Provisional Interconnection Study Report
Provisional Interconnection Request for GI-2019-3 (PI-2019-3)

75 MW Battery Energy Storage Generating Facility

Addition to PI-2019-2 (GI-2018-24)
Tap on the Comanche – Daniels Park 345 KV Line
Pueblo County, Colorado

Xcel Energy - Transmission Planning West
October 24, 2019

Executive Summary

The PI-2019-3 (PI) is the Provisional Interconnection Service Request for the ERIS request for GI-2019-3 (GI). The PI-2019-3 (GI-2019-3) is a 75MW increment in the Battery Energy Storage (BES) Generating Facility output of PI-2019-2 (GI-2018-24), such that the combined output of PI-2019-2 (GI-2018-24) and PI-2019-3 (GI-2019-3) will be 325MW. The hybrid generating facility will have the same nameplate capacity as PI-2019-2 i.e. a 250MW rated Solar Photovoltaic (PV) Generating Facility plus a 125MW rated Battery Energy Storage (BES) Generating Facility. The inverters, 34.5kV collector system, gen-tie configuration Point of Interconnection (POI) of PI-2019-3 are same as PI-2019-2. But PI-2019-3 changes the main step-up transformer configuration from one 34.5/345kV, 255/340/425MVA, Z=8.5% to two(2) 34.5/345kV, 114/152/190MVA main step-up transformers.

The proposed Commercial Operation Date (COD) of the PI is December 1, 2022. PI-2019-3 will not require back-feed as the POI will be back-fed as part of PI-2019-2 interconnection.

The main purpose of this study is to determine the system impact of increasing the output of PI-2019-2 from 250MW to 325MW. PI-2019-3 was studied for Provisional Interconnection Service and the net 325 MW rated output of the Generating Facility is assumed to be delivered to Public Service Company of Colorado (PSCo) native load, so existing PSCo generation was used as its sink.

The power flow analysis included steady state analysis with Comanche Unit #1 online and after its planned retirement. The study with Comanche Unit #1 online identified one new overload on the CSU system and one new overload on the PSCo system. In addition, it caused further increases in the two overloads identified in PI-2019-2 studies. The power flow analysis with the Comanche unit #1 retirement modeled did not identify any thermal violations attributable to the PI.

The short-circuit and breaker duty analysis determined that no breaker replacements are needed at the POI station and/or in neighboring PSCo stations.

The total estimated cost of the PSCo transmission system improvements required for PI-2019-3 to qualify for Provisional Interconnection Service is:

- **$100,000 (Tables 6 and 7)**

For PI-2019-3 interconnection:

Provisional Interconnection Service (after the retirement of Comanche#1) = 75MW

In case the Comanche Unit #1 retirement is delayed for any reason, the maximum output PI-2019-3 may be limited based on generation dispatch and available firm or non-firm capacity on the transmission system.

The Provisional Interconnection Service results above are contingent upon the transmission system improvements identified in Attachment 1.

The combined generation output of PI-2019-2 and PI-2019-3 hybrid facility at the POI shall not exceed 325MW at any time, which will be monitored by PSCo and limited by the Plant Controller at all times.

Security: *Since GI-2019-3 selected ERIS and the PI-2019-3 Generating Facility does not need any new Interconnection Facilities at the POI, except the ones already identified as part of PI-2019-2, the security associated with the Interconnection Facilities would be identified as part of PI-2019-2. No additional security is identified for PI-2019-3.*

The Interconnection Customer assumes all risk and liabilities with respect to changes between the Provisional Large Generator Interconnection Agreement and the Large Generator Interconnection Agreement, including changes in output limits and Interconnection Facilities, Network Upgrades, Distribution Upgrades, and/or System Protection Facilities cost responsibility.

Note: Provisional Interconnection Service in and of itself, does not convey transmission service.

Introduction

The PI-2019-3 (PI) is the Provisional Interconnection Service Request for GI-2019-3 (GI). The PI-2019-3 (GI-2019-3) is a 75MW increment in the Battery Energy Storage (BES) Generating Facility output of PI-2019-2 (GI-2018-24), such that the combined output of PI-2019-2 (GI-2018-24) and PI-2019-3 (GI-2019-3) will be 325MW. The hybrid generating facility will have the same nameplate capacity as PI-2019-2 i.e. a 250MW rated Solar Photovoltaic (PV) Generating Facility plus a 125MW rated Battery Energy Storage (BES) Generating Facility. The inverters, 34.5kV collector system, gen-tie configuration, Point of Interconnection (POI) of PI-2019-3 are same as PI-2019-2. But PI-2019-3 changes the main step-up transformer configuration from one 34.5/345kV, 255/340/425MVA, Z=8.5% to two(2) 34.5/345kV, 114/152/190MVA main step-up transformers.

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

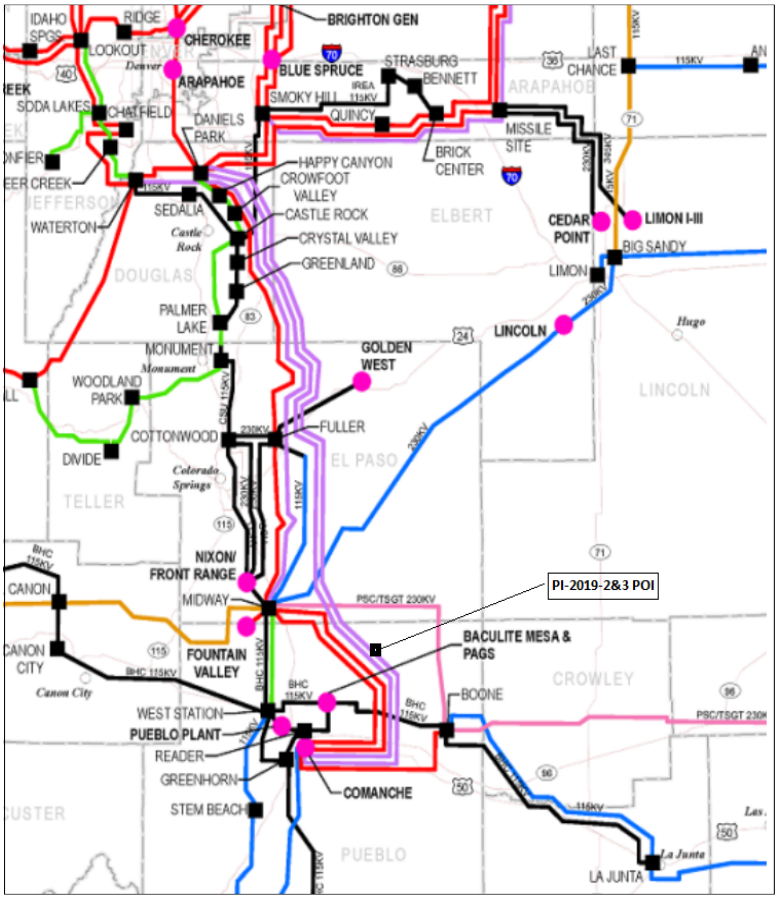

Figure 1- PI-2019-2 and PI-2019-3 Point of Interconnection and Study Area

The expected operating modes of the Generating Facility are:

I. 325MW rated generation output at the POI via combination of PV and BES
II. 125MW rated load at the POI for a maximum of four (4) hours when PV output is 0MW.

The proposed Commercial Operation Date (COD) of the PI is December 1, 2022. PI-2019-3 will not require back-feed as the POI will be back-fed for PI-2019-2.

The main purpose of this study is to determine the system impact of increasing the output of PI-2019-2 from 250MW to 325MW. Per the Provisional Interconnection Study Request, PI-2019-3 is studied for Provisional Interconnection Service[1] only. The corresponding GI-2019-3 chose an Energy Resource Interconnection Service (ERIS)[2]. For this evaluation, the 75 MW incremental output of PI-2019-3 is assumed to be delivered to PSCo native load, so existing PSCo generation is used to sink the PI output.

Study Scope and Analysis Criteria

The scope of this report includes steady state (power flow) analysis, transient stability analysis, short circuit analysis and appropriation level cost estimates (+/- 20% accuracy). The report also identifies the estimated Security[3] for the Provisional Interconnection. The power flow analysis identifies thermal and voltage violations in the PSCo system and the neighboring systems as a result of the interconnection of the GI for Provisional Interconnection Service. Several single contingencies are studied.

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 and satisfy acceptable dynamic performance criteria. 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 and need to be replaced.

The system impact analysis criteria are as follows:

PSCo adheres to applicable NERC Reliability Standards and WECC Reliability Criteria, as well as its internal transmission planning criteria for studies. The steady state analysis criteria are as follows:

[1] **Provisional Interconnection Service** shall mean an Interconnection Service provided by Transmission Provider associated with interconnecting the Interconnection Customer's Generating Facility to Transmission Provider's Transmission System and enabling that Transmission System to receive electric energy and capacity from the Generating Facility at the Point of Interconnection, pursuant to the terms of the Provisional Large Generator Interconnection Agreement and, if applicable, the Tariff.

[2] **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.

[3] **Security** estimates the risk associated with the Network Upgrades and Interconnection Facilities that could be identified in the corresponding LGIA.

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

The same list of contingencies was run on the benchmark case and the study case, and the results were compared.

For PSCo facilities, thermal violations attributable to the PI included any facilities (i) without a pre-existing thermal violation that resulted in a thermal loading >100% post the addition of the PI (ii) contributed to an incremental loading increase of 2% or more to the benchmark case loading. For non-PSCo facilities, thermal violations attributed to the PI include all new facility overloads with thermal loading of >100% and existing thermal overloads that increased by 1% or more from the benchmark case overload post the GI addition.

The voltage violations assigned to the PI include new voltage violations or existing voltage violations which resulted in a further variation of 0.1 per unit.

Transient stability criteria require that all generating machines remain in synchronism and all power swings should be well damped following a contingency event. Also, transient voltage performance should meet the following WECC Disturbance-Performance criteria:

- Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds for all contingencies
- For all contingencies, 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 contingencies without a fault, voltage dips at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.

The study area is the electrical system consisting of PSCo's transmission system and the neighboring transmission systems that are impacted by or that will impact interconnection of the PI. The study area for PI-2019-2 includes WECC designated zones 121, 700, 703, 704, 705, 709, 710, 712, 752 and 757.

System Impact Study Power Flow Case Creation

The Base Case used for the power flow analysis originated from the 2023HS case built for the 2018 TPL1 Work Group of the Colorado Coordinated Planning Group (CCPG). As part of the case build efforts for the TPL1 work group, the case was reviewed by PSCo and neighboring utilities within the CCPG foot print.

All transmission planned projects in PSCo's 10 year transmission plan that are expected to be in-service before July 2023 are modeled in the Base Case, consistent with the case season and year. These projects are described at:
(http://www.oasis.oati.com/woa/docs/PSCO/PSCOdocs/Q1_2019_Transmission_Plan.pdf)

The PSCo projects added to the Base Case include the following:

- Shortgrass 345kV Switching Station – ISD 2020
- Shortgrass – Cheyenne Ridge 345kV line – ISD 2020
- Graham Creek 115kV Substation – ISD 2021
- Husky 230/115kV Substation – ISD 2021
- Cloverly 115kV Substation – ISD 2021
- Ault – Husky 230kV line – ISD 2021
- Husky – Graham Creek – Cloverly 115kV line – ISD 2021
- Monument – Flying Horse 115kV Series Reactor – ISD 2021
- 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
- Increase Waterton – Martin1 tap 115kV line to 159MVA – ISD 2022

The Base Case also modeled PSCo's Poncha - Smeltertown 115kV line open.

The following additional changes were made to the Tri-State Generation and Transmission (TSGT) model in the Base Case per further review and comment from TSGT:

- 30MW San Isabel Solar tapping Ludlo Tap – Pinon Canyon 115kV line
- 80MW TSGT_0809 solar facility tapping Gladstone – Walsenburg 230kV line
- 100MW TSGT_STEM_PV solar facility at Stem Beach 115kV bus was removed from the model
- Fuller – Vollmer – Black Squirrel 115 kV line modeled at 173 MVA
- Fuller 230/115kV, 100MVA #2 transformer

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. Planned upgrade project in 1/2021
- Fountain Valley – MidwayBR 115kV line was modeled at 222MVA. Planned upgrade project in 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
- Grazing Yak Solar – ISD 2020
- Cottonwood 230/115kV auto-transformer replacement – ISD 2019
- Nixon – Kelker 230kV line upgrade – ISD 2019

The Base Case model includes the existing PSCo generation resources. The Base Case also modeled PI-2019-2 at 250MW output. . The other Provisional Interconnection requests modeled in the Base Case are are PI-2019-4 which has a GI queue position of GI-2018-25. There were no other higher-queued generators in the Provisional Interconnection queue with POI in the same generation pocket and no higher-queued generation in the Generation Interconnection queue which have a Power Purchase Agreement or have received the state approval in the Electric Resource Plan which qualified for inclusion in the Base Case.

The Benchmark Case for evaluating the system impact of PI-2019-3 generation output was created from the Base Case by changing the 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 1 below. The generation dispatch of the neighboring systems was provided by the neighboring utilities.

Table 1 – Generation Dispatch Used to Stress the Benchmark Case (MW is Gross Capacity)

Bus Name	ID	Status	PGen (MW)	PMax (MW)	Owner
APT_DSLS 4.1600	G1	0	0	10	BHE
BAC_MSA GEN1 13.800	G1	1	59.4	90	BHE
BAC_MSA GEN2 13.800	G1	1	59.4	90	BHE
BAC_MSA GEN4 13.800	G1	1	26.4	40	BHE
BAC_MSA GEN4 13.800	G2	1	26.4	40	BHE
BAC_MSA GEN4 13.800	S1	1	16.4	24.8	BHE
BAC_MSA GEN5 13.800	G1	1	26.4	40	BHE
BAC_MSA GEN5 13.800	G2	1	26.4	40	BHE
BAC_MSA GEN5 13.800	S1	1	16.4	24.8	BHE
BAC_MSA GEN6 13.800	G1	1	26.4	40	BHE
BUSCHRNCH_LO0.7000	1	1	35.2	60	BHE
BUSCHRWTG1 0.7000	G1	1	16.9	28.8	BHE
E_CANON 69.000	G1	0	0	8	BHE

PP_MINE 69.000	G1	0	0	3	BHE
PUB_DSLS 4.1600	G1	0	0	10	BHE
R.F.DSLS 4.1600	G1	0	0	10	BHE
RTLSNKWNDLO 0.7000	G1	1	35.2	60	BHE
ALMSACT1 13.800	G1	0	0	17	PSCo
ALMSACT2 13.800	G2	0	0	14	PSCO
COGENTRIX_PV 34.500	S3	1	19.5	30	PSCO
COMAN_1 24.000	C1	0	0	360	PSCO
COMAN_2 24.000	C2	1	365	365	PSCO
COMAN_3 27.000	C3	1	788	788	PSCO
COMAN_PV 34.500	S1	1	102	120	PSCO
CO_GRN_E 34.500	W1	1	64.8	81	PSCo
CO_GRN_W 34.500	W2	1	64.8	81	PSCo
FTNVL1&2 13.800	G1	1	36	40	PSCO
FTNVL1&2 13.800	G2	1	36	40	PSCO
FTNVL3&4 13.800	G3	1	36	40	PSCO
FTNVL3&4 13.800	G4	1	36	40	PSCO
FTNVL5&6 13.800	G5	1	36	40	PSCO
FTNVL5&6 13.800	G6	1	36	40	PSCO
GSANDHIL_PV 34.500	S1	1	12.4	19	PSCO
JKFULGEN 0.6900	W1	1	199.5	249.4	PSCO
LAMAR_DC 230.00	DC	0	0	210	PSCO
SOLAR_GE 34.500	S2	1	19.5	30	PSCO
SUNPOWER 34.500	S1	1	33.8	52	PSCO
TWNBUTTE 34.500	W1	1	60	75	PSCO
SI_GEN 0.6000	1	1	24	30	TSGT
TBII_GEN 0.6900	W	1	60	76	TSGT
TSGT_0809 0.6200	PV	1	80	100	TSGT
PI-2019-3	PV+BES	0	0	200	--

To analyze the impact of the planned retirement of Comanche #1 generator in 2022, a scenario Benchmark Case was created from the Benchmark Case described above by modeling Comanche #1 offline.

A Study case and a scenario study case were created from the Benchmark Case and Scenario Benchmark Case respectively by adding the PI-2019-3 interconnection facility at the proposed Point of Interconnection (tap assumed to be at 50% of line length of Comanche – Daniels Park 345 KV line #1). The 75 MW output from PI-2019-3 was sunk pro-rata to the PSCo units outside the study area.

The PI-2019-3 facility was modeled using the power flow modeling data provided by the Generation Interconnection Customer. The power flow analysis modeled the combined output of PI-2019-2 and PI-2019-3 at 325MW, as a combination of 200MW PV and 125MW BES. The stability studies modeled the 325MW Generating Facility as a combination of 200MW solar PV and 125MW BES, the other operating scenarios of the hybrid facility are studied as part of PI-2019-2.

A power flow analysis was performed, and the results of the Benchmark Case vs Study Case, and the scenario Benchmark Case vs Scenario Study Case were compared to determine the impacts due to addition of PI-2019-3, and the Provisional Interconnection Service capacity of PI-2019-3.

The steady state analysis was performed using PTI's PSSE Ver. 33.12.0 program and the ACCC contingency analysis tool.

The transient stability analysis was performed using General Electric's PSLF Ver.21.0_07 program. Three phase faults were simulated for selected single and multiple contingencies using standard clearing times. The voltage and frequency of transmission busses in the study area, and the relative rotor angle of generators in the study area were recorded and analyzed. PSLF's DYTOOLS EPCL program was used to simulate the disturbances.

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Power Flow Analysis Results

Table 2 Power Flow Analysis Results of PI-2019-3 – 75MW increment in PI-2019-2 generation output

Note – Thermal overloads for single contingencies are calculated using the normal rating of the facility. All overloads are in red.

Summary of Power Flows from Single Contingency Analysis 2023 Heavy Summer Case												
				Facility Loading without PI-2019-2&3		Facility Loading With PI-2019-2 only		Facility Loading With PI-2019-2&3				
Monitored Facility (Line or Transformer)	Type	Owner	Branch Rating MVA (Norm)	N-1 Flow MVA (Norm)	N-1 Flow % of Rating (Norm)	N-1 Flow MVA (Norm)	N-1 Flow % of Rating (Norm)	N-1 Flow MVA (Norm)	N-1 Flow % of Rating (Norm)	% Change (Benchmark Vs PI-2019-2)	% Change (Benmark Vs PI-2019-2&3	NERC Single Contingency
Briargate – Cottonwood 115 KV line	Line	CSU	150.0	147.9	98.6%	150	100%	150.9	100.6%	1.4%	2.0%	Cottonwood – Kettle Creek 115kV line
Buckley – Smoky hill 230kV line	Line	PSCo	382.4	365.6	95.6%	386.6	101.1%	393.9	103%	5.5%	7.4%	Greenwood – Monaco12 230kV line
Daniels Park – Prairie1 230kV line #1	Line	PSCo	478.0	446.4	93.4%	483.3	101.1%	494.2	103.4%	7.7%	10%	Daniels Park – Prairie3 230kV line #1
Daniels Park – Prairie3 230kV line #1	Line	PSCo	478.0	441.2	92.3%	478	100%	489.5	102.4%	7.7%	10.1%	Daniels Park – Prairie1 230kV line #1

The results of the single contingency analysis (P1 and P2-1) for the case with Comanche Unit #1 online are given in Table 2. The addition of PI-2019-3 caused one new overload in the CSU system and new overload on the PSCo system. In addition, it also contributed to an increase in the overloads seen after PI-2019-2 interconnection. Since the combined output of PI-2019-2 &3 will be 325MW, the analysis compared the overloads for the full 325MW output. The facility overloads attributed to PI-2019-3 are as follows:

- Briargate – Cottonwood 115 KV line loading increased from 98.6% to 100.6% (CSU facility)
- Buckley – Smoky hill 230 KV line loading increased from 95.6% to 103.0% (PSCo facility)
- Daniels Park - Prairie1 230 KV line loading increased from 93.4% to 103.4% (PSCo facility)
- Daniels Park – Prairie3 230 KV line loading increased from 92.3% to 102.4% (PSCo facility)

The scenario with Comanche Unit #1 retirement modeled did not result in any thermal or voltage violations.

Hence, in case the Comanche Unit #1 retirement is delayed for any reason, the maximum output PI-2019-3 may be limited based on generation dispatch and available firm or non-firm capacity on the transmission system.

If Comanche Unit #1 is retired as planned, the maximum Provisional Interconnection Service capacity of PI-2019-3 is 75MW

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.

Voltage Regulation and Reactive Power Capability

The Interconnection Customer is required to interconnect its Large Generating Facility with PSCo's Transmission System in accordance with the *Xcel Energy Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW* (available at:

http://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Interconnection/Interconnections-POL-TransmissionInterconnectionGuidelineGreat20MW.pdf).

Accordingly, the following voltage regulation and reactive power capability requirements at the POI are applicable to this interconnection request:

- To ensure reliable operation, all Generating Facilities interconnected to the PSCo transmission system are expected to adhere to the *Rocky Mountain Area Voltage Coordination Guidelines (RMAVCG)*. Accordingly, since the POI for this interconnection request is located within Southeast Colorado - Region 4 defined in the *RMAVCG*; the applicable ideal transmission system voltage profile range is 1.02 – 1.03 per unit at regulated buses and 1.0 – 1.03 per unit at non-regulated buses.

- Xcel Energy's OATT (Attachment N effective 10/14/2016) 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 as long as the Generating Facility does not have to operate outside its 0.95 lag – 0.95 lead dynamic power factor range capability.

- 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 (34.5kV or 345kV bus) 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 and the 1.0 – 1.03 per unit voltage range standards at the 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 Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and voltage ranges (noted above).

According to the modeling data provided by the Customer for PI-2019-2&3, the Generating Facility has the following modeling parameters:

- Solar PV: Pmax =250MW, Pmin =0, Qmax = 121.31Mvar, Qmin = -121.31Mvar
- BES: Pmax =125MW, Pmin=-125MW, Qmax=54.66Mvar, Qmin=-54.66Mvar

Since the net output at the POI after PI-2019-2 and PI-2019-3 will be 325MW, the below reactive capability analysis is performed for 325MW output. The reactive capability evaluation for the other output levels has been performed as part of PI-2019-2.

Table 3 - Reactive Capability Evaluation

Gen MW(PV/BESS)/Mvar (PV/BESS)	Gen Voltage (p.u.) - (PV/BESS)	High Side Main Station Transformer Voltage (p.u.)	High Side MW	High Side Mvar	High Side Power Factor	lead/lag	POI Voltage (p.u.)	POI MW	POI MVar	POI Power Factor
325 MW/176 Mvar	1.121/1.126	1.037	320.2	121.6	0.935	lag	1.037	320.2	121.6	0.935
325 MW/-176 Mvar	0.874/0.842	0.966	316.7	-271.7	0.759	lead	0.966	316.7	-271.7	0.759
325 MW/158.8 Mvar	1.109/1.118	1.034	320.3	105	0.950	lag	1.034	320.3	105	0.950
325 MW/-47.4 Mvar	0.976/0.96	0.997	319.9	-104.9	0.950	lead	0.997	319.9	-104.9	0.950
32.5 MW/9.2 Mvar	1.024/1.026	1.018	32.5	10.7	0.950	lag	1.034	320.3	105	0.950

32.5 MW/-12 Mvar	1.011/1.008	1.014	32.4	-10.6	0.950	lead	0.997	319.9	-104.9	0.950

From the analysis in Table-3, the Generating Facility is capable of meeting 0.95 PF at the high side of the main step-up transformer for the 325MW output, and can achieve atleast 1 per unit voltage at the POI.

Transient Stability Study Results

Table 4 Transient Stability Analysis Results

Stability Scenarios						
#	**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 – PI-2019-2 Switching Station 345	4.0	Maximum transient voltage dips within criteria	Stable with positive damping

			KV line			
10	Comanche 345kV	3ph	Comanche – Daniels Park 345kV line 2 and Daniels Park – PI_2019_2 Switching Station 45 KV line	4.0	Maximum transient voltage dips within criteria	Stable with positive damping

The results of the transient stability analysis are given in Table 4. It is determined that the interconnection of PI-2019-3 produced no adverse system stability impact. The following results were obtained for every case and disturbance analyzed:

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

Transient stability plots showing surrounding bus voltages, bus frequencies, generator terminal voltages, generator relative angles, generator speeds, and generator power output for each of the disturbances runs for each study scenario have been created and documented in Appendix B. Furthermore, it is the responsibility of the Interconnection Customer to ensure that its generating facility is capable of meeting the voltage ride-through and frequency ride-through (VRT and FRT) performance specified in the NERC Reliability Standard PRC-024.

Short Circuit and Breaker Duty Analysis

The calculated short circuit levels and Thevenin system equivalent impedances at the Comanche – Daniels Park 345kV POI are shown in Table 5.

Table 5 – Short Circuit Parameters at the PI-2019-2 345kV Switching Station POI

	Without PI-2019-2&3 Interconnection	With PI-2019-2 Interconnection only	With PI-2019-2&3 Interconnection
Three Phase Current	8331A	8331A	8331A
Single Line to Ground Current	6094A	6588A	6602A

Positive Sequence Impedance	1.848+j23.837 ohms	1.848+j23.837 ohms	1.848+j23.837 ohms
Negative Sequence Impedance	1.890+j23.841 ohms	1.890+j23.841 ohms	1.890+j23.841 ohms
Zero Sequence Impedance	7.398+j49.752 ohms	20.689+j39.679 ohms	20.723+j39.465 ohms

A preliminary breaker duty study did not identify any circuit breakers that became over-dutied"[2] as a result of adding this generation.

Costs Estimates and Assumptions

PSCo Engineering has developed Appropriations level cost estimates (AE) for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the Interconnection Customer's proposed generation facility. The cost estimates are in 2019 dollars with escalation and contingencies applied. 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.

The estimated total cost for the required upgrades is **$100,000.**

Figure 2 below is a conceptual one-line of the proposed interconnection. The Point of Interconnection will be same as PI-2019-2, i.e., a tap on the Comanche-Daniels Park 345kV Transmission line.

The following (Tables 6 and 7) list the improvements required to accommodate the interconnection and the delivery of the customer's 75 MW battery storage facility generation output to PSCo native load. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to revision as a more detailed and refined design is produced

The Transmission Provider has specified and estimated the cost of the equipment, engineering, procurement and construction work needed to interconnect PI-2019-2. The results of the engineering analysis for facilities owned by the Transmission Provider are appropriation level estimates and are summarized in Tables 6 and 7.

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

Table 6: “Transmission Provider’s Interconnection Facilities” includes the nature and estimated cost of the Transmission Provider's Interconnection Facilities and an estimate of the time required to complete the construction and installation of such facilities.

Table 7: “Network Upgrades Required for Interconnection includes the nature and estimated cost of the Transmission Provider's Network Upgrades necessary to accomplish the interconnection and an estimate of the time required to complete the installation of such facilities.

Upgrades identified in Tables 6 and 7 are illustrated in Figure 2 which shows the physical and electrical connection of the Interconnection Customer’s Generating Facility to the Transmission Provider’s Transmission System. The one-line diagram also identifies the electrical switching configuration of the interconnection equipment, including, without limitation: the transformer, switchgear, meters, and other station equipment.

Conclusion:

The total estimated cost of the PSCo transmission system improvements required for PI-2019-3 to qualify for Provisional Interconnection Service is:

- **$100,000 (Tables 6 and7)**

For PI-2019-3 interconnection:

Provisional Interconnection Service (after the retirement of Comanche#1) = 75MW

In case the Comanche Unit #1 retirement is delayed for any reason, the maximum output PI-2019-3 may be limited based on generation dispatch and available firm or non-firm capacity on the transmission system.

The Provisional Interconnection Service results above are contingent upon the transmission system improvements identified in Attachment 1.

The combined generation output of PI-2019-2 and PI-2019-3 hybrid facility at the POI shall not exceed 325MW at any time, which will be monitored by PSCo and limited by the Plant Controller at all times

Security: *Since GI-2019-3 selected ERIS and the PI-2019-3 Generating Facility does not need any new Interconnection Facilities at the POI, except the ones already identified as part of PI-2019-2, the security associated with the Interconnection Facilities would be identified as part of PI-2019-2. No additional security is identified for PI-2019-3.*

The Interconnection Customer assumes all risk and liabilities with respect to changes between the Provisional Large Generator Interconnection Agreement and the Large Generator Interconnection Agreement, including changes in output limits and Interconnection Facilities, Network Upgrades, Distribution Upgrades, and/or System Protection Facilities cost responsibility.

Note: Provisional Interconnection Service in and of itself, does not convey transmission service.

Table 6 – Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's PI-2019-2 &3 Switching Station (New switching station)	Interconnnect Customer to tap at the Comanche-Daniels Park switching station 345kV bus. The new equipment includes: • testing.	$0.100
	Transmission line tap into substation:	0
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction	0
	Total Cost Estimate for Transmission Providers Interconnection Facilities	**$0.100**
Time Frame	**Site, design, procure and construct**	**12 Months**

Table 7 - Network Upgrades for Interconnection (ERIS)

Element	Description	Cost Est. (Millions)
N/A	N/A	0
	Siting and Land Rights support for substation construction	0
	Total Cost Estimate for Network Upgrades for Interconnection	**0**

Time Frame	**Site, design, procure and construct**	**N/A**

Cost Estimate Assumptions

- Appropriation level project cost estimates (AE) for Interconnection Facilities were developed by PSCo Engineering. A level of accuracy of ±20% is specified for AE's.
- Estimates are based on 2019 dollars (appropriate contingency and escalation applied).
- "Allowance for Funds Used during Construction" (AFUDC) has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The Battery Storage Facility is 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.
- The estimated time to design, procure and construct the interconnection facilities is approximately 12 months after authorization to proceed has been obtained.
- Customer will string OPGW fiber into substation as part of the transmission line construction scope, which will be done as part of PI-2019-2.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.
- Line and substation bus outages will be necessary during the construction period. Outage availability could potentially be problematic and extend requested backfeed date due. However, additional bus outages will not be required for PI-2019-3 since it is part of PI-2019-2
- Since PI-2019-3 is part of PI-2019-2, the Power Quality Metering (PQM) installed per PI-2019-2 shall be adequately designed.
- 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.

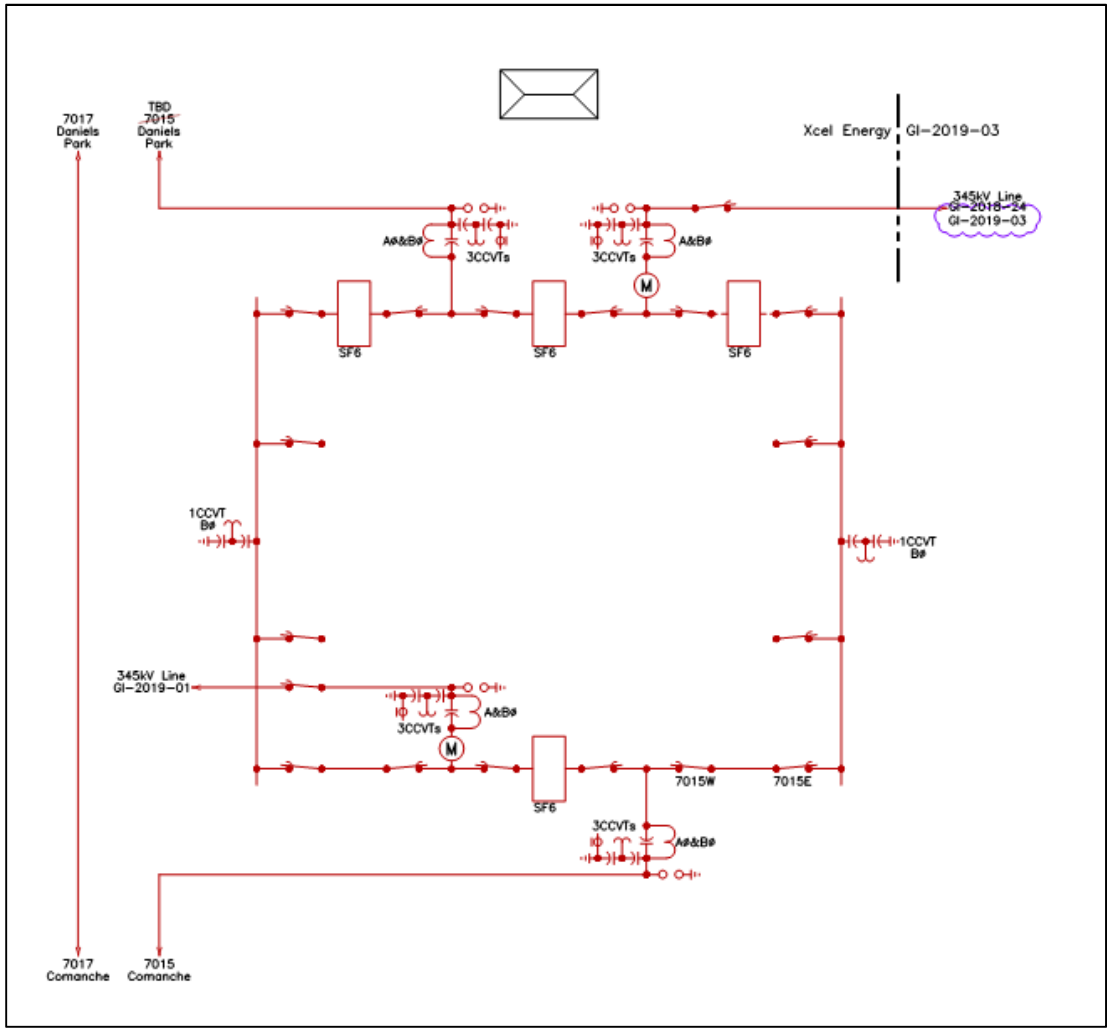
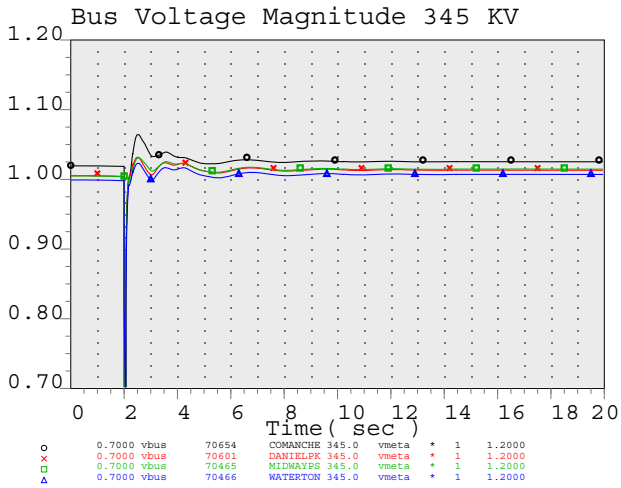


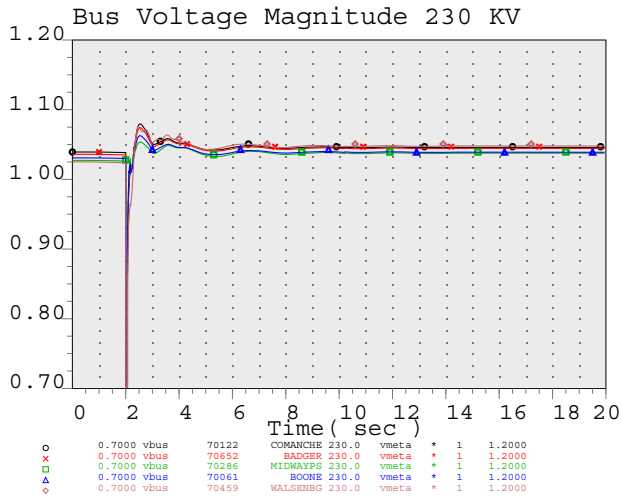
Figure 2 – Preliminary one-line of PI-2019-2&3 POI – “PI-2019-2 Switching Station”

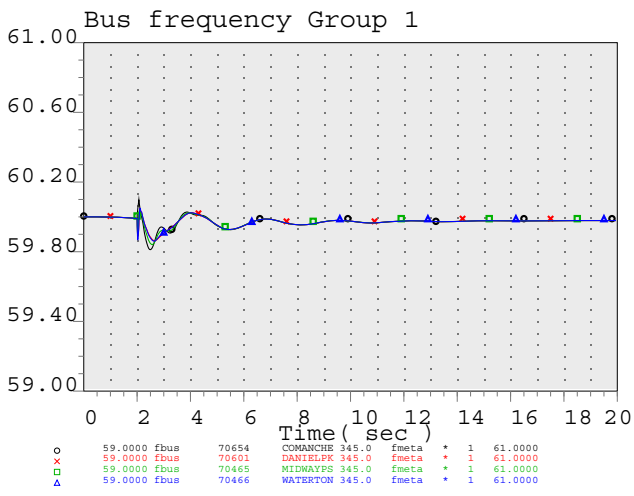
Attachment 1 – Contingent Facilities Assigned to PI-2019-3

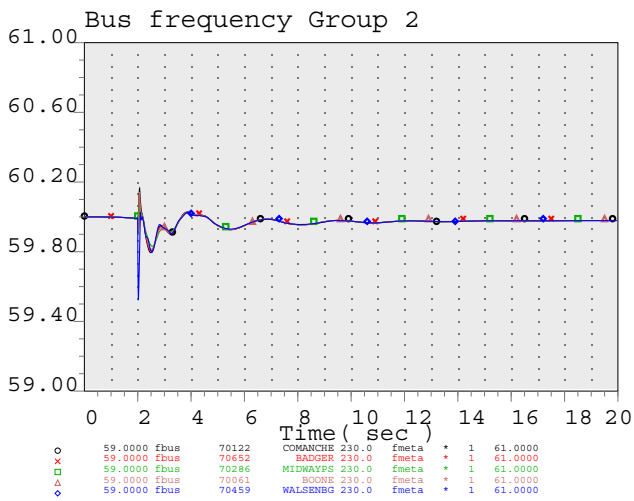
The following is the list of the unbuilt Interconnection Facilities and Network Upgrades upon which the PI-2019-3 request's costs, timing, and study findings are dependent, and if delayed or not built, could cause a need for re-studies of the Interconnection Request or a reassessment of the Interconnection Facilities and/or Network Upgrades and/or costs and timing. PI-2919-3's maximum allowable output may be decreased if these Contingent Facilities are not in-service.

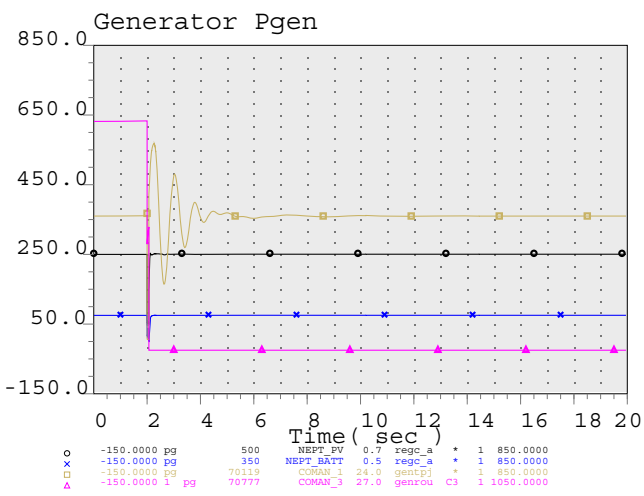
1. The following unbuilt transmission projects modeled in the Base Case
   - Monument – Flying Horse 115kV Series Reactor – ISD 2021
   - Upgrade Villa Grove – Poncha 69kV Line to 73MVA – ISD 2021
   - Upgrade Poncha - Sargent - San Luis Valley 115kV line to 120MVA – ISD 2021
   - Increase Waterton – Martin1 tap 115kV line to 159MVA – ISD 2022
   - TSGT's planned project to uprate the Fuller – Vollmer – Black Squirrel 115 kV line to 173 MVA
   - TSGT's planned project - Fuller 230/115kV, 100MVA #2 transformer
   - BHE's planed project to uprate the Fountain Valley – DesertCove 115kV line to 171MVA
   - BHE's planned project to uprate the Fountain Valley – MidwayBR 115kV line to 171MVA
   - BHE's Pueblo West Substation
   - BHE's Skyline Ranch Substation
   - BHE's West Station – Greenhorn 115kV line Rebuild project
   - CSU's project to close Tesla - Cottonwood 34.5kV line and open the Kettle Creek – Tesla 34.5kV line
   - CSU's new Cottonwood 230/115kV auto-transformer replacement
   - CSU's Nixon – Kelker 230kV line uprate project
2. Network Upgrades for Interconnection assigned to PI-2019-3 (refer to Table 6 and 7 of this report)

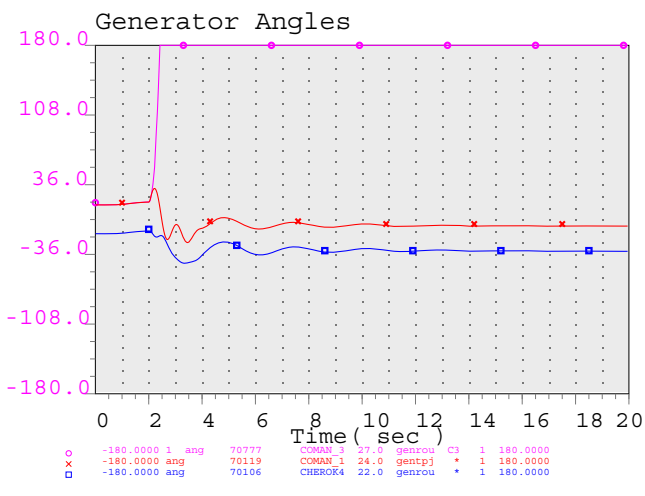






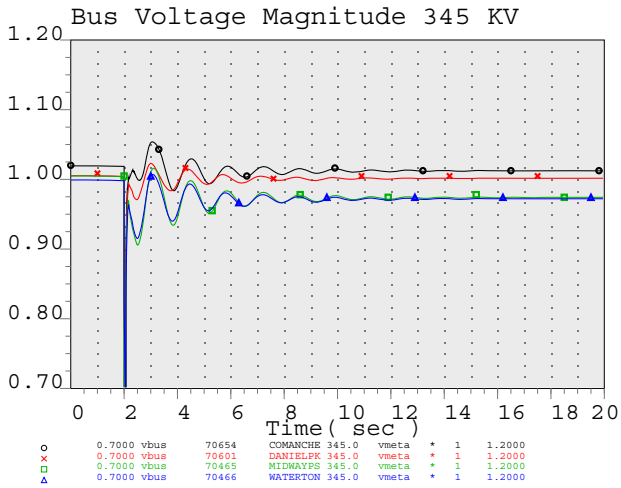


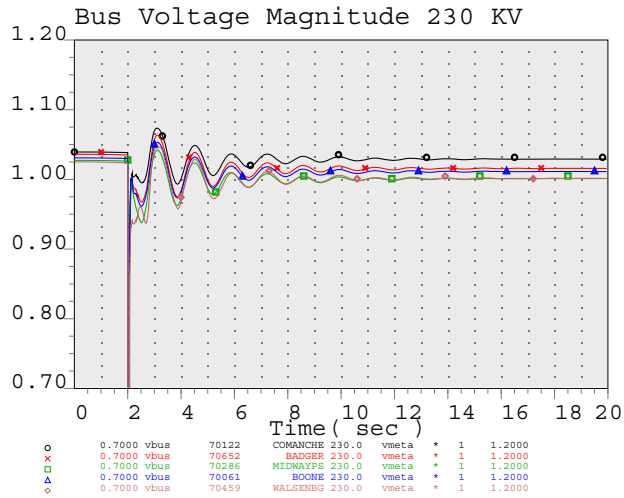


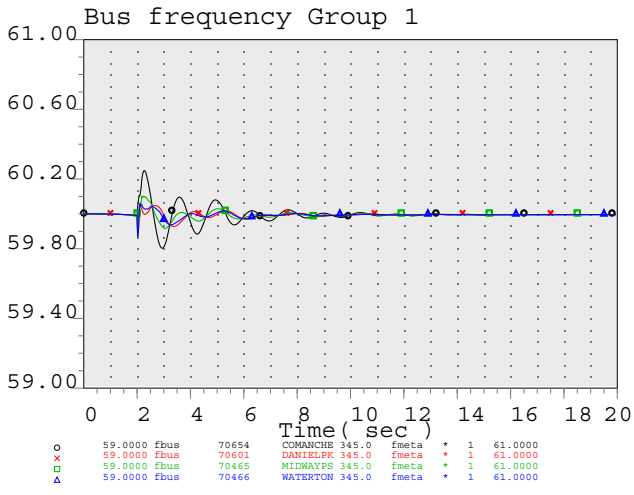


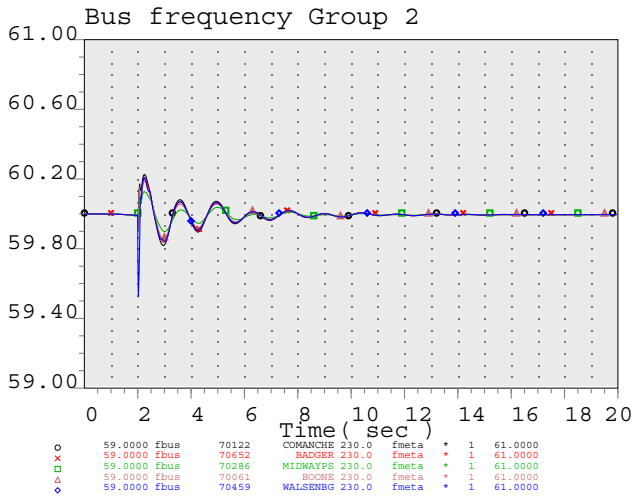
PI-2019-3
PV - 250 MW, BES - 75 MW

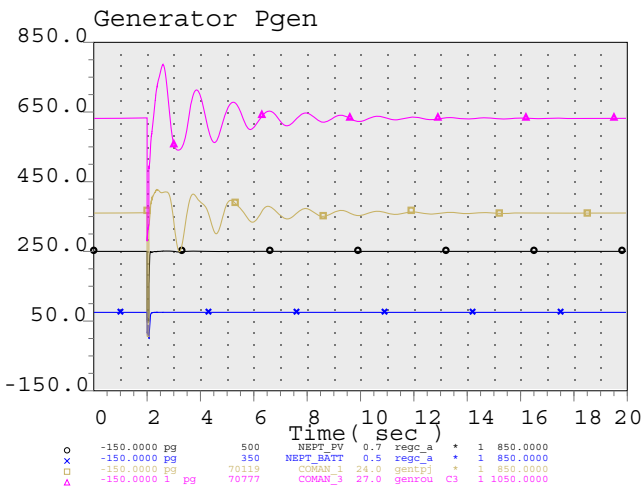
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: Comanche unit 3

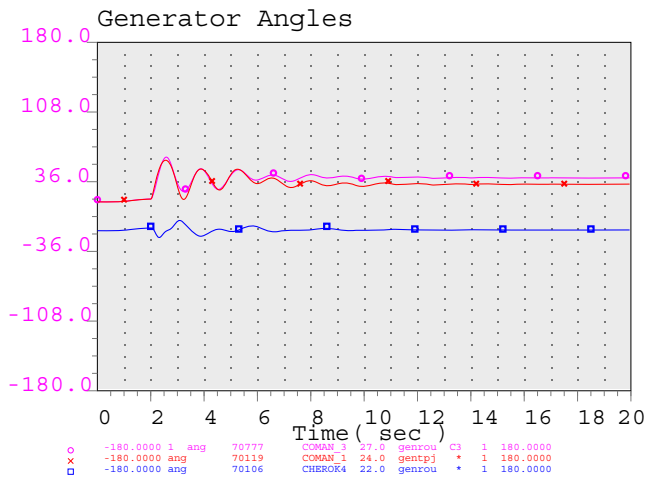






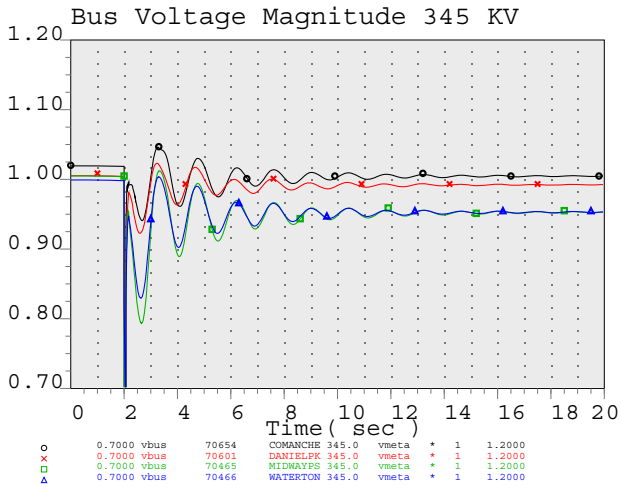


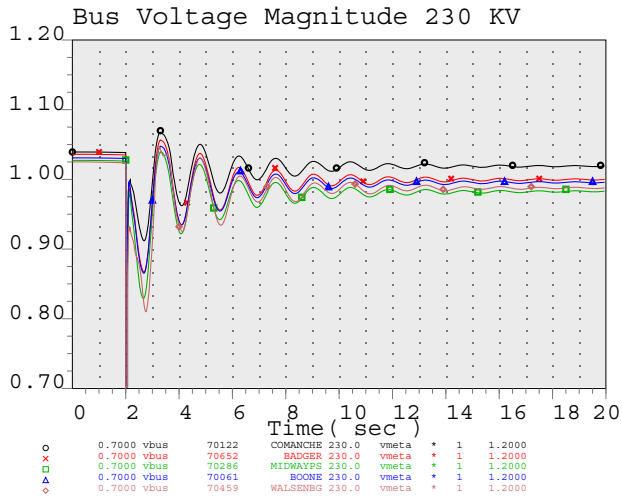


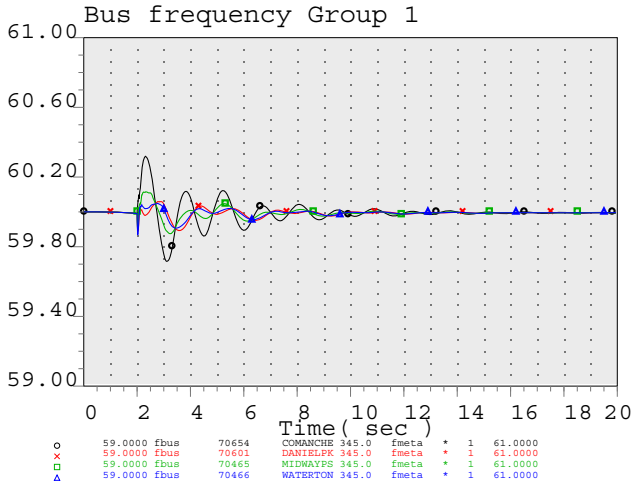


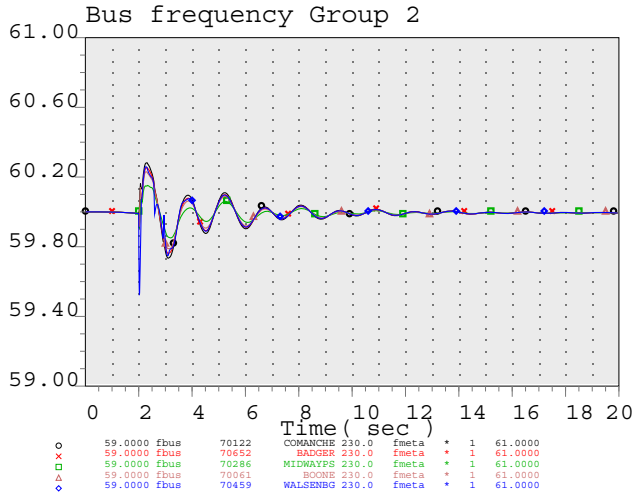
PI-2019-3
PV - 250 MW, BES - 75 MW

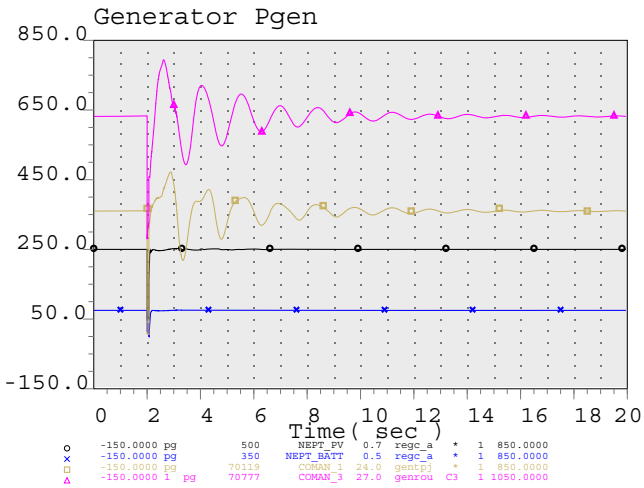
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: lose Comanche - Daniels Park 345 KV line #2
and Comanche - PI-2019-3 POI 345 KV line

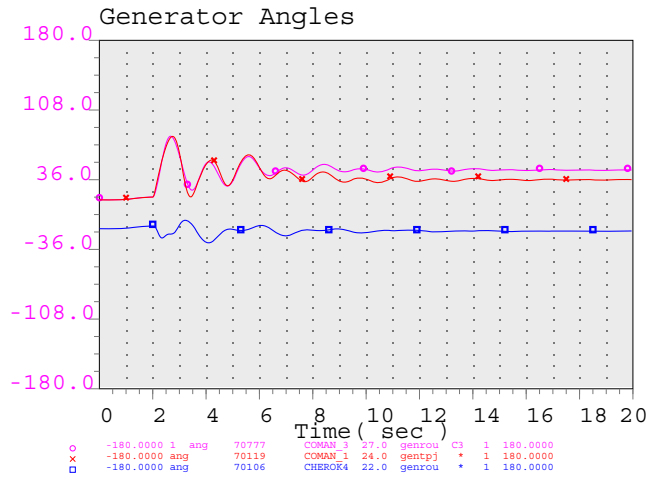






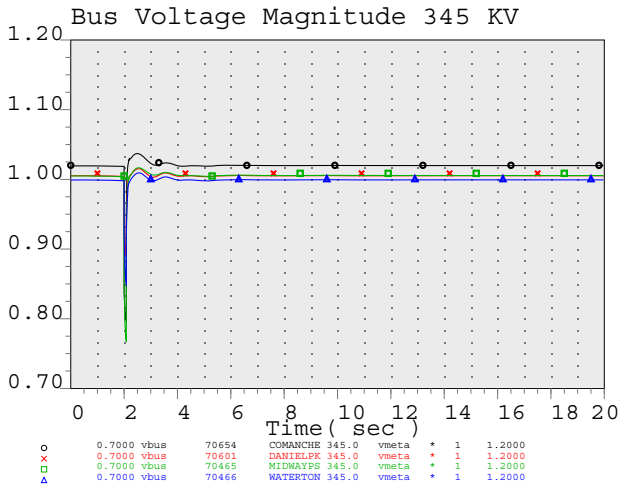


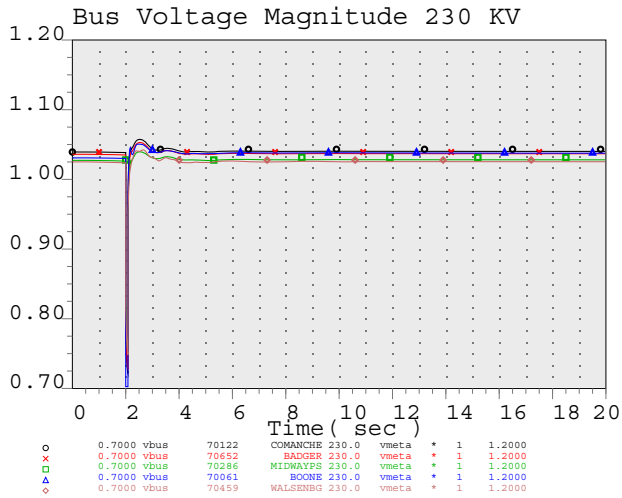


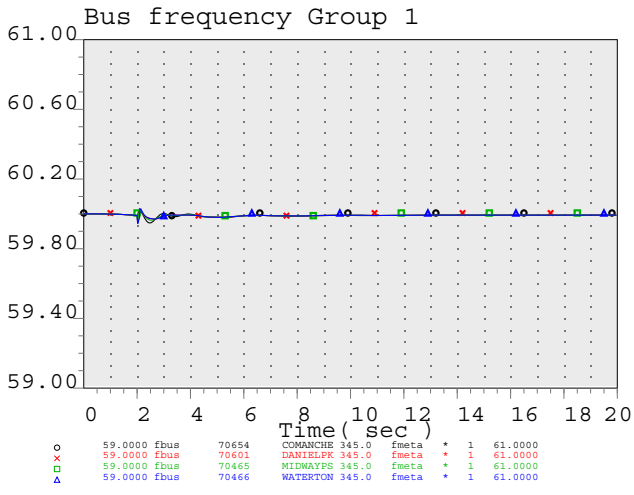


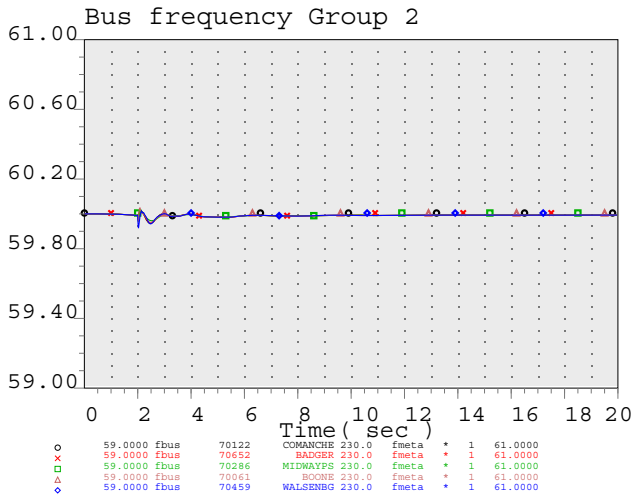
PI-2019-3
PV - 250 MW, BES - 75 MW

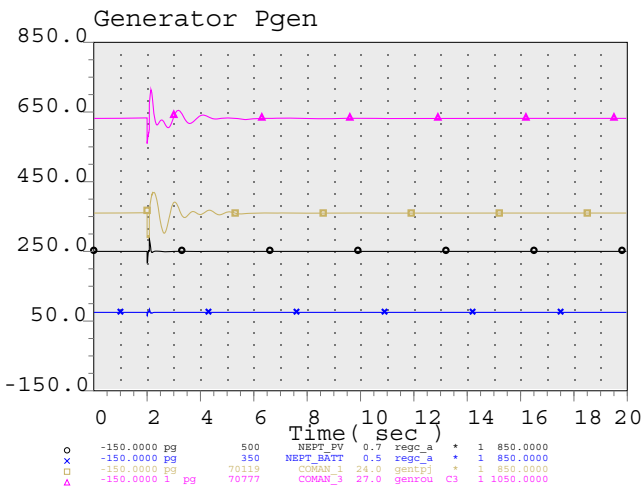
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: lose Comanche - Daniels Park 345kV line #2
and Daniels Park - PI-2019-3 POI 345 KV line

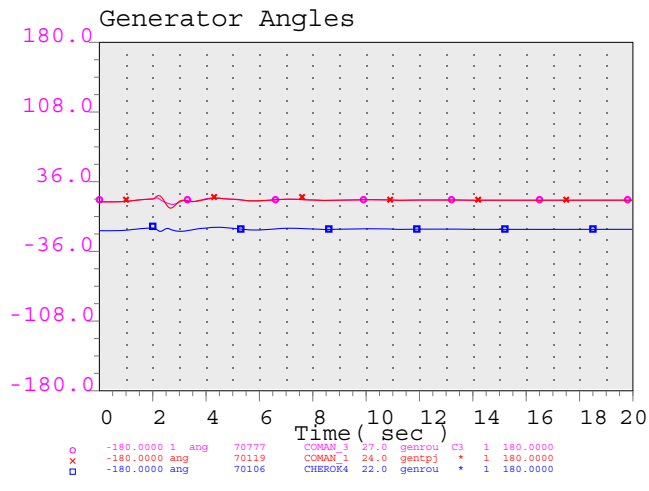






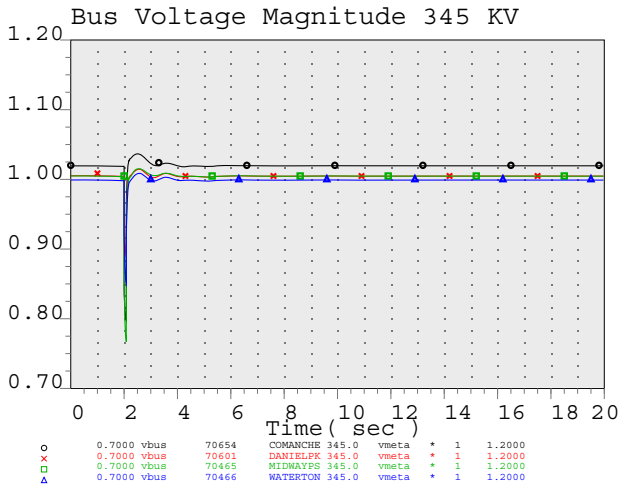


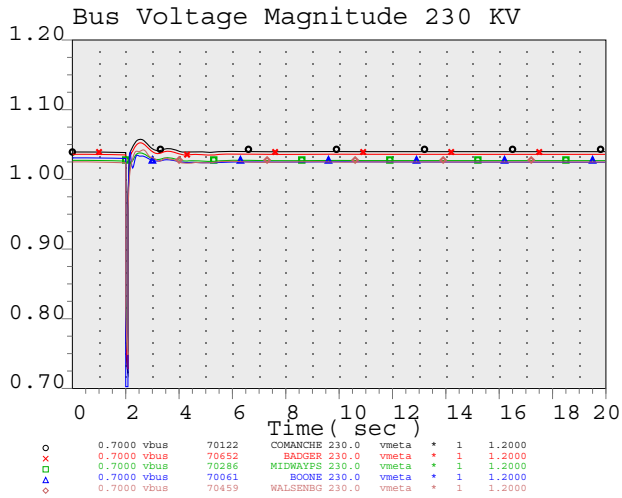


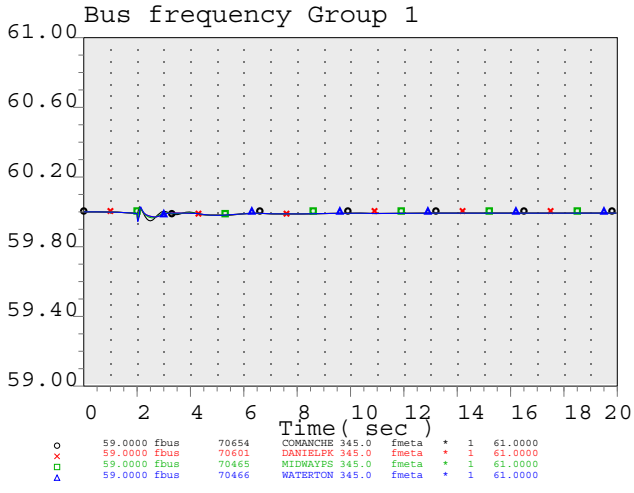


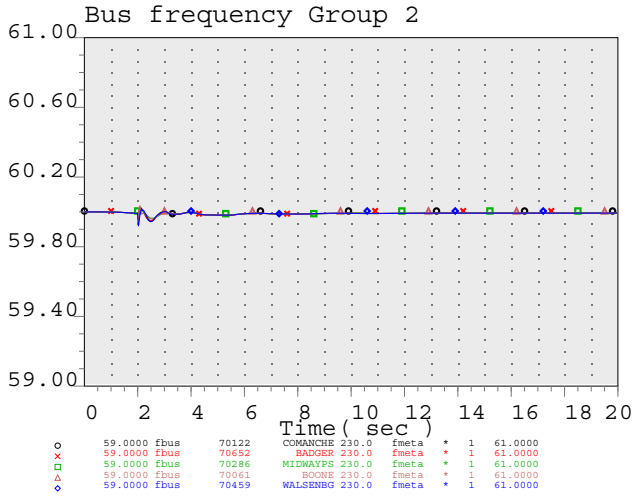
PI-2019-3
PV - 250 MW, BES - 75 MW

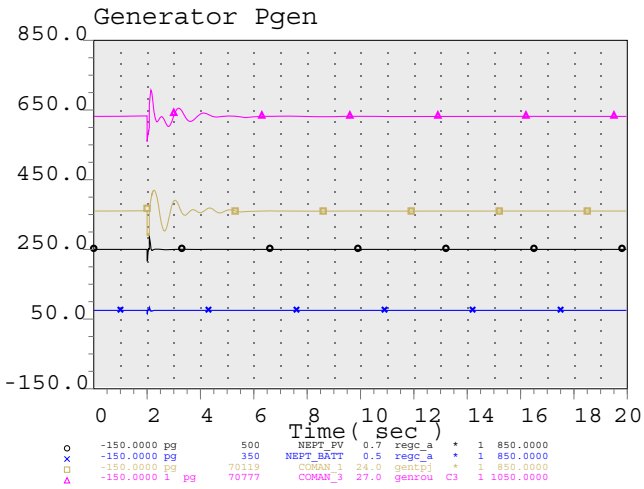
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone 230/115 KV bank

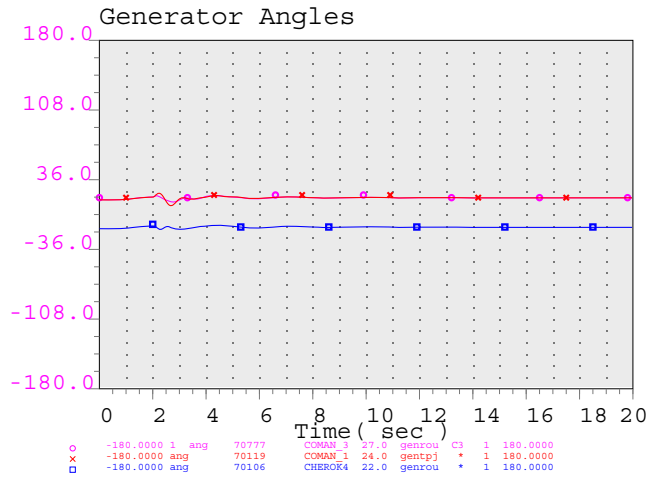






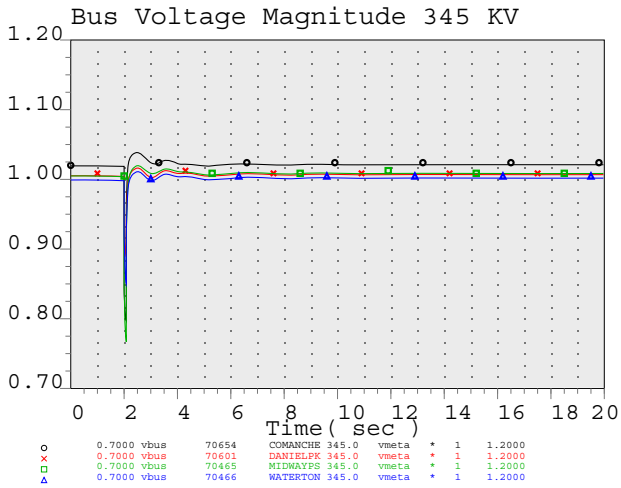


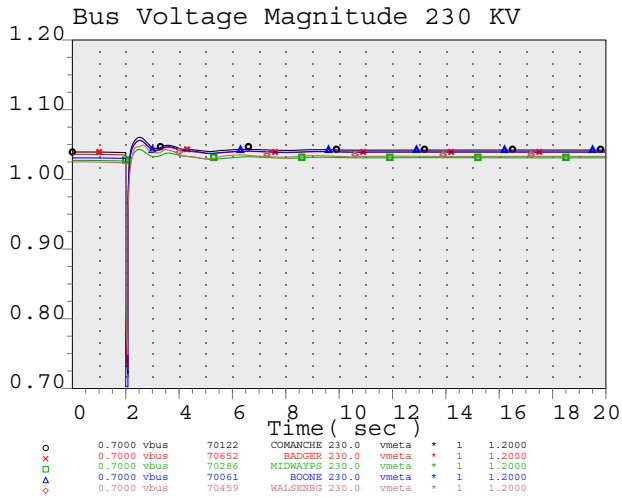


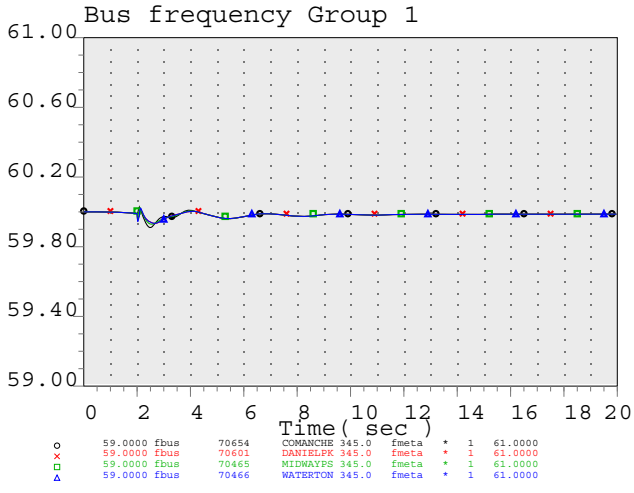


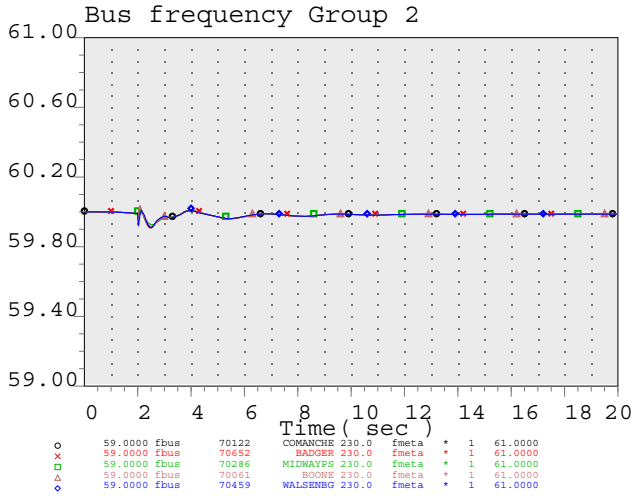
PI-2019-3
PV - 250 MW, BES - 75 MW

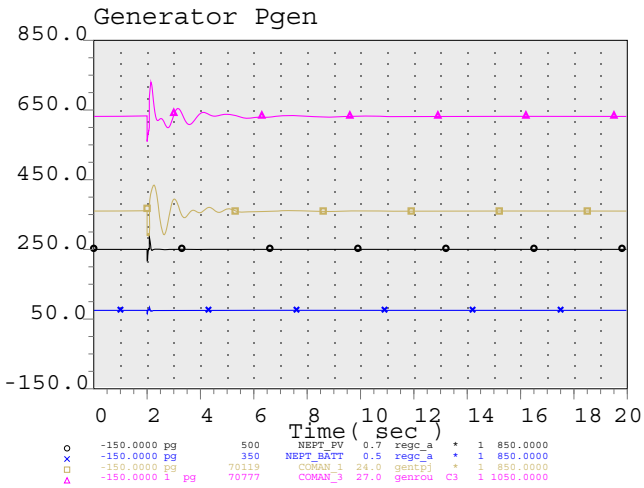
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Comanche 230 KV line

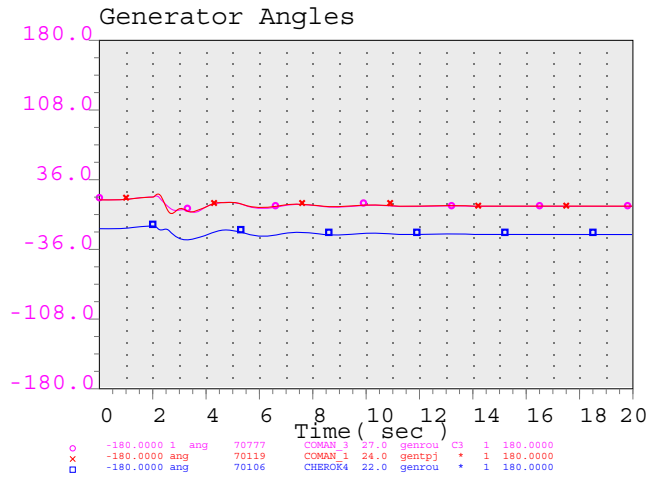




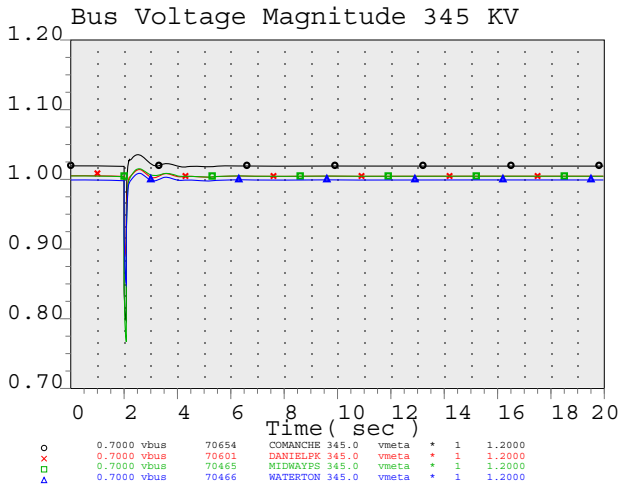


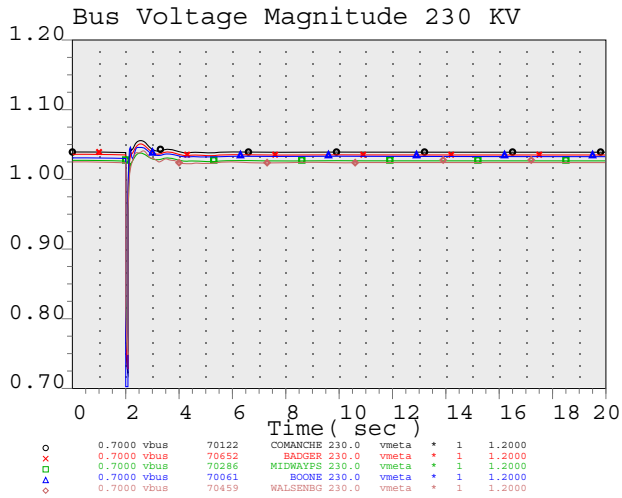


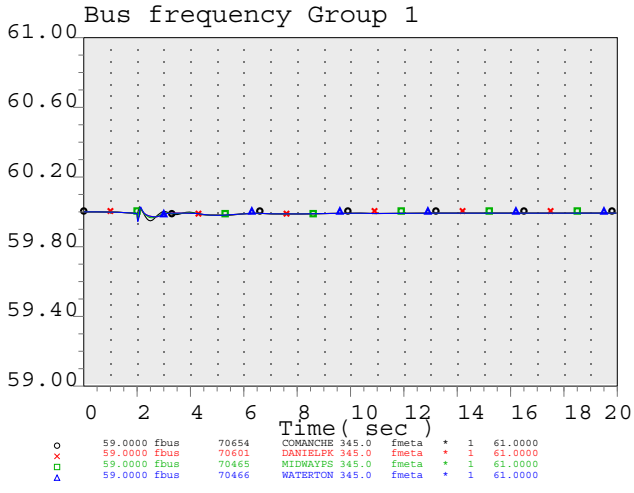


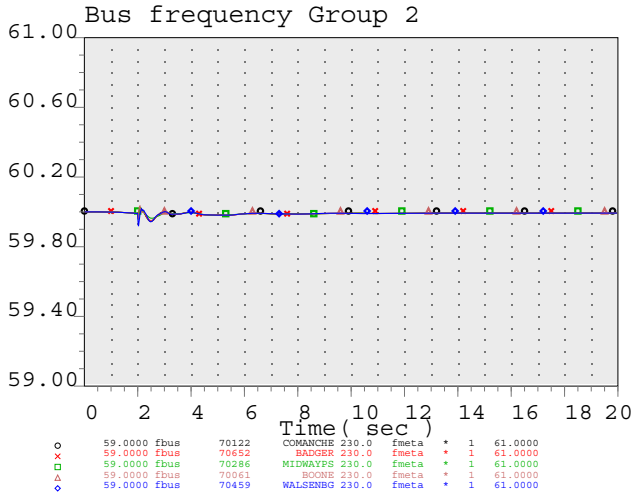


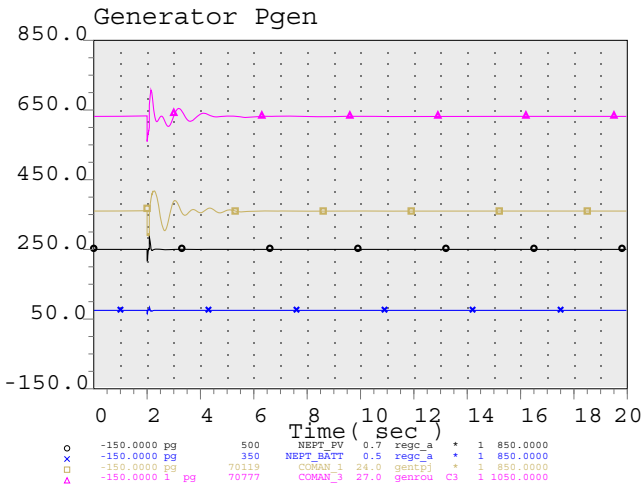
PI-2019-3
PV - 250 MW, BES - 75 MW

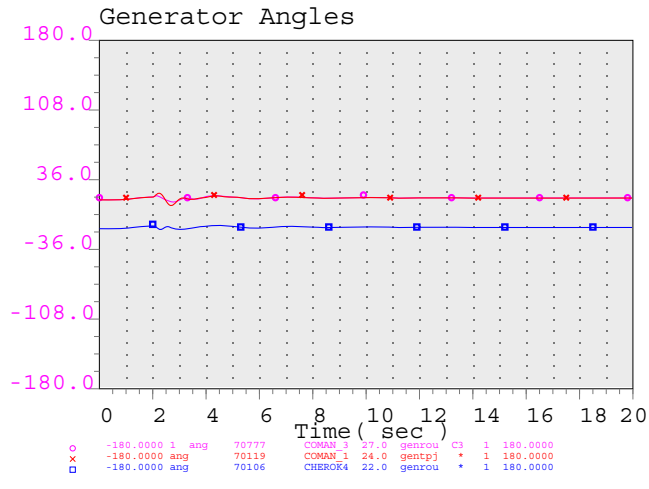






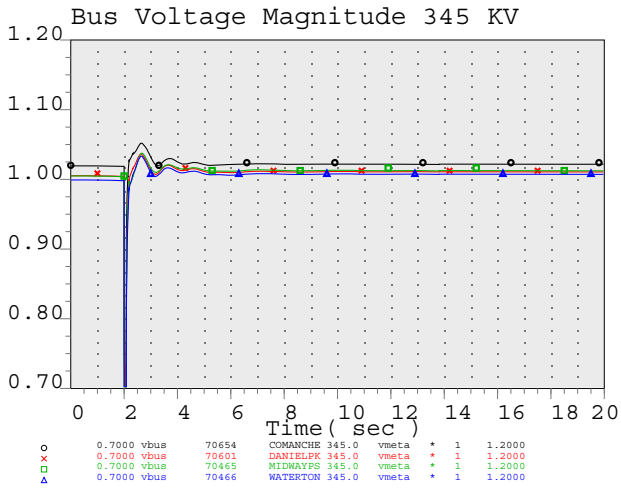


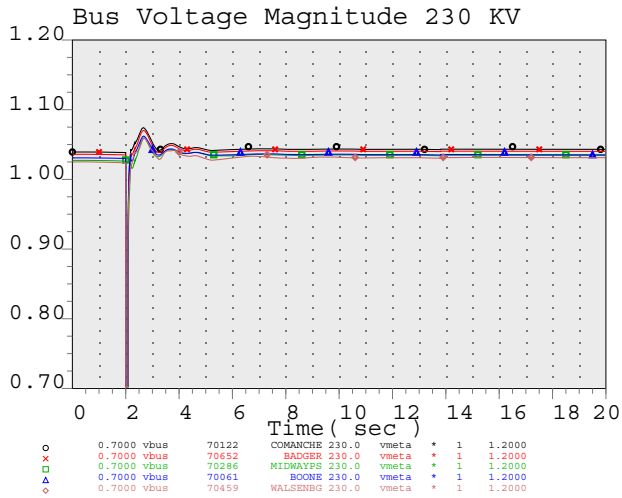


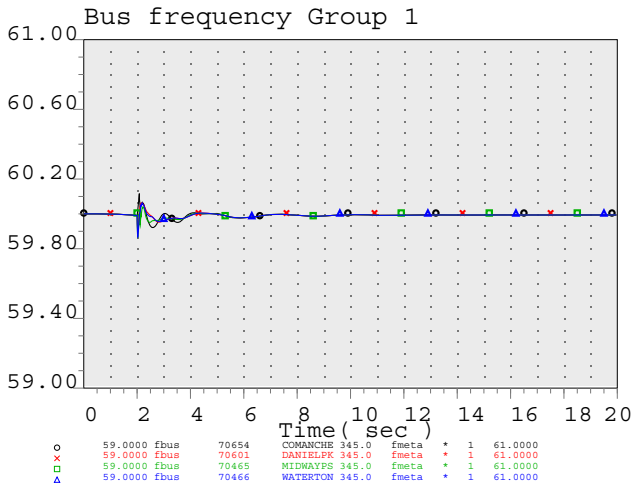


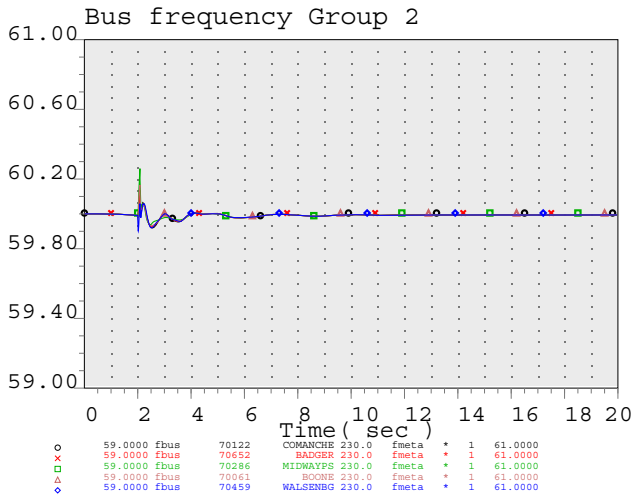
PI-2019-3
PV - 250 MW, BES - 75 MW

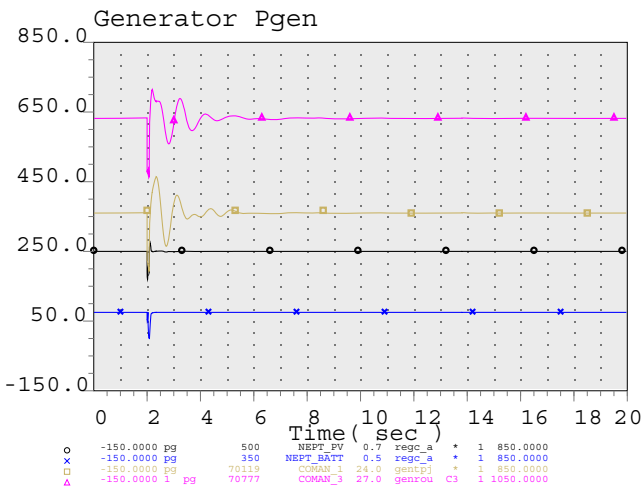
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Midway 230 KV Line

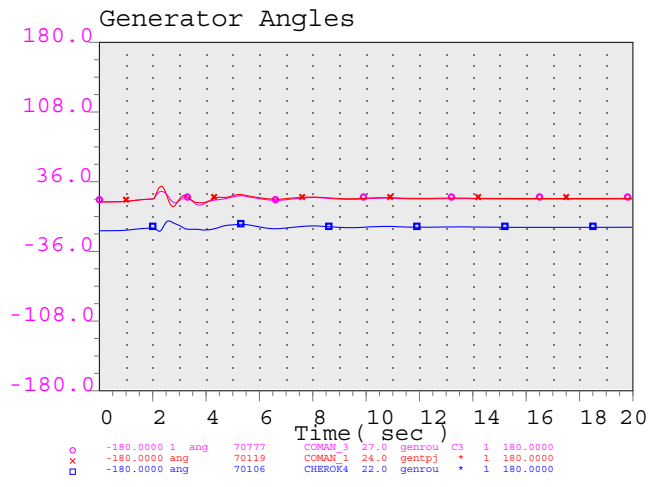






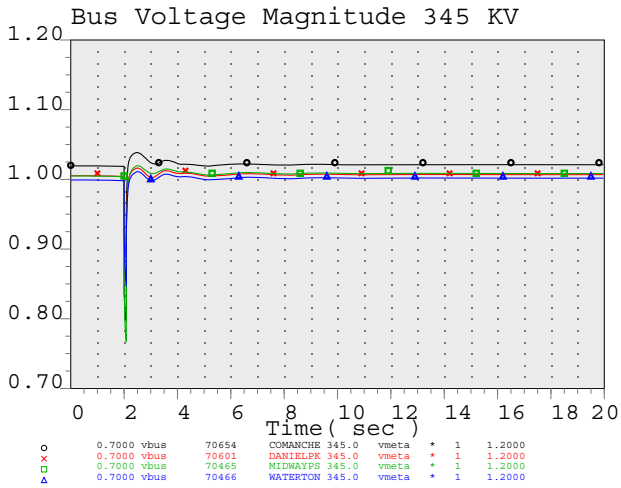


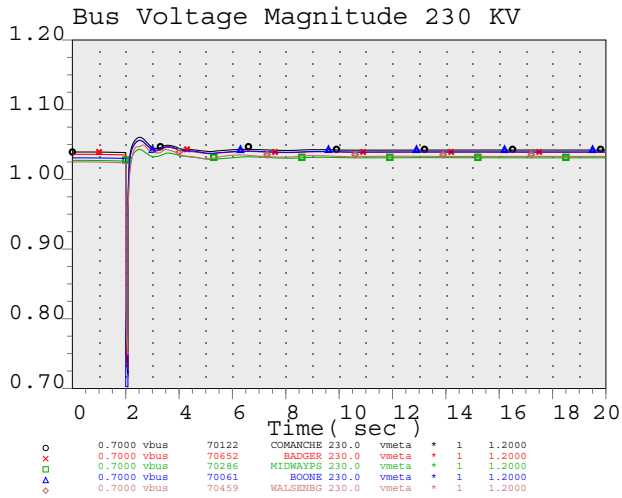


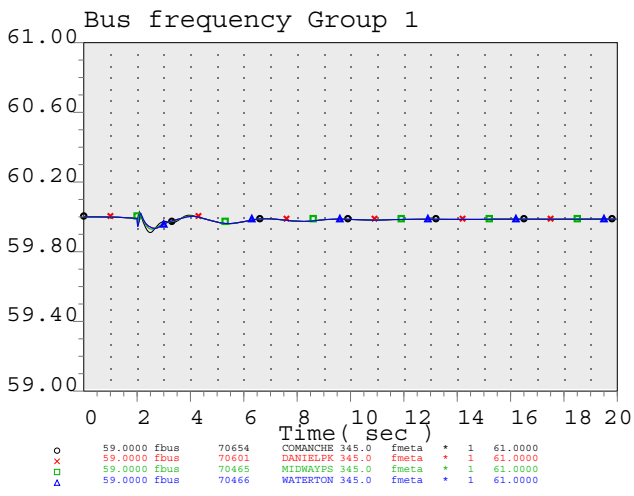


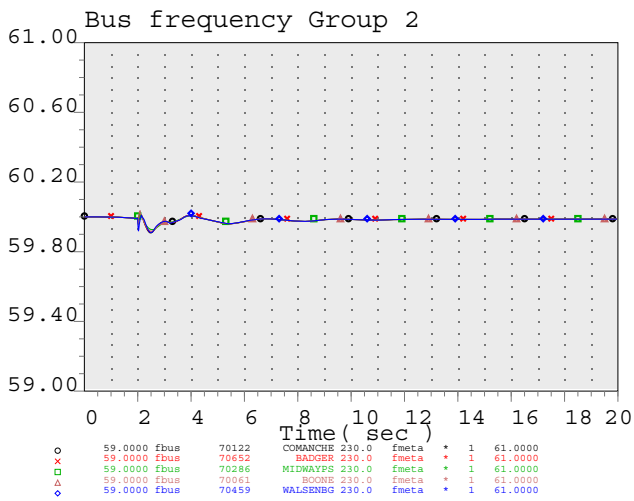
PI-2019-3
PV - 250 MW, BES - 75 MW

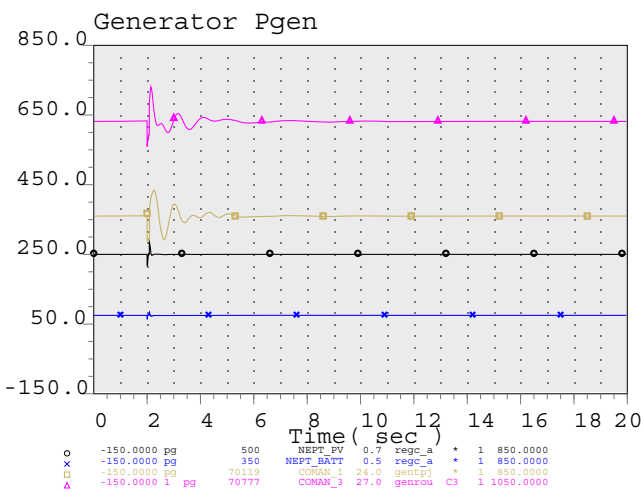
Fault: MIDWAYPS 345 KV 5 cycle 3-ph bus fault
Outage: lose Fountain Valley gen

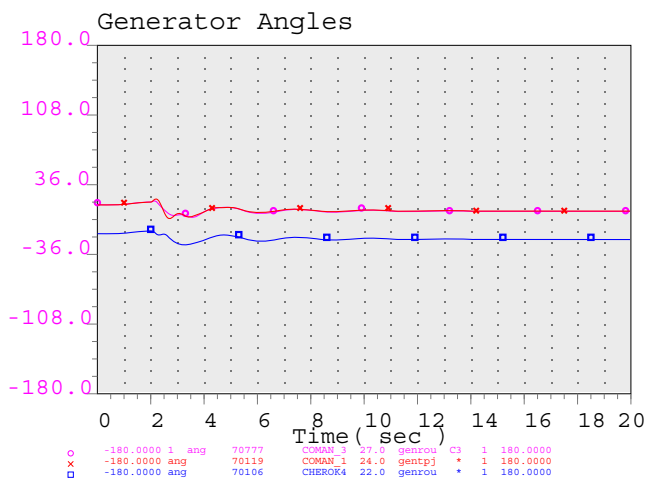




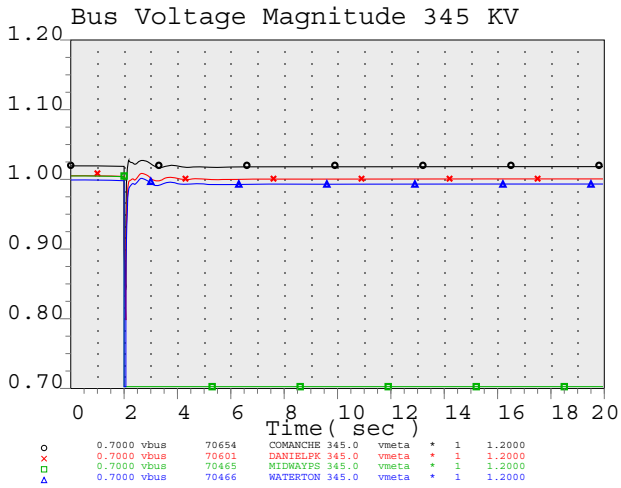


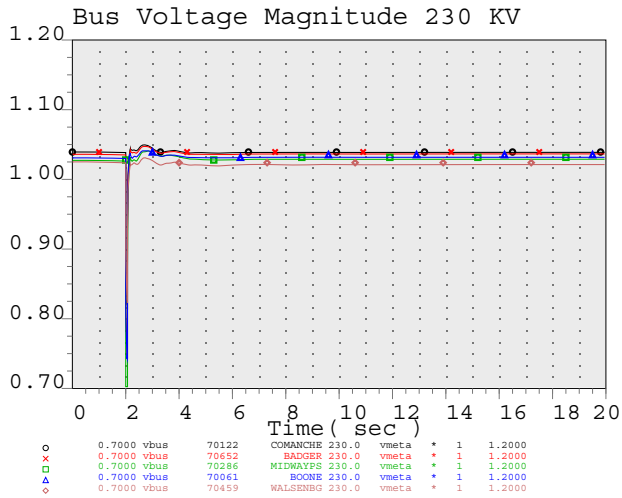


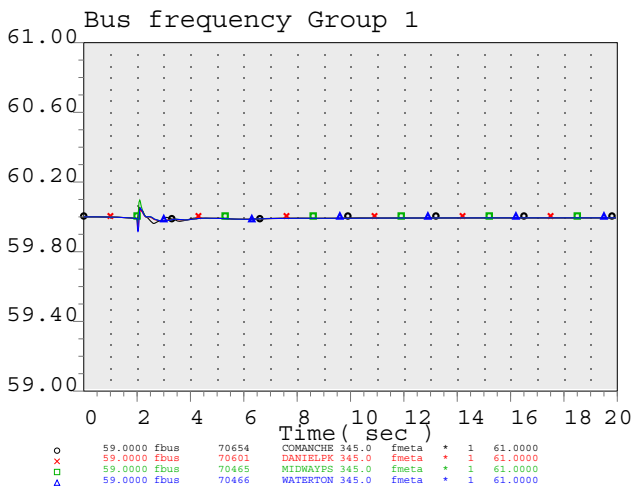


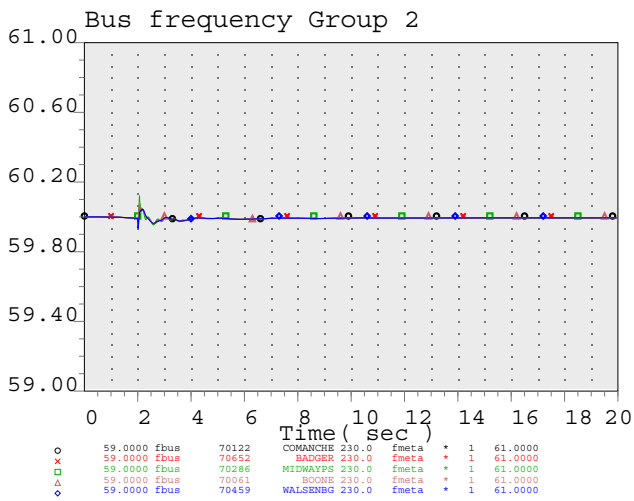


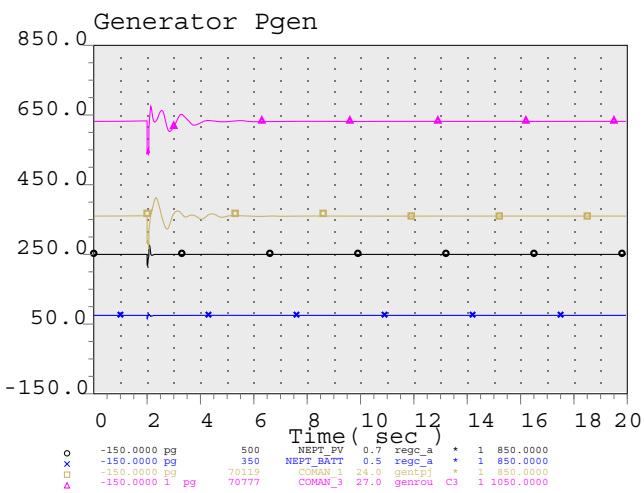
PI-2019-3
PV - 250 MW, BES - 75 MW

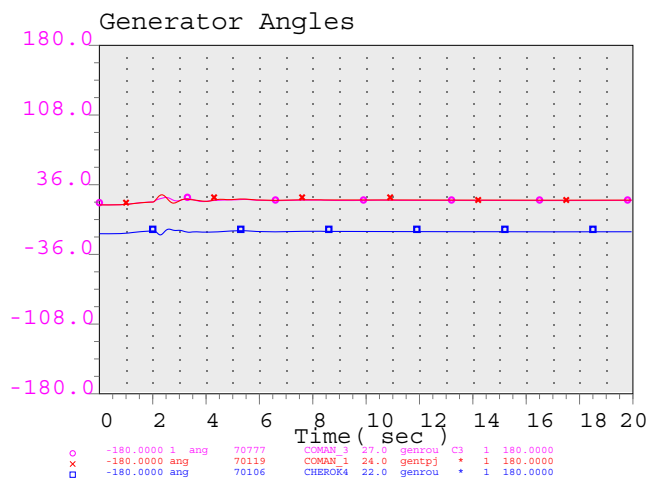




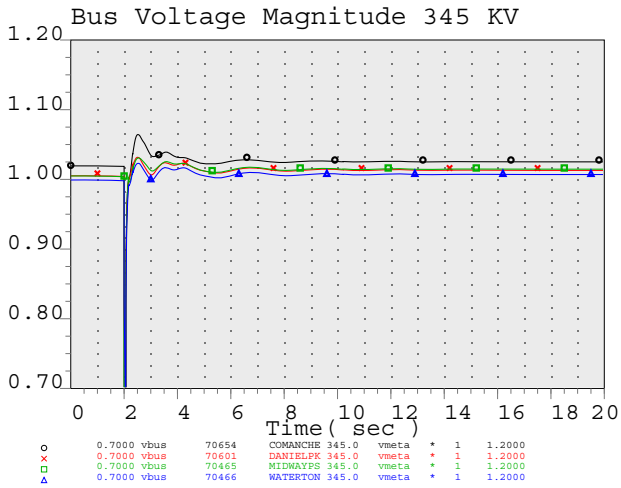


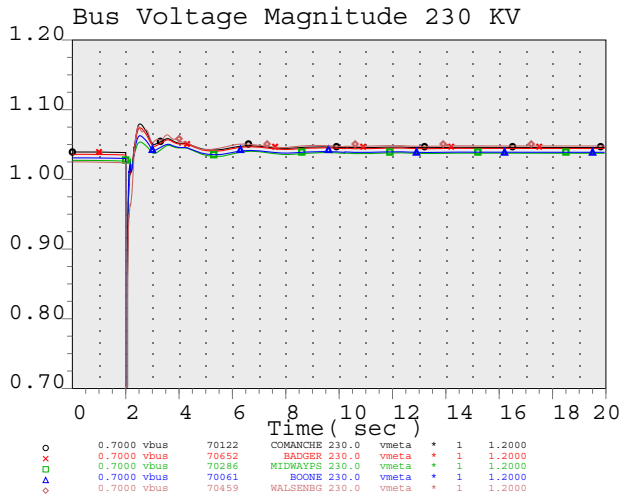


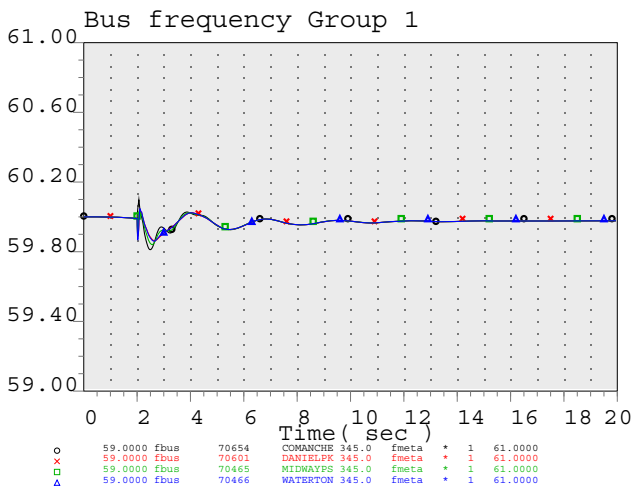


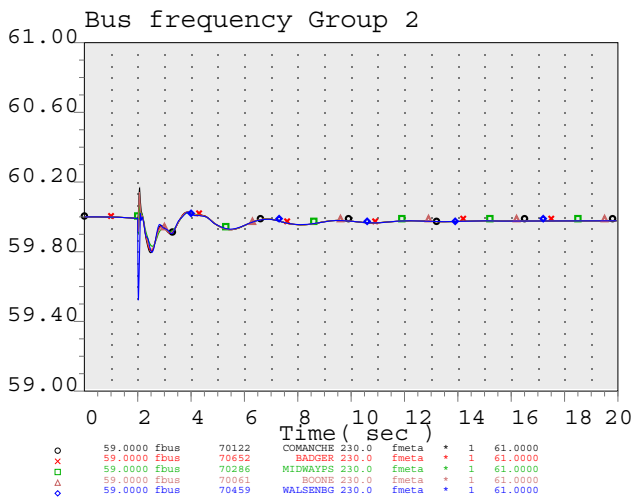


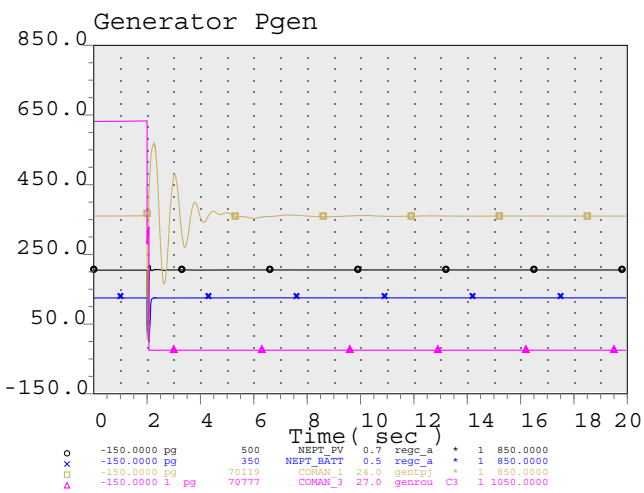
PI-2019-3
PV - 250 MW, BES - 75 MW

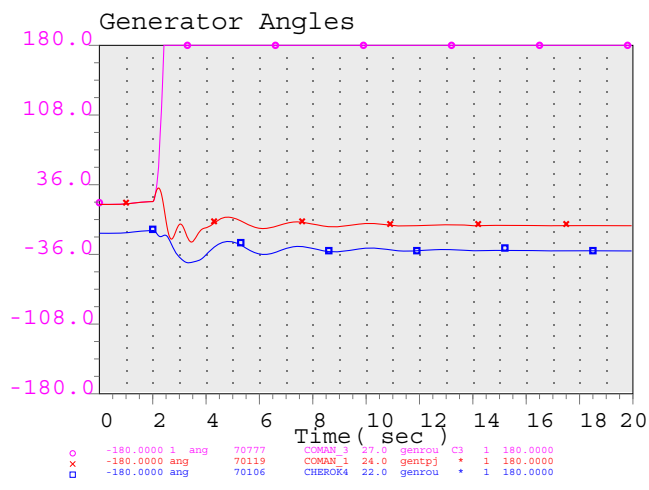






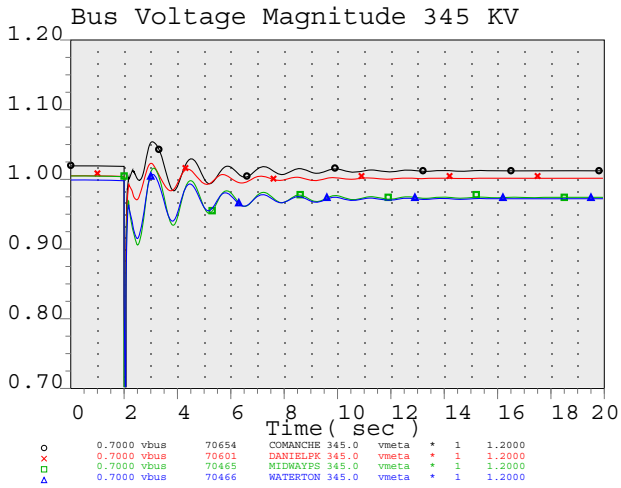


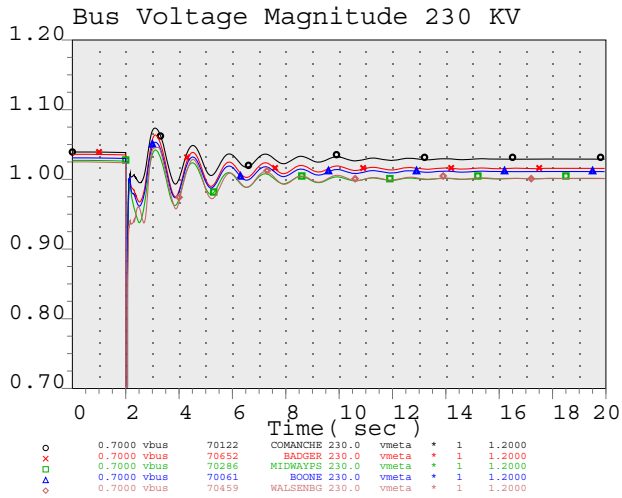


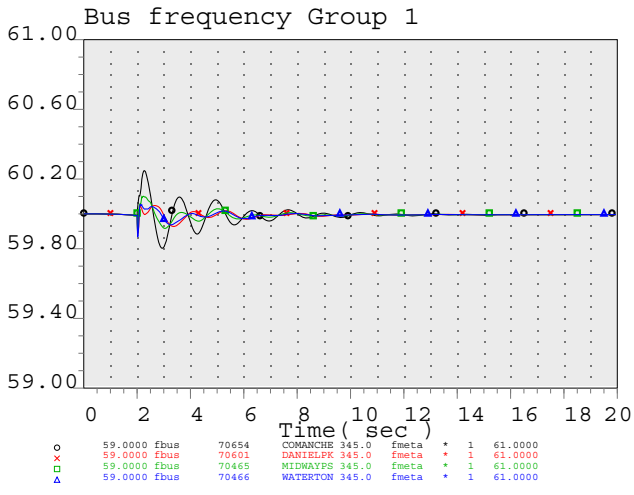


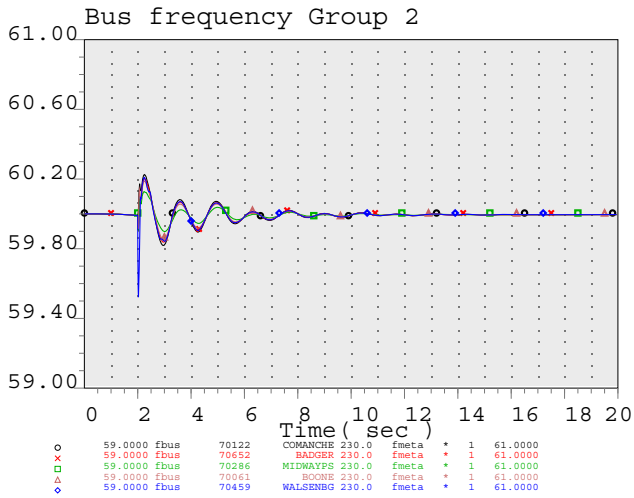
PI-2019-3
PV - 200 MW, BES - 125 MW

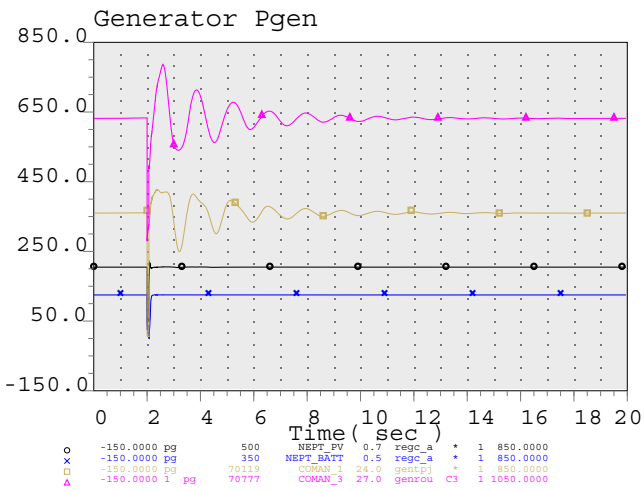
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: Comanche unit 3

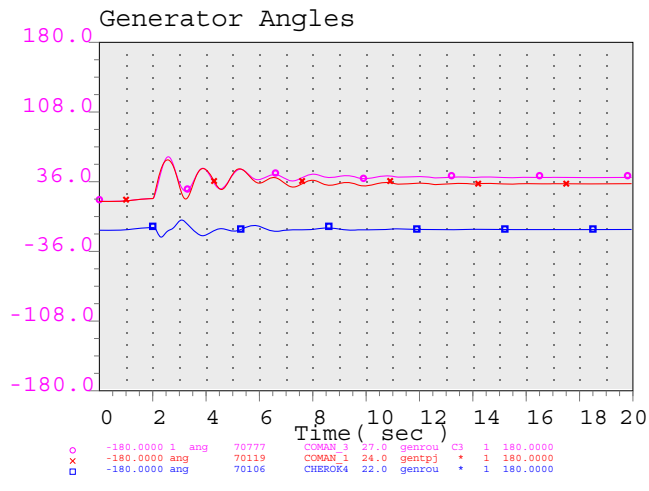






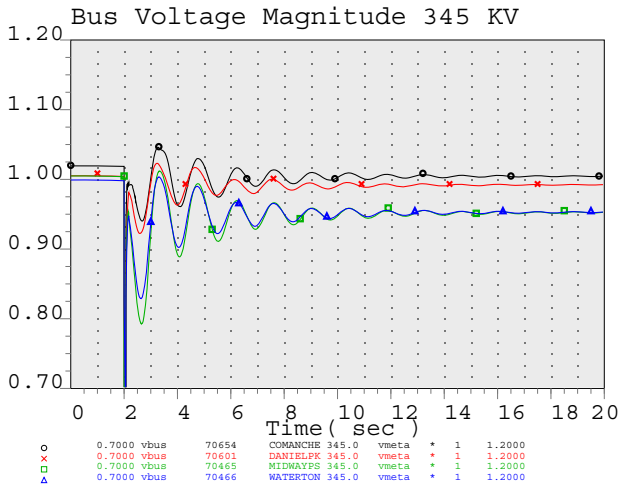


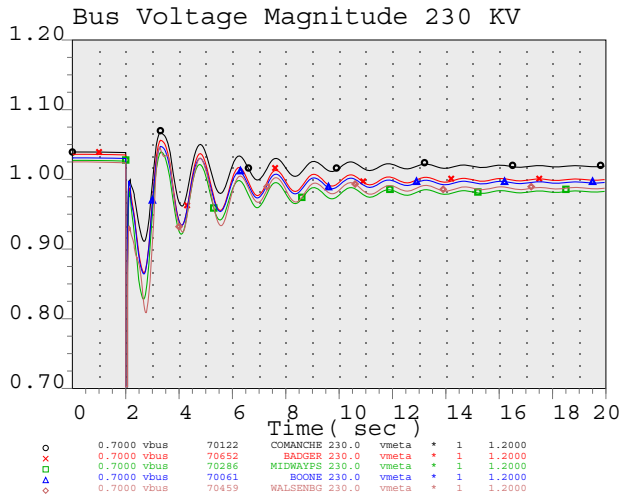


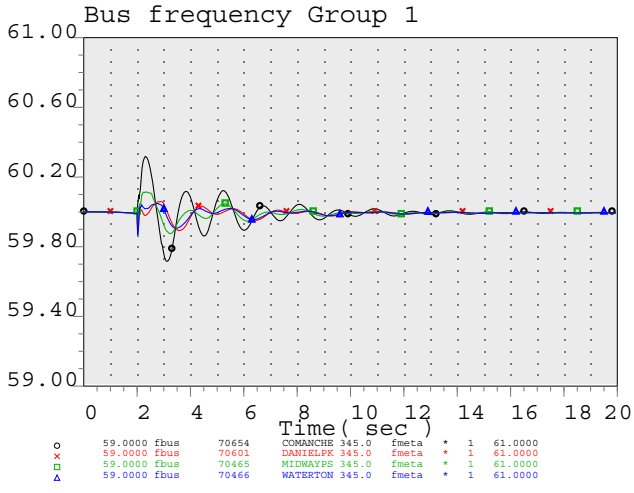


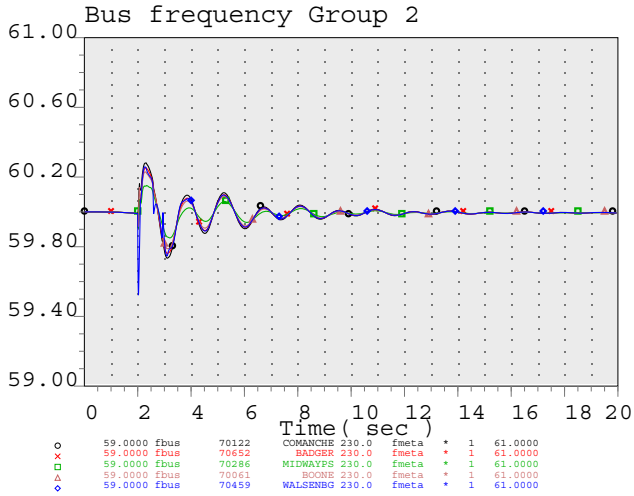
PI-2019-3
PV - 200 MW, BES - 125 MW

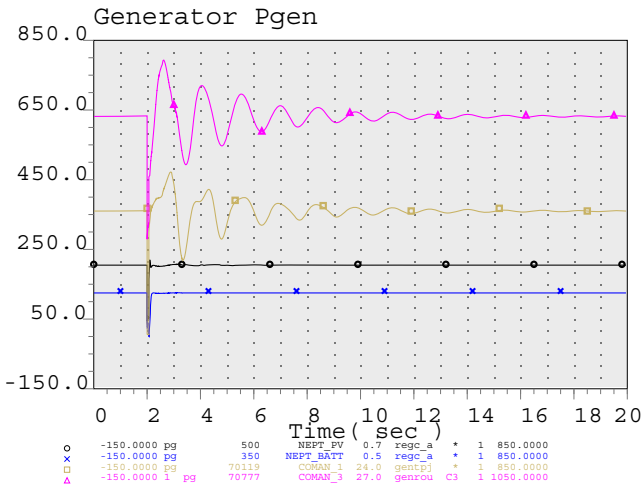
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: lose Comanche - Daniels Park 345 KV line #2 and
Comanche - PI-2019-3 POI 345 KV line

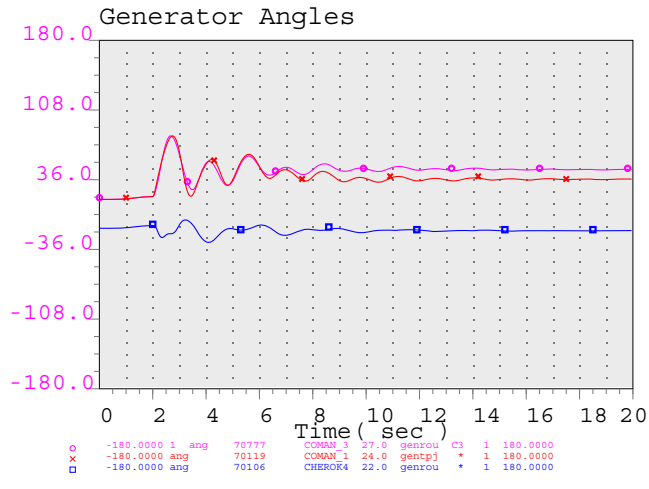






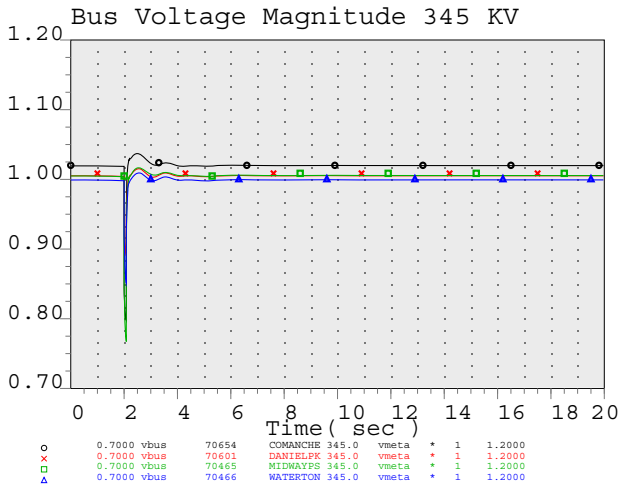


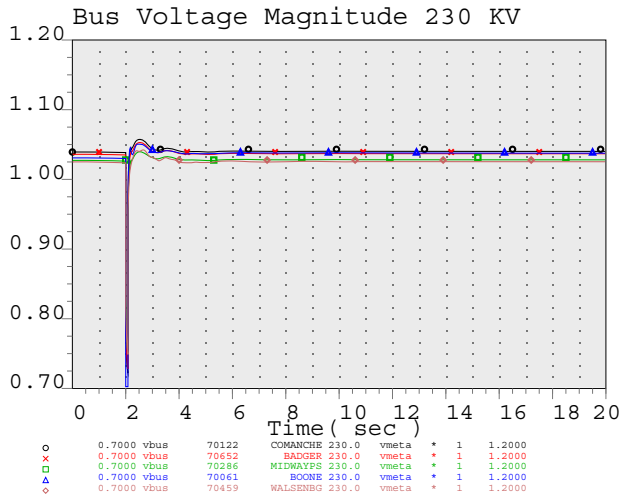


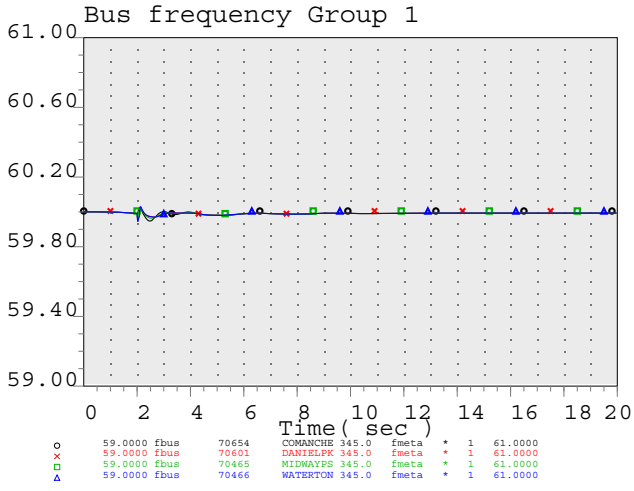


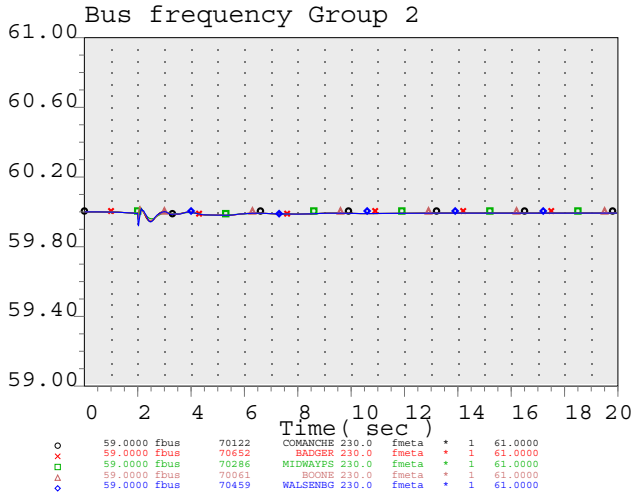
PI-2019-3
PV - 200 MW, BES - 125 MW

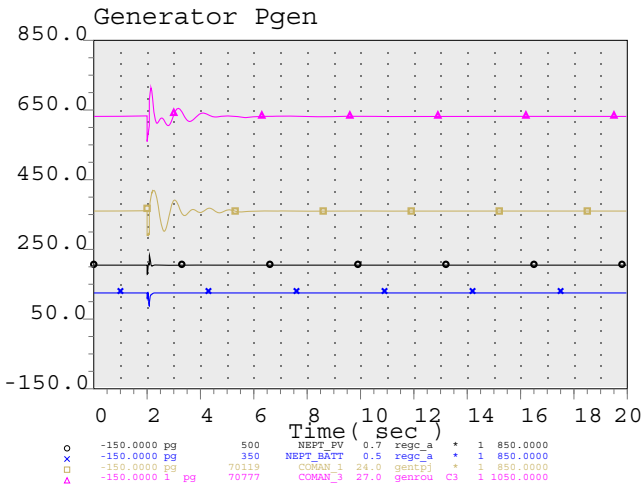
Fault: Comanche 345 KV 4 cycle 3-ph bus fault
Outage: lose Comanche - Daniels Park 345 KV line #2 and Daniels Park - PI-2019-3 POI 345 KV line

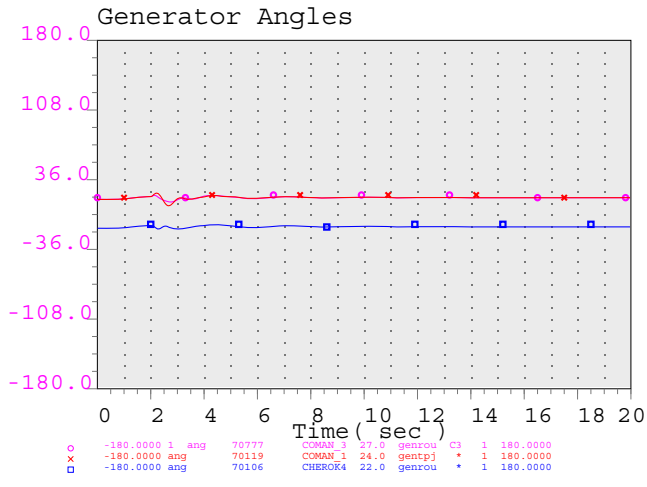






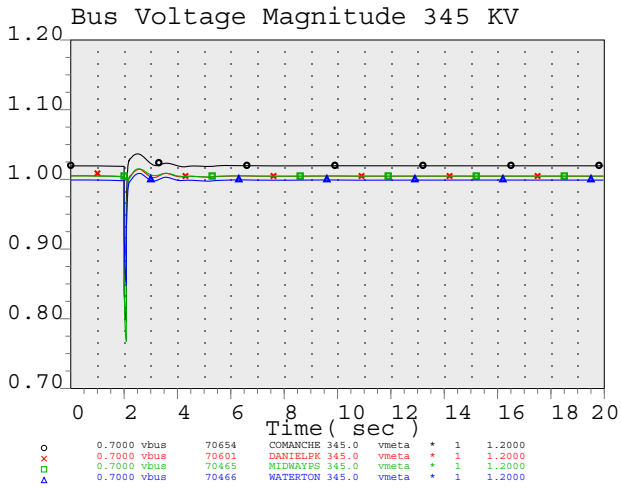


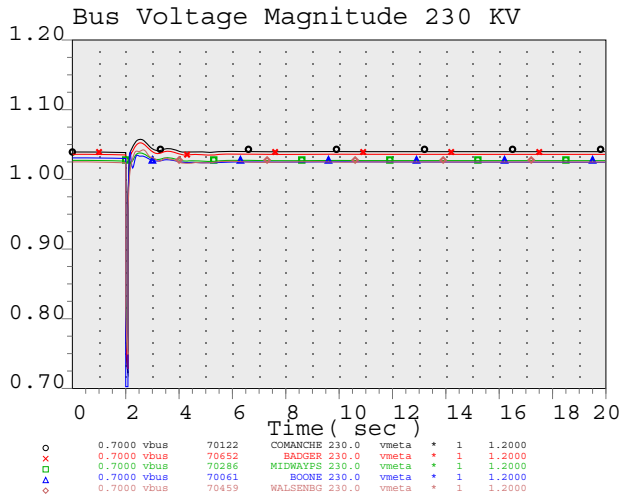


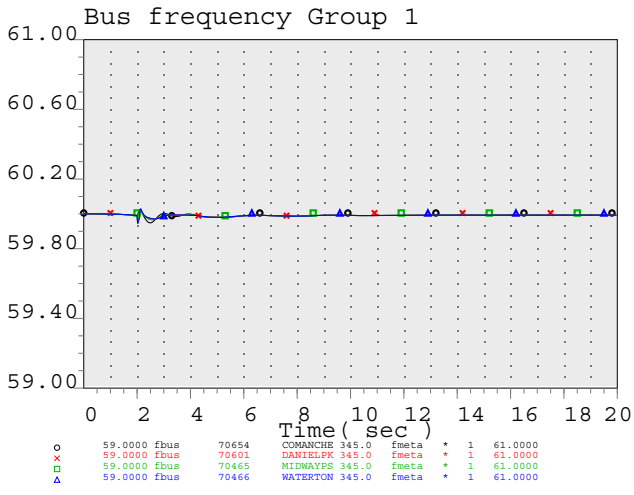


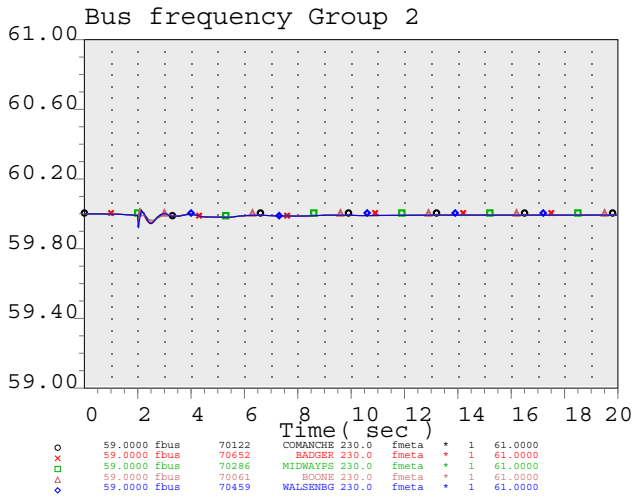
PI-2019-3
PV - 200 MW, BES - 125 MW

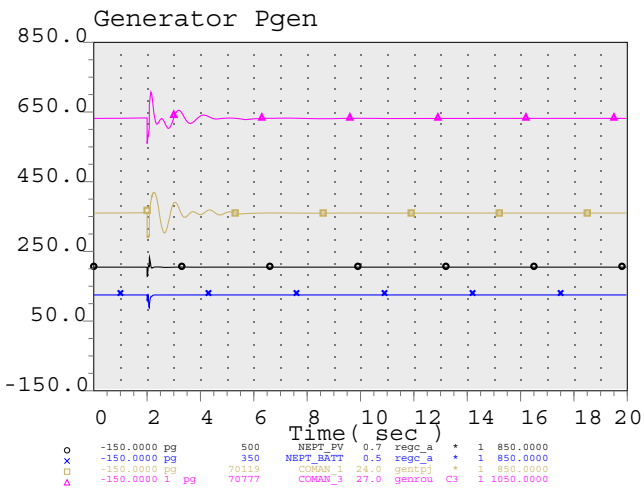
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone 230/115 KV bank

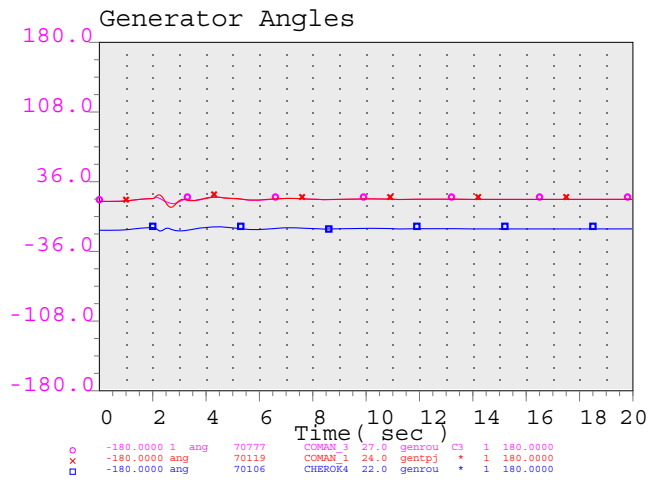




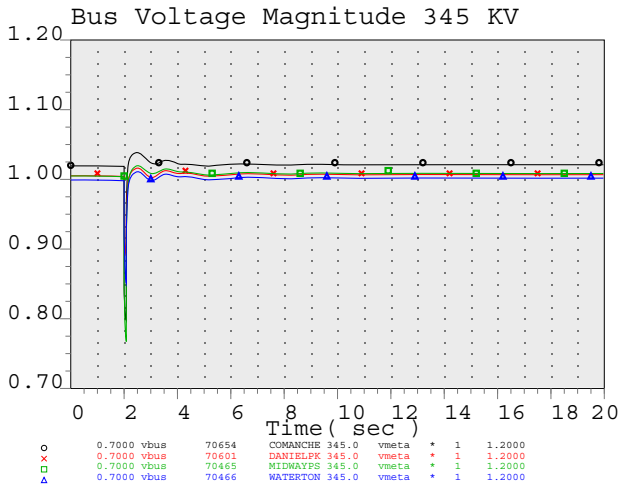


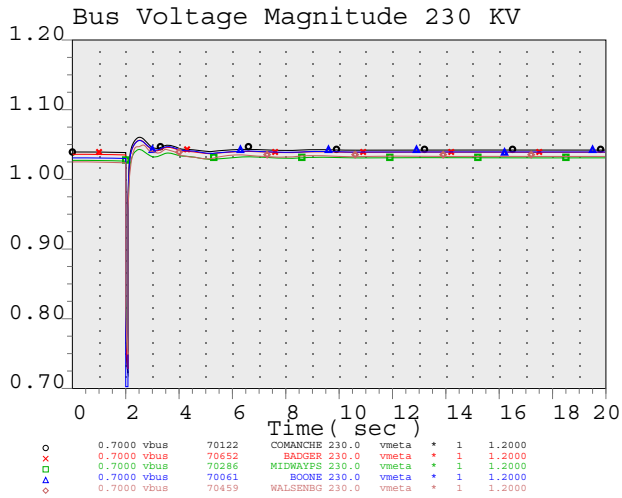


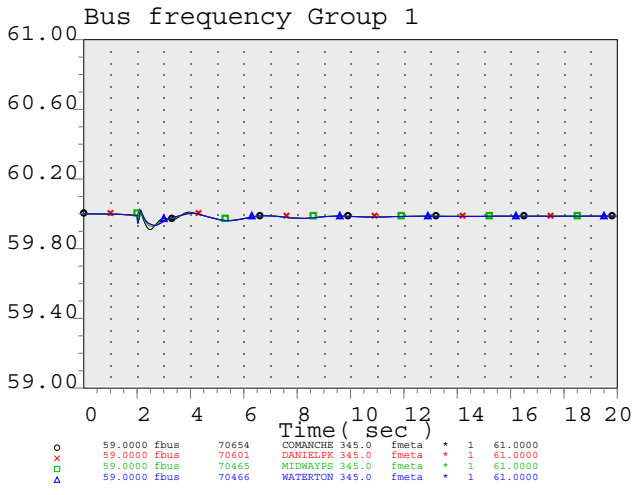


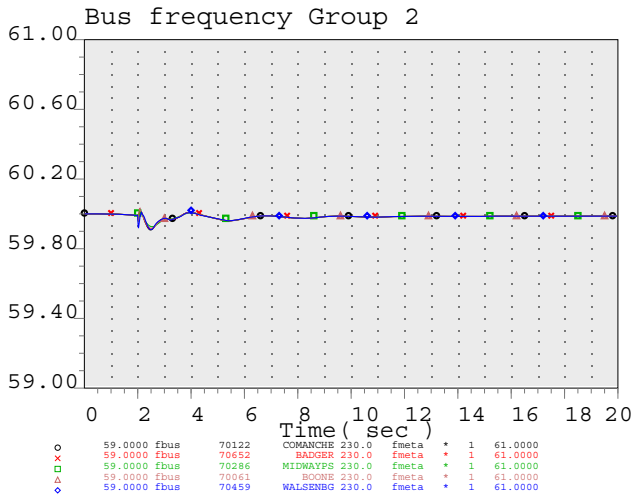


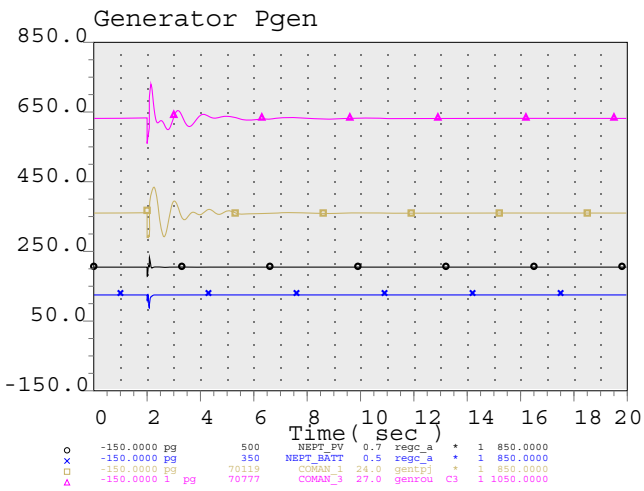
PI-2019-3
PV - 200 MW, BES - 125 MW

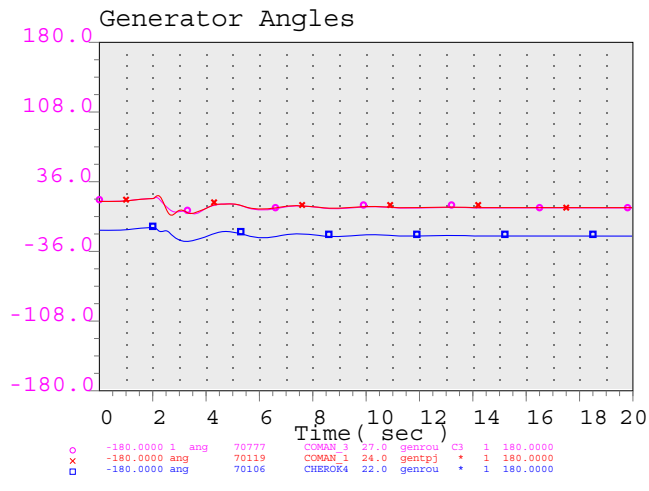




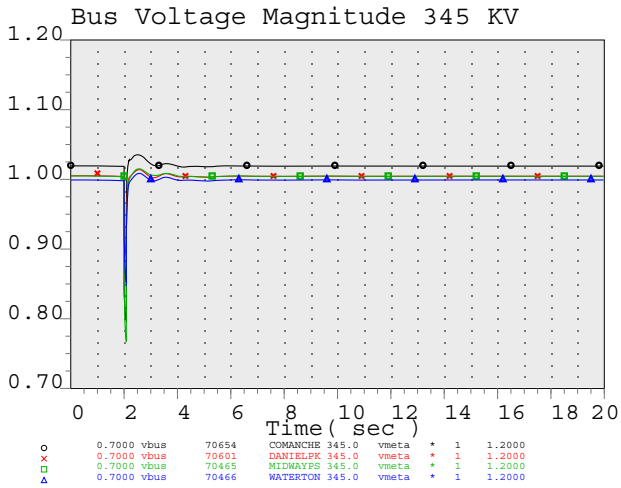


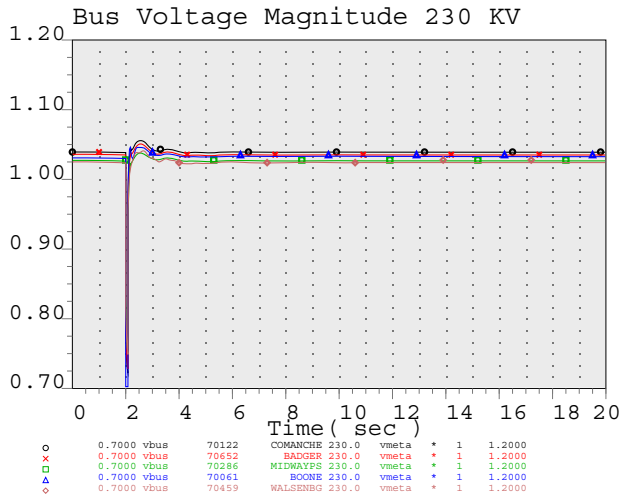


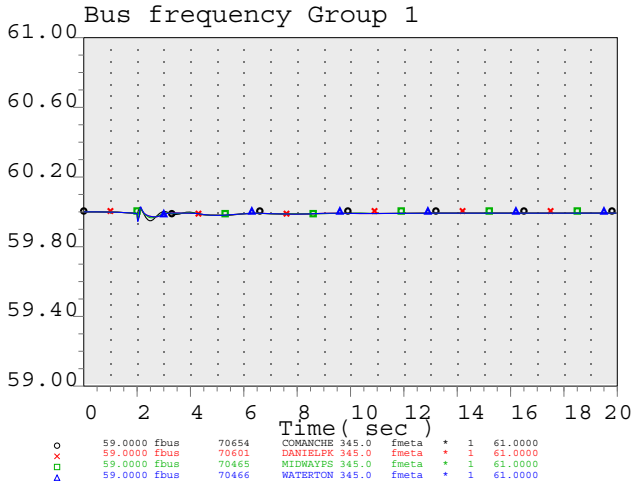


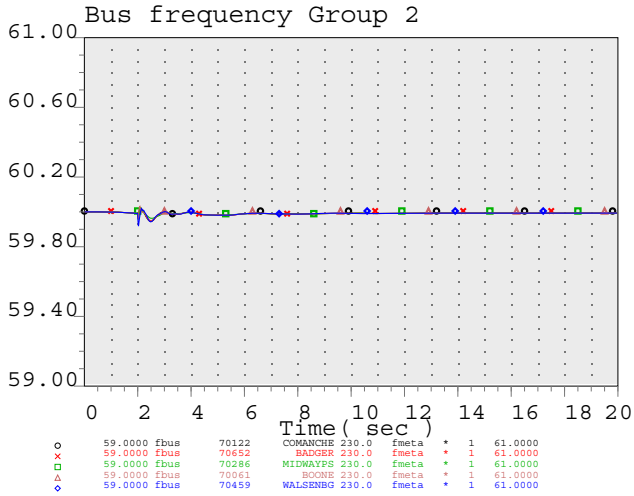


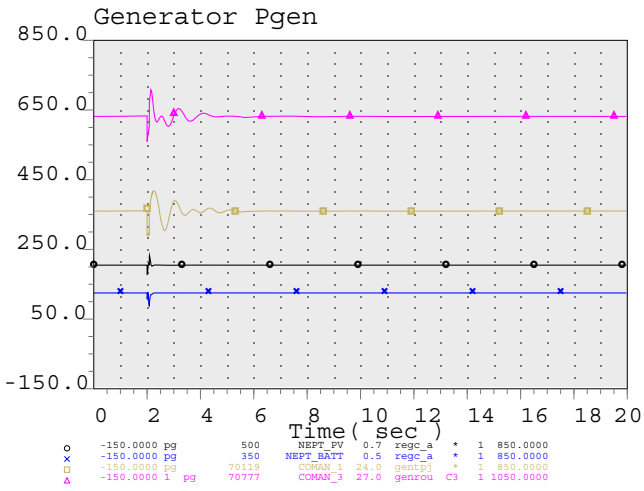
PI-2019-3
PV - 200 MW, BES - 125 MW

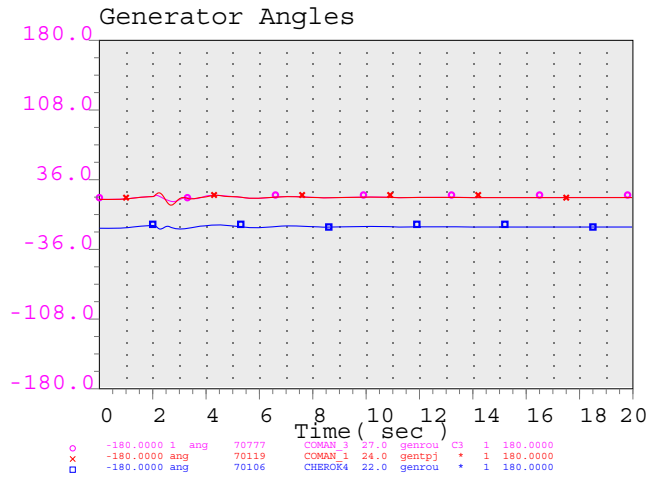






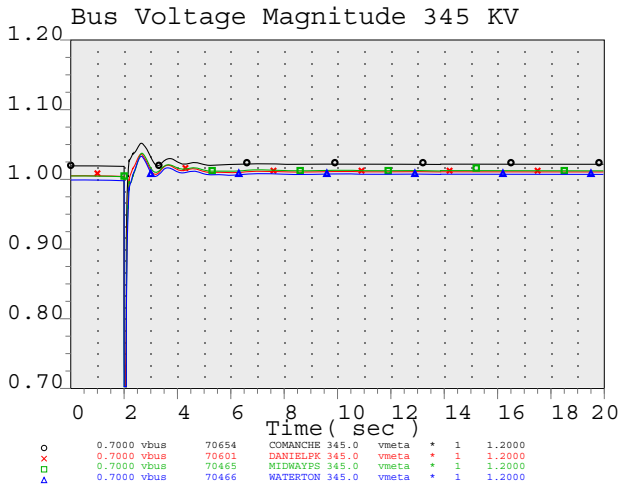


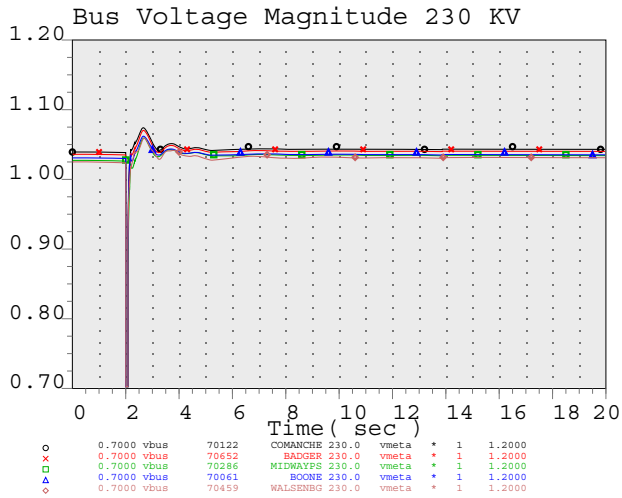


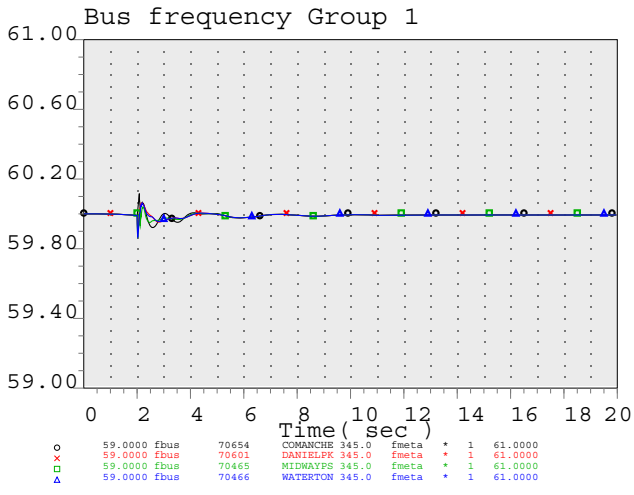


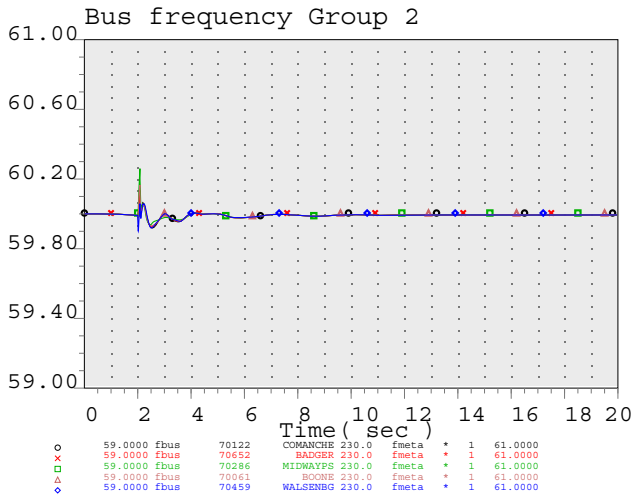
PI-2019-3
PV - 200 MW, BES - 125 MW

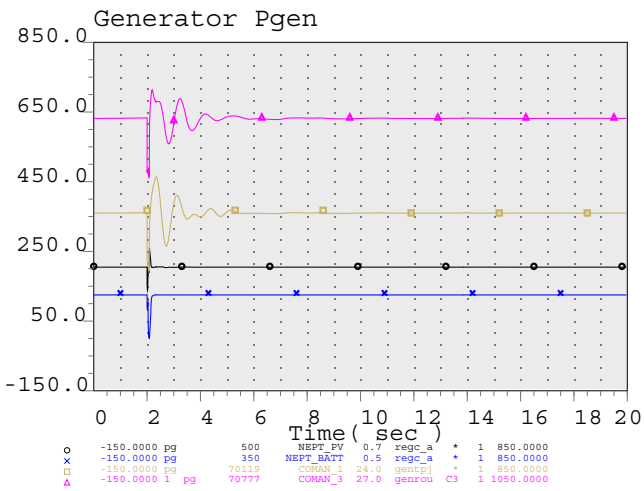
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Boone - Midway 230 KV line

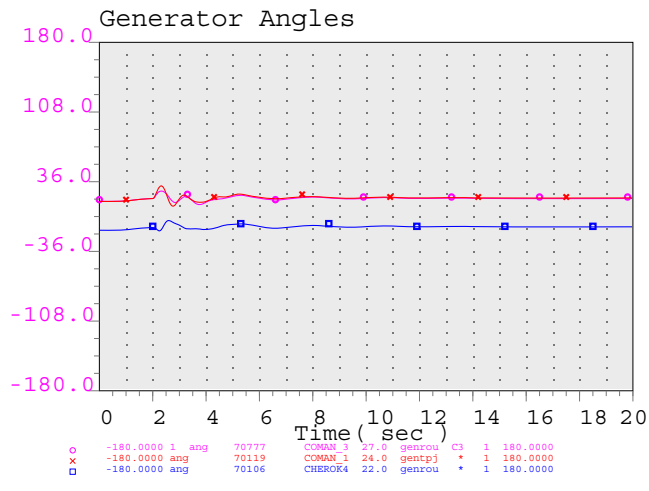






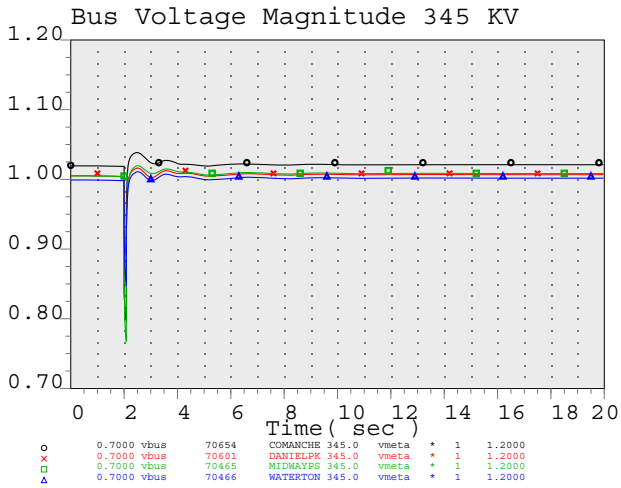


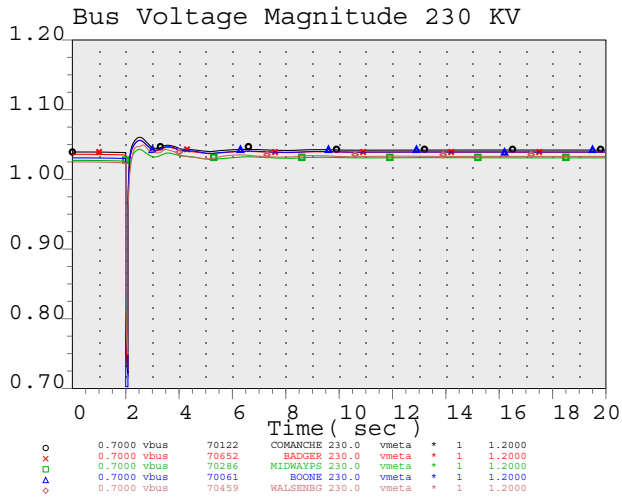


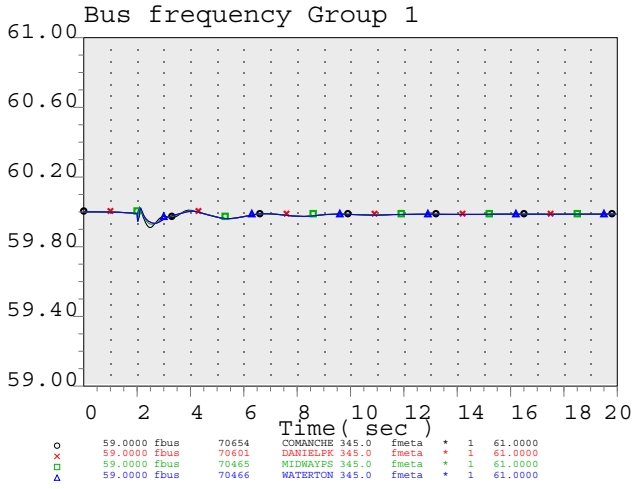


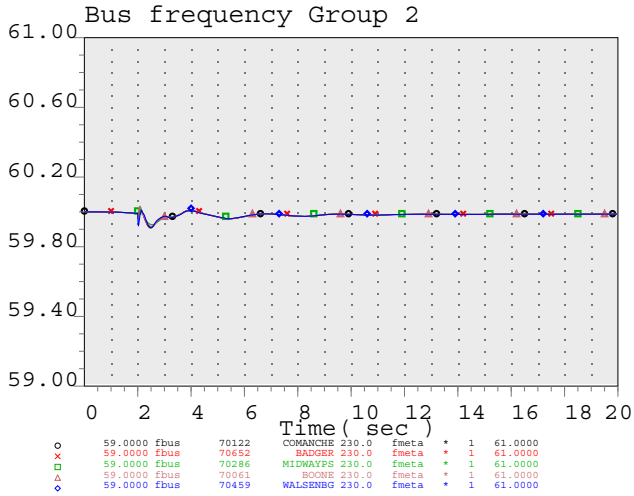
PI-2019-3
PV - 200 MW, BES - 125 MW

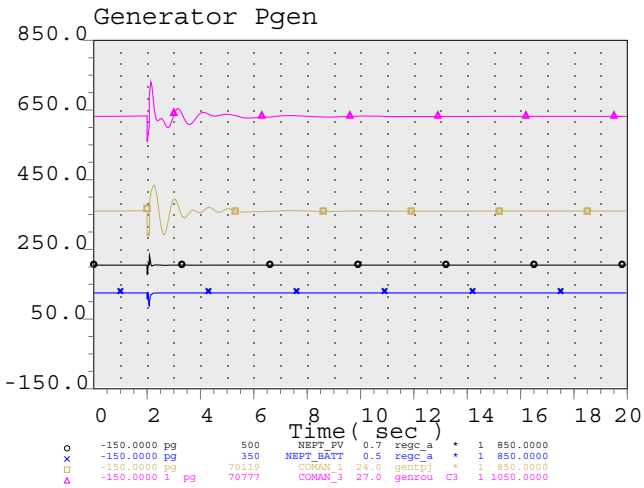
Fault: MIDWAYPS 345 KV 5 cycle 3-ph bus fault
Outage: lose Fountain Valley gen

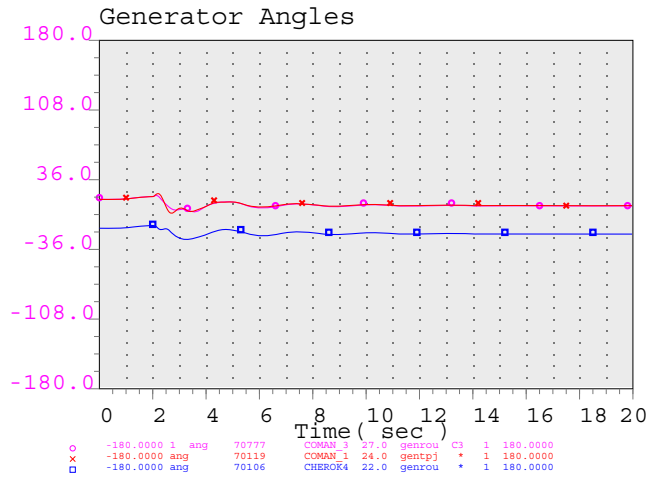






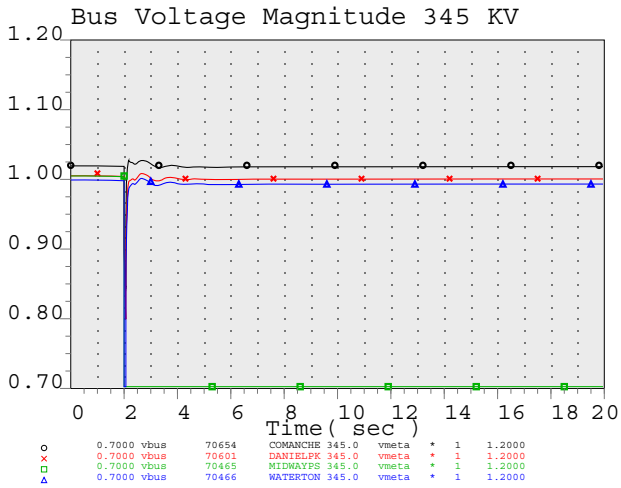


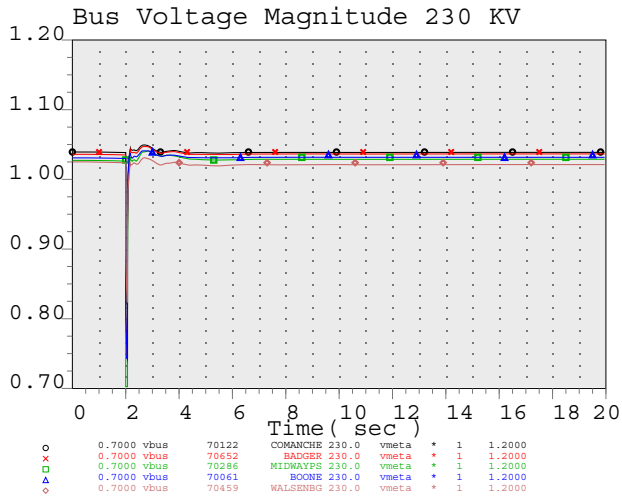


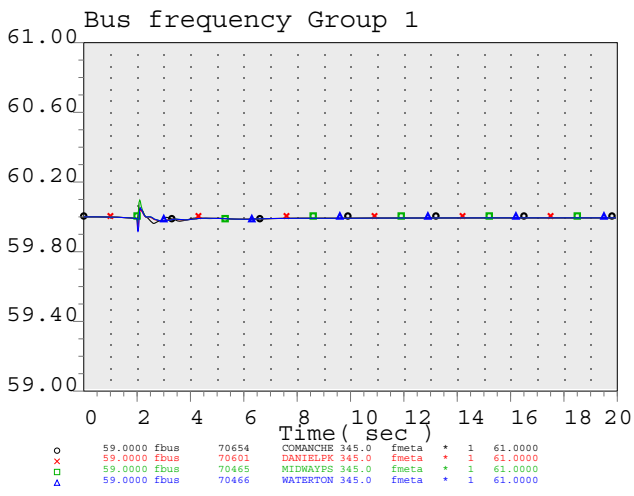


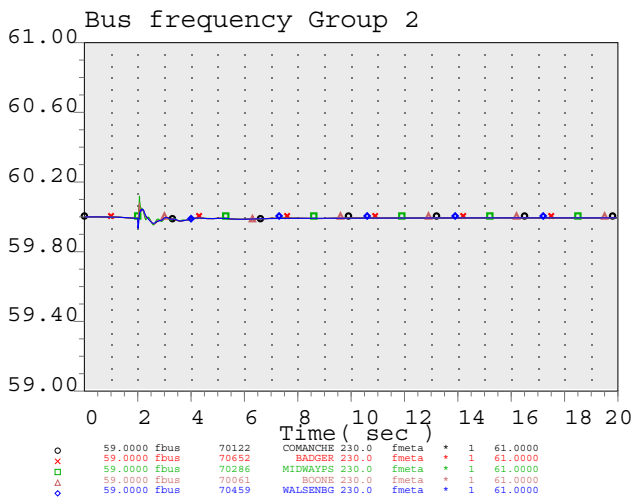
PI-2019-3
PV - 200 MW, BES - 125 MW

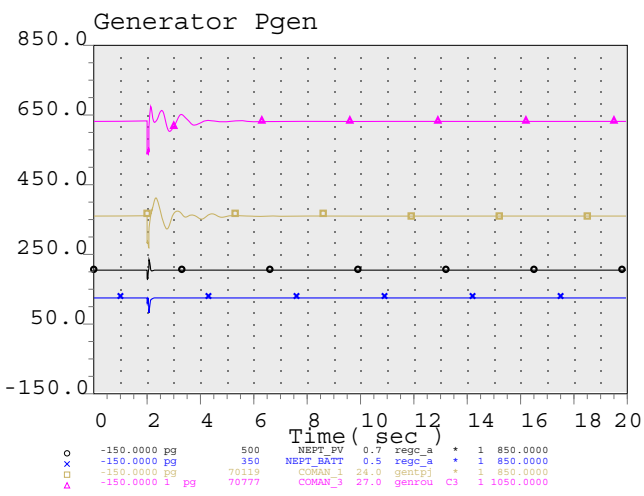
Fault: Boone 230 KV 5 cycle 3-ph bus fault
Outage: lose Lamar - Boone 230 KV line and Lamar gen

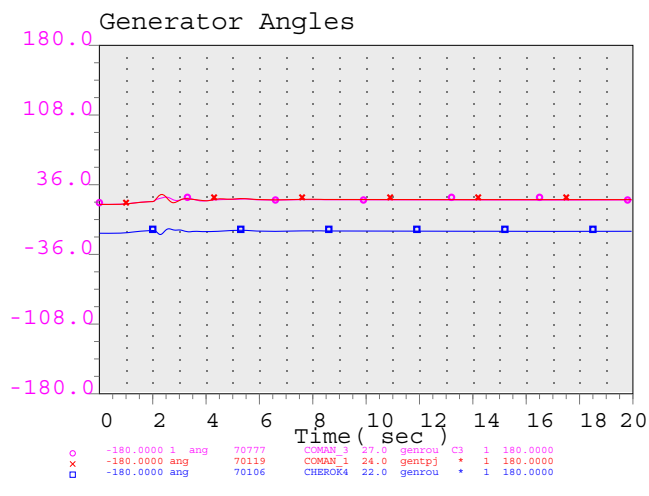












PI-2019-3
PV - 200 MW, BES - 125 MW

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