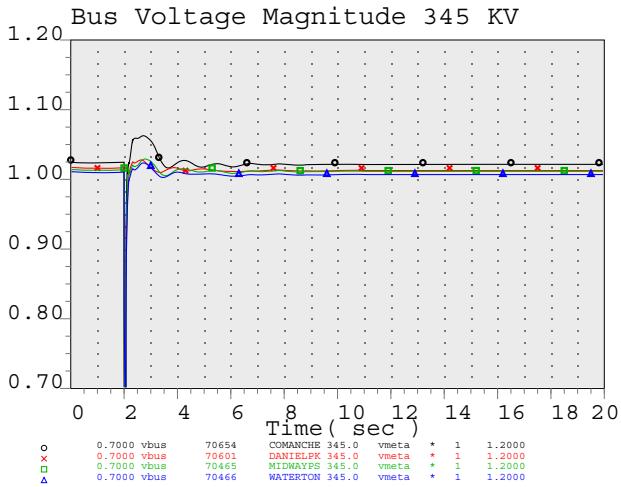


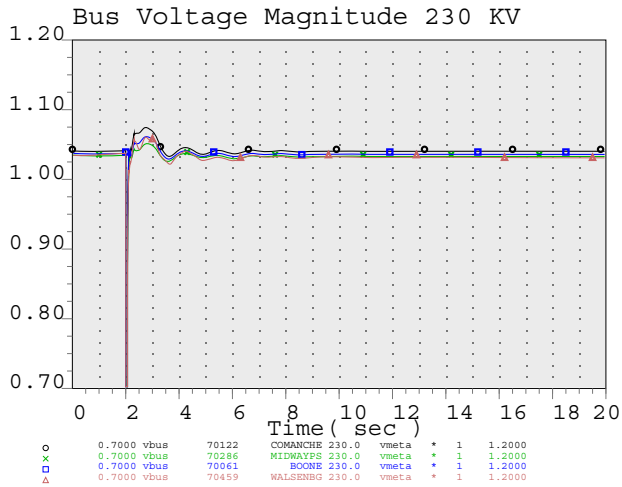


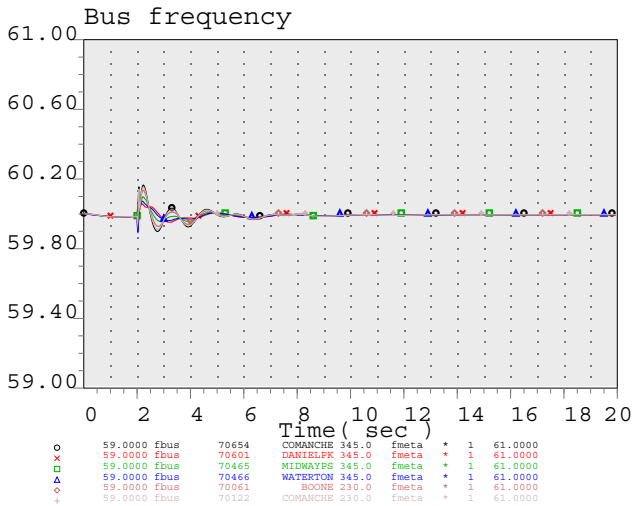


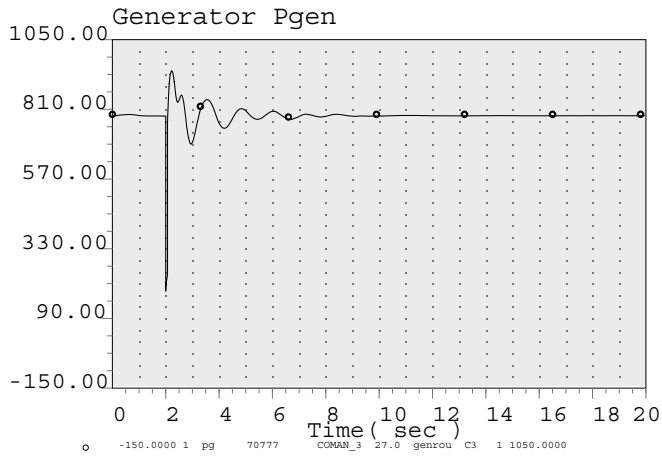


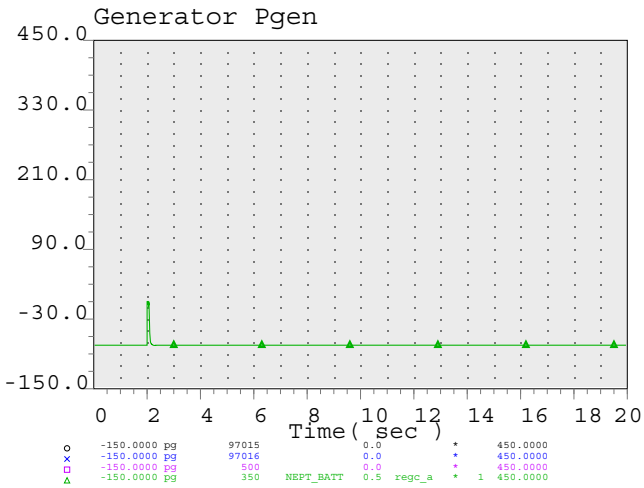
Fault: MIDWAYPS 345 KV 4 cycle 3-ph bus fault
Outage: lose MidwayPS 345/230 KV and MidwayPS - Waterton 345 KV line

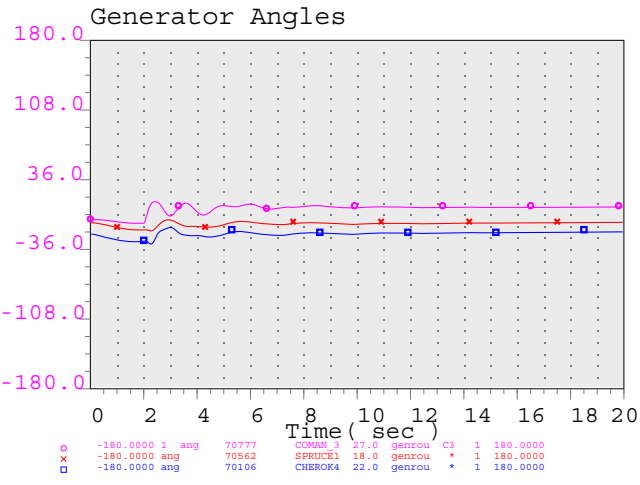












Fault: Comanche 345 KV 4 cycle 3-ph bus fault
outage: lose Comanche - Daniels Park 345 KV and
lose Tundra - Daniels Park 345 KV line