1RSC-2020 Phase 2 Study Report

11/16/2020

Table of Contents

1.0 Executive Summary 4

1.1 1RSC-2020-1 4

1.2 1RSC-2020-2 5

1.3 1RSC-2020-4 5

2.0 Introduction 6

3.0 Description of the GIRs 6

3.1 Description of 1RSC-2020-1 6

3.2 Description of 1RSC-2020-2 7

3.3 Description of 1RSC-2020-4 7

4.0 Study Scope 10

4.1 Study Pocket Determination 10

4.2 Study Criteria 10

4.2.1 Steady-State Criteria 11

4.2.2 Transient Stability Criteria 11

4.3 Study Methodology 12

4.3.1 Steady State Assessment Methodology 12

4.3.2 Transient Stability Study Methodology 13

4.3.3 Contingency Analysis Area 13

5.0 Base Case Modeling Assumptions 13

6.0 Generation Interconnection Service Analysis 13

6.1 Voltage and Reactive Power Capability Evaluation 13

6.2 Southern Colorado Study Pocket Analysis 14

6.2.1 Study Case Modeling 14

6.2.2 Steady State Analysis 14

6.2.3 Transient Stability Results 17

6.2.4 Short Circuit Analysis Results 18

6.2.5 Affected Systems 19
6.2.6 Summary of Analysis 19
6.3 Western Slope Study Pocket Analysis 19
6.3.1 Study Case Modeling 19
6.3.2 Steady State Analysis 20
6.3.3 Transient Stability Analysis Results 22
6.3.4 Short Circuit Analysis Results 23
6.3.5 Affected Systems 24
6.3.6 Summary of Analysis 24
7.0 Generation Interconnection Service Cost Estimates and Assumptions 24
7.1 Total Costs of Network Upgrades 24
7.2 Cost Estimates of Station and Other Network Upgrades by GIR 25
7.2.1 Summary of Transmission Provider's Interconnection Facilities and Network Upgrades Costs allocated to 1RSC-2020-1 25
7.2.2 Summary of Interconnection Facilities and Network Upgrades Costs allocated to 1RSC-2020-2 27
7.2.3 Summary of Interconnection Facilities and Network Upgrades Costs allocated to 1RSC-2020-4 28
8.0 Summary of Generation Interconnection Service Results 29
8.1 Cost Estimate Assumptions 30
8.2 1RSC-2020-1: 31
8.3 1RSC-2020-2: 31
8.4 1RSC-2020-4: 32
9.0 Contingent Facilities 32

1.0 Executive Summary

The 1RSC-2020 (RSC) includes three (3) Generation Interconnection Request (GIR)s: 1RSC-2020-1, 1RSC-2020-2 and 1RSC-2020-4.

1RSC-2020-1 is a 72MW$_{ac}$ net rated Solar Photovoltaic (PV) Generating Facility requesting Energy Resource Interconnection Service (ERIS). The Point of Interconnection (POI) is a tap on the Hartsel – Tarryall 230kV line.

The 1RSC-2020-2 is a 75MW$_{ac}$ increment in the output of GI-2018-24. The POI is same as GI-2018-24.

The 1RSC-2020-4 is a 53MW$_{ac}$ expansion of GI-2014-8. The 1RSC-2020-4 will use the same POI and gen-tie as GI-2014-8.

The 1RSC-2020-2 and 1RSC-2020-4 GIRs are ERIS requests, and are studied under the Southern Colorado study pocket. The studies are performed using the 2023HS Base Case and modeled heavy south to north flow on the Comanche – Midway – Jackson Fuller – Daniels Park transmission system.

The 1RSC-2020-1 is studied under the Western Slope study pocket analysis. The studies are performed using the 2023HS Base Case and modeled heavy TOT5 west-to-east flows.

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

1.1 1RSC-2020-1

The total estimated cost of the transmission system improvements for 1RSC-2020-1 is $19.499 Million (Tables 15a and 15b)

Energy Resource Interconnection Service of 1RSC-2020-1 is: 72MW (after required transmission system improvements in Table 15a and 15b)

A Certificate of Public Convenience & Necessity (CPCN) is needed for the construction of the 1RSC-2020-1 230kV Switching Station. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of 1RSC-2020-1.

1.2 1RSC-2020-2

The total estimated cost of the transmission system improvements for 1RSC-2020-2 is $0.05 Million (Tables 16a and 16b)

Energy Resource Interconnection Service of 1RSC-2020-2 is: 75MW (after required transmission system improvements in Table 16a and 16b)

The maximum combined output of GI-2018-24 and 1RSC-2020-2 at the POI shall not exceed 325MW at any time, which will be limited using the Plant Controller. The GIR output will also be monitored by PSCo operations. The construction of the Tundra 345kV Switching Station for GI-2018-24 will require a CPCN and 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 1RSC-2020-2

1.3 1RSC-2020-4

The total estimated cost of the transmission system improvements for 1RSC-2020-4 is $0.05 Million (Tables 17a and 17b)

Energy Resource Interconnection Service of 1RSC-2020-2 is: 53MW (after required transmission system improvements in Table 17a and 17b).

The ERIS assumes GI-2014-12 LGIA is withdrawn if 1RSC-2020-4 moves forward. Also, the combination of GI-2014-8 and 1RSC-2020-4 at the Boone 230kV POI shall not exceed 113MW.

The interconnection of 1RSC-2020-4 is dependent on the construction of GI-2014-8 and associated Interconnection Facilities and Network Upgrades identified in the GI-2014-8 LGIA.

2.0 Introduction

Public Service Company of Colorado (PSCo) studied three (3) GIRs in Phase 1 of the 1RSC-2020 (RSC) and all three GIRs moved to Phase 2 of the RSC. The total Interconnection Service requested in the RSC is 200MW. The GIRs in the RSC are identified by their queue numbers – 1RSC-2020-1, 1RSC-2020-2 and 1RSC-2020-4, and a summary of the GIRs is given in Table 1. As shown in Table 1, all the GIRs requested Energy Resource Interconnection Service (ERIS)[1].

Table 1 – Summary of GIRs in the RSC

Generation Interconnection Number	Current Cluster	Date of Valid Request	Capacity (MW)	Maximum MW Output-Summer	Maximum MW Output-Winter	Location (County/State)	Station or Transmission Line POI	Projected In-Service Date	Service Type
RESOURCE SOLICITATION CLUSTER #1 (1RSC-2020)									
1RSC-2020-01	1RSC-2020	2/21/2020	72	72	72	Park County, CO	Hartsel Substation	12/31/2022	ERIS
1RSC-2020-02	1RSC-2020	1/24/2020	75	75	75	Pueblo County, CO	Comanche-Daniels Park 345kV	12/1/2022	ERIS
1RSC-2020-03	1RSC-2020	1/24/2020	50	50	50	Pueblo County, CO	Badger Hill 230kV	12/1/2022	ERIS
1RSC-2020-04	1RSC-2020	3/2/2020	53	53	53	Pueblo County, CO	Boone 230kV Switchyard	7/31/2022	ERIS

3.0 Description of the GIRs

3.1 Description of 1RSC-2020-1

1RSC-2020-1 is a 72MW$_{ac}$ net rated Solar Photovoltaic (PV) Generating Facility that will be located in Park County, Colorado. The Solar PV Generating Facility will consist of twenty-three (23) TMEIC 3.36MW, ±0.95PF inverters, each with its own 630V/34.5kV, 3.7MVA, Z=8% pad-mounted step-up transformer. The 34.5kV collector system will connect to one (1) 63/80/100MVA, 34.5/230/13.8kV wye-wye-delta, Z=10% main step-up transformer which will connect to the PSCo transmission system via a 250 foot, 230kV transmission tie-line. The POI is a tap on PSCo's Hartsel – Tarryall 230kV line, at approximately mid length. The Generating Facility configuration also includes an 18Mvar capacitor bank on the 34.5kV bus.

[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

The tap position on the Tarryall – Hartsel 230kV line will require building a new switching station referred to as "1RSC-2020-1 230kV Switching Station" in this report.

The proposed Commercial Operation Date (COD) of 1RSC-2020-1 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 1RSC-2020-2

The 1RSC-2020-2 is a 75MW$_{ac}$ increment in the output of GI-2018-24 hybrid Generating Facility received in the Transitional Cluster. The combined output of 1RSC-2020-2 and GI-2018-24 at the POI will be 325MW$_{ac}$. The hybrid Generating Facility will have the same nameplate capacity as GI-2018-24 i.e., AC-coupled 250MW rated Solar PV generator and a 125MW rated Battery Energy Storage (BES) generator. The inverters, pad mount step-up transformer, 34.5kV collector system, gen-tie configuration and POI remain the same between 1RSC-2020-2 and GI-2018-24. But 1RSC-2020-2 changes the main step-up transformer configuration from one (1) 34.5/345/13.8kV, 255/340/425MVA Z=8.5% transformer to two (2) 34.5/345kV, 114/152/190MVA main step-up transformers.

The proposed COD of the 1RSC-2020-2 is same as GI-2018-24, i.e., December 31, 2022. The POI will be backfed for GI-2018-24, so a back-feed date is not applicable to 1RSC-2020-2.

The net output of GI-2018-24 and 1RSC-2020-2 will not exceed 325MW at any time, which will be limited using the Plant Power Controller. The PV and BES generating facilities will operate in back-feed voltage control mode.

3.3 Description of 1RSC-2020-4

The Interconnection Customer confirmed that 1RSC-2020-4 represents the same project as GI-2014-12 where the POI is changed to the Boone 230kV Substation. Also, the Interconnection Customer confirmed that 1RSC-2020-4 is to be considered as an expansion of the higher-queued GI-2014-8. Upon the execution of the 1RSC-2020-4 LGIA, the combination of GI-2014-8 and 1RSC-2020-4 will represent one 113MW Generating Facility at the Boone 230kV Substation.

The 1RSC-2020-4 is a 53MW$_{ac}$ net expansion of GI-2014-8 which is a 60MW$_{ac}$ Solar PV Generating Facility that will be located in Pueblo County, Colorado. The 1RSC-2020-2 shares the same POI as GI-2014-8, which is PSCo's Boone 230kV Substation.

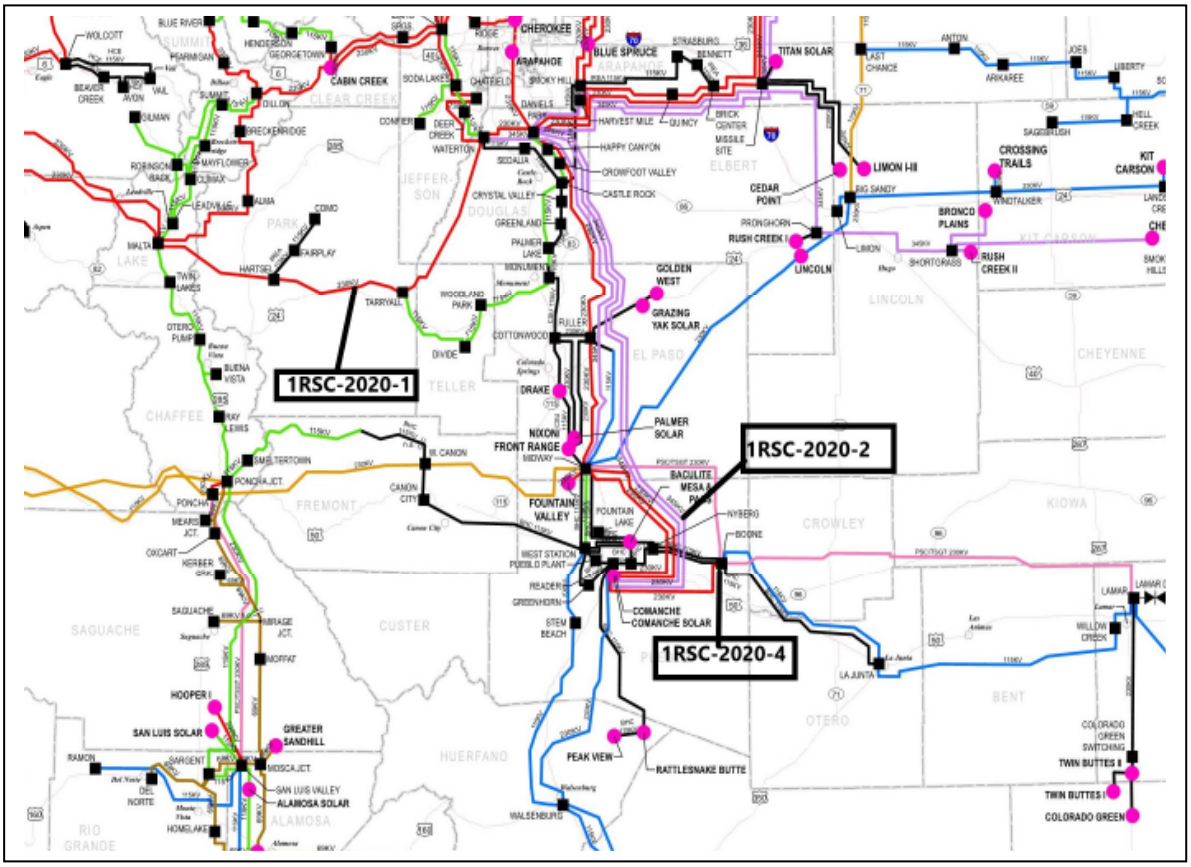
The total 113MW generating facility will consist of two sets of thirty-four (34) HEM FS3430M 3.37MW/3.55MVA, ±0.95PF inverters, each with its own 645V/34.5kV, 3.55MVA, Z=8.5% pad-mounted step-up transformer. The 34.5kV collector system will connect to one (1) 34.5/230/13.8kV, wye-wye-delta 133/174/218MVA, Z=8.0% main step-up transformer which will connect to PSCo's Boone 230kV Substation via a 0.3 mile, 230kV transmission tie-line. The Generating Facility configuration also includes a 20Mvar capacitor bank on the 34.5kV bus.

The proposed COD of the 1RSC-2020-4 is December 31, 2022. The POI will be backfed for GI-2014-8, so a back-feed date is not applicable to 1RSC-2020-4.

Note – The 1RSC-2020 was previously referred to as 2020 Spring Resource Solicitation Cluster during Phase 1 of the Definitive Interconnection System Impact Study process. The GIRs are labeled as RSC-2020-1, RSC-2020-2 and RSC-2020-4 previously. The naming convention for the Cluster and the GIRs is changed during Phase 2, but there were no changes to the GIRs. The Cluster is referred to as 1RSC-2020 instead of 2020 Spring Resource Solicitation Cluster. The GIRs are referred to as 1RSC-2020-1, 1RSC-2020-2 and 1RSC-2020-4 instead of RSC-2020-1, RSC-2020-2 and RSC-2020-4 respectively.

The approximate locations of the three GIRs in the RSC and the surrounding transmission system are shown in Figure 1 below.

Figure 1 – Approximate Locations of the POIs of the GIRs in the RSC



4.0 Study Scope

The purpose of the study is to determine the system impact of interconnecting all the three GIRs in the RSC for Interconnection Service, as requested in Table 1.

The scope of the study which is Phase 2 of the Definitive Interconnection System Impact Study (DISIS) process consists of:

a) An updated power flow/voltage analysis (if necessary),
b) stability analysis and short circuit analysis for the Interconnection Customers remaining in the Cluster.
c) Non-binding cost estimates for the Transmission Provider's Interconnection Facilities, Station Network Upgrades and Network Upgrades required to reliability interconnect the GIRs.
d) The report identifies total costs and each Interconnection Customer's estimated allocated costs.
e) The report also identifies the Contingent Facilities applicable to each GIR.

Since there were no system modeling changes since the Phase 1 report and all GIRs in the Phase 1 study moved to Phase 2, the steady state analysis is not updated. This report focused on items 'b' thru 'e' listed above.
The stability analysis is performed using the study criteria in Section 4.2.2 and study methodology in Section 4.3.2.
For 1RSC-2020-2 and 1RSC-2020-4, the analysis only evaluated the impacts due to the 75MW and 53MW incremental capacities respectively.

4.1 Study Pocket Determination

Similar to the evaluation done during Phase 1, 1RSC-2020-1 is in Western Colorado region and falls under the "Western Colorado" study pocket. 1RSC-2020-2 and 1RSC-2020-4 are in the Southern Colorado region and fall under the "Southern Colorado" study pocket.

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 for each study pocket analysis.

4.2.1 Steady-State Criteria

The steady state analysis criteria are as follows:

P0 - System Intact conditions:

Thermal Loading: <=100% 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 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 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.

4.3 Study Methodology

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.

For PSCo facilities, thermal violations include any facilities without a pre-existing thermal violation that (i) resulted in a thermal loading >100% in the Study Case after the Study Pocket GIR cluster addition and (ii) contributed to an incremental loading increase of 2% or more to the benchmark case loading.

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

The voltage violations include all new voltage violations in the PSCo system and Affected Party's system which resulted in a further variation of 0.1 per unit.

The study pocket thermal and voltage violations are attributed to individual GIRs in the study pocket by calculating their individual contributions using DFAX criteria.

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

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

If violations are identified, the study evaluates if a generation redispatch combination eliminates the violation by using the Optimum Power Flow (OPF) software tool. If generation redispatch is unable to eliminate the violation, upgrades will be required to provide the requested ERIS. The maximum allowed output without requiring additional Network Upgrades for the ERIS GIRs will be identified in subsequent phases of this study.

The OPF is run using the following generation dispatch assumptions:

1. All existing resources on the PSCo Transmission System are considered.
2. The Pmin of wind and solar generator's is 0MW.
3. The Pmin of conventional generation is as provided in the WECC models.

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 stability analysis is performed by running select single and multiple contingencies in the Study Pocket.

5.0 Base Case Modeling Assumptions

The 2023HS Base Case created for Phase 1 studies is used for Phase 2 as there were no system modeling changes expected. See Section 5.0 of the RSC Phase 1 report posted here for Base Case modeling details https://www.rmao.com/public/wtpp/Final_Studies/2020%20Spring%20Resource%20Solicitaion%20Cluster%20Phase%201%20study%20report.pdf.

6.0 Generation Interconnection Service Analysis

Similar to the Phase 1 report, the Interconnection Service for 1RSC-2020-1 is determined using the Western Colorado study pocket analysis. The 1RSC-2020-2 and the 1RSC-2020-4 are in the Southern Colorado study pocket, so the Interconnection Service for 1RSC-2020-2 and 1RSC-2020-4 is determined using the Southern Colorado study pocket analysis.

6.1 Voltage and Reactive Power Capability Evaluation

The Voltage and Reactive Power Capability of each GIR is evaluated in Phase 1 studies. Since there were no changes to the GIRs since Phase 1 studies, the reactive power evaluation is not re-studied. As shown in Phase 1 report, all three GIRs were able to meet ±0.95pf at the high side of the main step-up transformer while maintaining at least 0.95-1.05 p.u. voltage at the POI.

See Section 6.1 of the RSC Phase 1 report posted here for details https://www.rmao.com/public/wtpp/Final_Studies/2020%20Spring%20Resource%20Solicitaion%20Cluster%20Phase%201%20study%20report.pdf.

6.2 Southern Colorado Study Pocket Analysis

6.2.1 Study Case Modeling

The Southern Colorado Study Pocket Study Case created for Phase 1 studies is used for Phase 2 studies. As stated in the Section 6.2.2. of the Phase 1 report, the Study Case is created from the Benchmark Case by increasing the GI-2018-24 output to 325MW for 1RSC-2020-2 and modeling 1RSC-2020-4 at the Boone 230kV Substation using the GIR modeling data provided by the Interconnection Customer. The total 128MW output of the two GIRs is sunk to the PSCo Fort Saint Vrain Generation in the Northern Colorado. See Section 6.2.2 of the Phase 1 report for details.

https://www.rmao.com/public/wtpp/Final_Studies/2020%20Spring%20Resource%20Solicitaion%20Cluster%20Phase%201%20study%20report.pdf.

6.2.2 Steady State Analysis

As stated above, the Steady State Analysis results from Phase 1 of the DISIS are valid. The results of the analysis are summarized below.

Table 2 – Power Flow Analysis Results of Southern Colorado Study Pocket GIRs – Overloads identified in 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	Type of Overload	OPF Identified
				MVA Flow	% Line Loading	MVA Flow	% Line Loading				
Daniels Park – Prairie 1 230kV # 1	Line	PSCo	576	581.8	101.0%	603.1	104.7%	3.7%	Daniels Park – Prairie 3 230kV # 1	Beyond POI Sub	Yes
Daniels Park – Prairie 3 230kV # 1	Line	PSCo	576	576	100.0%	597.3	103.7%	3.7%	Daniels Park – Prairie 1 230kV # 1	Beyond POI Sub	Yes

MIDWAYPS 115/230 KV #1	Xfmr	PSCo	100	123.6	123.6%	127.9	127.9%	4.3%	DANIELPK – TUNDRA 345 kV line 2	Beyond POI Sub	Yes
Palmer Lake – Monument 115kV #1	Line	PSCo / CSU	108	120.3	111.4%	127.9	118.4%	7.0%	Daniels Park – Fuller 230kV Line # 1	Beyond POI Sub	Yes

For the stressed generation dispatch used, the addition of Southern Pocket GIRs (1RSC-2020-2 and 1RSC-2020-4) resulted in one new overload in the PSCo system and also increased the pre-existing overload on the CSU and PSCo lines.

Table 3 – Power Flow Analysis Results of Southern Colorado Study Pocket GIRs – Overloads identified in Multiple Contingencies

Overloaded Facility	Type	Owner	Facility Emergency Rating (MVA)	Facility Loading in Benchmark Case		Facility Loading in Study Case		% Change due to Study Pocket GIRs	Multiple Contingency Definition
				MVA Flow	% Line Loading	MVA Flow	% Line Loading		
Boone – Midway 230kV # 1	Line	PSCo	318.7	337.5	105.9%	368.1	115.5%	9.6%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Daniels Park – Fuller 230kV # 1	Line	PSCo	478	700.3	146.5%	736.6	154.1%	7.6%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Pueblo Plant – Reader 115kV # 1	Line	BHE	160	192.5	120.3%	200.6	125.4%	5.1%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
HydePark – Pueblo Plant 115kV # 1	Line	BHE	160	174.7	109.2%	183.0	114.4%	5.2%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Midway 230/115kV # 1	Xfmr	PSCo	100	177.5	177.5%	186.2	186.2%	8.7%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1

Midway – Comanche 230kV # 1	Line	PSCo	478	462.7	96.8%	488.0	102.1%	5.3%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Midway – Fuller 230kV # 1	Line	PSCo	382.4	463.9	121.3%	483.6	126.6%	5.3%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Midway – GI-2014-9 230kV # 2	Line	PSCo	478	473.7	99.1%	500.0	104.6%	5.5%	P7: Comanche – Daniels Park 345kV Line # 2 & Tundra – Daniels Park 345kV Line # 1
Black Forest Tap – Black Squirrel 115kV # 1	Line	TSGT	173	183.7	106.2%	192.5	111.3%	5.1%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Fuller 230/115kV # 1	Xfmr	TSGT	100	99.5	99.5%	103.0	103.0%	3.5%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Fuller 230/115kV # 2	Xfmr	TSGT	100	99.5	99.5%	103.0	103.0%	3.5%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Gresham – Black Forest Tap 115kV # 1	Line	TSGT	173	178.4	103.1%	186.8	108.0%	4.9%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
MidwayPS – MidwayBR 230kV # 2	Line	PSCo/ WAPA	576	644	111.8%	679.7	118.0%	6.2%	P7: Midway – Waterton 345kV Line #1 & Midway – Fuller 230kV Line # 1
Monument – Gresham 115kV # 1	Line	TSGT	145	174.1	120.1%	182.6	125.9%	5.8%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Palmer Lake – Monument 115kV # 1	Line	PSCo/ CSU	108	186.7	172.9%	197.6	183.0%	10.1%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Vollmer – Black Squirrel 115kV # 1	Line	TSGT	173	213.7	123.5%	222.5	128.6%	5.1%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
Vollmer – Fuller 115kV # 1	Line	TSGT	173	214.5	124%	223.5	129.2%	5.2%	P7: Midway – Waterton 345kV Line #1 & Daniels Park – Fuller 230kV Line # 1
West Canyon – Hogback 115kV # 1	Line	BHE	120	127.1	105.9%	134.2	111.8%	5.9%	P4: Midway – Fuller 230kV Breaker Failure
West Canyon 230/115kV # 1	Line	BHE	100	103.5	103.5%	111.2	111.2%	7.7%	P4: Midway – Fuller 230kV Breaker Failure

The multiple contingency analysis shows several new overloads and increases to existing and Study Case overloads after the addition of the Southern Colorado Pocket Cluster GIRs. PSCo is in the process of identifying system mitigations which may include automatic generation adjustments schemes for the PSCo multiple contingencies studies in Table 3 above. These future mitigations will address the existing and new overloads, GIRs in the Southern Colorado study pocket may become part of the mitigations and included in automatic generation adjustments.

The 1RSC-2020-2 and 1RSC-2020-4 are ERIS requests and the OPF identified redispatch scenarios for each of the overloads. Since all ERIS overloads were mitigated using redispatch, and no new Network Upgrades are identified, the full ERIS can be accommodated for all the GIRs as described below:

- ERIS of 1RSC-2020-2 is 75MW
- ERIS of 1RSC-2020-4 is 53MW

6.2.3 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

The results of the contingency analysis are shown in Table 8. The transient stability plots are shown in Appendix A-1 to this report.

Table 4 - Transient Stability Analysis Result – Southern Colorado Study Pocket

Stability Scenarios						
#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability
1	Boone 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Stable	Stable
2	Boone 230kV	3ph	Boone – Comanche 230kV	5.0	Stable	Stable
3	Boone 230kV	3ph	Boone – Midway 230kV	5.0	Stable	Stable
4	Comanche 345 kV	3ph	Comanche#3 generator	4.0	Stable	Stable
5	Lamar 230kV	3ph	Lamar – Boone 230kV line and all generation at Lamar	5.0	Stable	Stable
6	MidwayPS 230kV	3ph	All Fountain Valley gas units	5.0	Stable	Stable
7	MidwayPS 230kV	3ph	Lose MidwayPS-Fuller, Midway PS-Midway WA line, all Midway_WA 115kV and Midway_WA 230kV lines	5.0	Stable	Stable
8	MidwayPS 345kV	3ph	MidwayPS – Waterton 345kV line & Midway 230/345kV xfmr	4.0	Stable	Stable
9	Comanche 345kV	3ph	Comanche – Daniels Park 345kV line and Comanche – Tundra 345 kV line	4.0	Stable	Stable
10	Comanche 345kV	3ph	Comanche – Daniels Park 345kV line and Daniels Park – Tundra 345 kV line	4.0	Stable	Stable

6.2.4 Short Circuit Analysis Results

A breaker duty study on the PSCo transmission system did not identify any circuit breakers that became over-dutied"[2] 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 5 and 6. The analysis is performed for the entire Southern Colorado Cluster together and individual POI short circuit and Thevenin equivalent impedance values are reported separately.

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

Table 5 – Short Circuit Parameters at 1RSC-2020-2 POI, Tundra 345kV Switching Station

	Before the Southern Colorado Cluster addition	After Southern Colorado Cluster addition
Three Phase Current	8580A	8431A
Single Line to Ground Current	6702A	6657A
Positive Sequence Impedance	3.083+j23.072 ohms	1.970+j23.603 ohms
Negative Sequence Impedance	3.112+j23.073 ohms	1.999+j23.606 ohms
Zero Sequence Impedance	21.169+j39.353 ohms	21.200+j39.140 ohms

Table 6 – Short Circuit Parameters at 1RSC-2020-4 POI, Boone 230kV Substation

	Before the Southern Colorado Cluster addition	After Southern Colorado Cluster addition
Three Phase Current	10626A	10525A
Single Line to Ground Current	9639A	9407A
Positive Sequence Impedance	1.502+j7.212 ohms	1.328+j12.793 ohms
Negative Sequence Impedance	1.524+j7.224 ohms	1.352+j12.795 ohms
Zero Sequence Impedance	2.781+j16.642 ohms	2.948+j17.283 ohms

6.2.5 Affected Systems

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

6.2.6 Summary of Analysis

The maximum ERIS identified for 1RSC-2020-2 is 75MW

The maximum ERIS identified for 1RSC-2020-4 is 53MW

6.3 Western Slope Study Pocket Analysis

6.3.1 Study Case Modeling

The Western Slope Study Pocket Study Case created for Phase 1 studies is used for Phase 2 studies. As explained in the Phase 1 report, the Study Case is created from the Benchmark Case by modeling 1RSC-2020-1 on the Tarryall – Hartsel 230kV line using the GIR modeling data

provided by the Interconnection Customer. The 72MW output of the GIR is sunk to the PSCo Pawnee Generation in the Northern Colorado.

https://www.rmao.com/public/wtpp/Final_Studies/2020%20Spring%20Resource%20Solicitaion%20Cluster%20Phase%201%20study%20report.pdf.

6.3.2 Steady State Analysis

As stated above, the Steady State Analysis results from Phase 1 of the DISIS are valid. The results of the analysis are summarized in Table 7.

Table 7 – Power Flow Analysis Results of Western Slope Study Pocket GIRs – Overloads Identified in 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		
Cabin Creek 230/115 # T1	Xfmr	PSCo	54	57.4	106.3%	58.2	107.9%	1.5%	Cabin Creek – Dillon 230kV Line # 1
Henderson – Portal 115kV # 1	Line	PSCo	120	127.0	105.8%	128.7	107.3%	1.4%	Cabin Creek – Dillon 230kV Line # 1
Cabin Creek – IdahoSprings 230kV # 1	Line	PSCo	473	607.0	128.3%	615.4	130.1%	1.8%	Cabin Creek – Lookout 230kV Line # 1
Cabin Creek – Lookout 230kV # 1	Line	PSCo	478	603.7	126.3%	612.1	128.0%	1.8%	Cabin Creek – IdahoSprings 230kV # 1
Idaho Springs – Lookout 230kV # 1	Line	PSCo	473	586.5	124.0%	594.9	125.8%	1.8%	Cabin Creek – Lookout 230kV Line # 1
Tarryall 230/115kV # T1	xfmr	PSCo	100	91.5	91.5%	105.7	105.7%	14.2%	Tarryall – Waterton 230kV Line # 1

The addition of 1RSC-2020-1 caused several overloads on the PSCo system. The facility overloads impacted by the addition of 1RSC-2020-1 are as follows:

- Cabin Creek 230/115kV Transformer #T1 loading increased from 106.3% to 107.9% (PSCo facility)
- Henderson - Portal 115 KV line loading increased from 105.8% to 107.3% (PSCo facility)
- Cabin Creek - Idaho Springs 230 KV line loading increased from 128.3% to 130.1% (PSCo facility)
- Cabin Creek - Lookout 230 KV line loading increased from 126.3% to 128.0% (PSCo facility)
- Idaho Springs - Lookout 230 KV line loading increased from 124.0% to 125.8% (PSCo facility)
- Tarryall 230/115kV transformer loading increased from 91.5% to 105.7% (PSCo facility)

Table 8 describes the mitigation measures used to address contingency overloads in Table 7. The Cabin Creek – Georgetown 115kV line and Cabin Creek generation reduction are existing TOT5 operating practices that are used by the Path Manager, Western Area Power Administration, when it conducts TOT5 seasonal and planning studies to achieve 1680MW.

Table 8 – TOT5 Mitigation Measures to Address Criteria Violations

Monitored Facility (Line or Transformer)	NERC Single Contingency	Mitigation Measure
Cabin Creek 230/115kV Transformer #T1	Cabin Creek – Dillon 230kV Line	Open the Cabin Creek-Georgetown 115kV line (Existing TOT5 Operating Practice)
Henderson – Portal 115kV Line	Cabin Creek – Dillon 230kV Line	Open the Cabin Creek-Georgetown 115kV line (Existing TOT5 Operating Practice)
Cabin Creek – Idaho Springs 230kV Line	Cabin Creek – Lookout 230kV Line	Reduce Cabin Creek generation (Existing TOT5 Operating Practice)
Cabin Creek – Lookout 230kV Line	Cabin Creek – Idaho Springs 230kV Line	Reduce Cabin Creek generation (Existing TOT5 Operating Practice)
Idaho Springs – Lookout 230kV Line	Cabin Creek – Lookout 230kV Line	Reduce Cabin Creek generation (Existing TOT5 Operating Practice)
Tarryall 230/115kV Tansformer	Tarryall – Waterton 230kV Line	Re-Dispatch 1RSC-2020-1 to reduce the overload (Proposed TOT5 Operating Practice)

Note - The Cabin Creek-Dillon 230kV contingency overload in Phase 1 report is based on a reduced transmission line rating that is anticipated in 2020-2021 as a result of PSCo changing its line rating methodology. Per the latest change in study methodology, PSCo is not considering planned rating changes for studies. Based on the current rating of this line, the line overload does not exist.

The Tarryall 230/115kV transformer contingency overload occurs due to the combination of (i) very high TOT5 west-to-east flows (ii) 1RSC-2020-1 project at its maximum output (iii) outage of the Tarryall – Waterton 230kV line.

Similar to the existing Operating Practices developed for high west-to-east TOT5, re-dispatching the 1RSC-2020-1 output will be proposed as a new TOT5 operating practice, and therefore this study assumes 1RSC-2020-1 may be curtailed for an outage of the Tarryall – Waterton 230kV line. The 1RSC-2020-1 output may also be limited based on existing firm and non-firm capacity available on the system.

As the Western Slope study analysis models very high TOT5 flow, running multiple contingency analysis on such a stressed case may result in unrealistic overloads. Hence, only single contingency analysis is performed.

6.3.3 Transient Stability Analysis Results

The results of the transient stability analysis are given in Table 9. The following results were obtained for the disturbances analyzed:

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

The results of the contingency analysis are shown in Table 8. The transient stability plots are shown in Appendix A-2 to this report.

Table 9 - Transient Stability Analysis Result – Western Slope Study Pocket

Stability Scenarios						
#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Post-Fault Voltage Recovery	Angular Stability

1	Line-end fault at 1RSC-2020-1 230kV Switching Station on Tarryall - 1RSC-2020-1 230kV Switching Station line	3ph	1RSC-2020-1 230kV Switching Station – Tarryall 230kV line	5.0	Stable	Stable
2	Line-end fault at Hartsel on Hartsel - Malta 230kV line	3ph	Malta - Hartsel 230kV line	5.0	Stable	Stable
3	Line-end fault at Tarryall on Tarryall - Waterton 230kV line	3ph	Tarryall – Waterton 230kV line	5.0	Stable	Stable
4	Line-end fault at Malta on Alma - Malta 230kV line	3ph	Malta – Alma 230kV line	5.0	Stable	Stable
5	Line-end fault at Malta on Basalt - Malta 230kV line	3ph	Malta – Basalt 230kV line	5.0	Stable	Stable
6	Line-end fault at Malta on Hopkins - Malta 230kV line	3ph	Malta – Hopkins 230kV line	5.0	Stable	Stable
7	Line-end fault at Malta on Mt. Elbert - Malta 230kV line	3ph	Malta – Mt.Elbert 230kV line	5.0	Stable	Stable
8	Line-end fault at Hartsel on Hartsel - 1RSC-2020-1 230kV Switching Station line	3ph	Hartsel – 1RSC-2020-1 230kV switching Station 230kV line	5.0	Stable	Stable

6.3.4 Short Circuit 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 West Slope Study Pocket GIR – 1RSC-2020-1.

The short-circuit fault current values and Thevenin equivalent impedances the 1RSC-2020-1 POI, tap on the Tarryall – Hartsel 230kV line are shown in Table 10.

Table 10 – Short Circuit Parameters at 1RSC-2020-1 POI, tapping Tarryall – Hartsel 230kV line

	Before the Western Slope Cluster addition	**After the Western Slope Cluster addition**
Three Phase Current	5849A	6047A
Single Line to Ground Current	4684A	5214A
Positive Sequence Impedance	2.574+j22.561 ohms	2.564+j22.567 ohms
Negative Sequence Impedance	2.589+j22.565 ohms	2.579+j22.570 ohms

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

Zero Sequence Impedance	6.809+j39.079 ohms	5.234+j33.920 ohms

6.3.5 Affected Systems

There are no Affected Systems identified in the Western Slope study pocket analysis.

6.3.6 Summary of Analysis

The maximum ERIS identified for 1RSC-2020-1 is 72MW.

7.0 Generation Interconnection Service Cost Estimates and Assumptions

There are three types of costs identified in the study-

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

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

7.1 Total Costs of Network Upgrades

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

Table 11 – Total cost of Station Network Upgrades by POI

POI	Total Cost	GIRs Sharing the POI
1RSC-2020-1 230kV Switching Station	$18,174,000	1RSC-2020-1
Tundra Switching Station	0	1RSC-2020-2
Boone 230kV Substation	0	1RSC-2020-4

No other Network Upgrades were identified in this study.

7.2 Cost Estimates of Station and Other Network Upgrades by GIR

Table 12 – Allocation of 1RSC-2020-1 230kV 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 11)
1RSC-2020-1	72MW	100%	$18,174,000

Table 13 – 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 11)
1RSC-2020-2	75MW	100%	0

Table 14 – Allocation of Boone 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 11)
1RSC-2020-4	53MW	100%	0

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

The total cost of the required Upgrades for 1RSC-2020-1 to interconnect on PSCo's Tarryall – Hartsel 230kV line is **$19.499 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $1.325 Million**
- **The cost of Station Network Upgrades is $18.174 Million**

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

The list of improvements required to accommodate the interconnection of 1RSC-2020-1, the Customer's 72MW Solar PV Generating Facility are given in Tables 15a and 15b. A CPCN will be required to build the 1RSC-2020-1 230kV Switching Station to accommodate the interconnection. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and

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

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

Table 15a – 1RSC-2020-1 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
1RSC-2020-1 230kV Switching Station	Interconnect Customer to tap at the Hartsel-Tarryall switching station 230kV bus. The new equipment includes: • One 230kV dead end and one girder • Three 230kV arresters • One 230kV 2000A Switch • One set (of three) high side metering units • Fiber communication equipment • Station controls • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing.	$1.250
	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	**$1.325**
Time Frame	**Site, design, procure and construct**	**36 Months**

Table 15b – 1RSC-2020-1 Station Network Upgrades

Element	Description	Cost Est. (Millions)
1RSC-2020-1 230kV Switching Station	Install a new three position ring bus switching station on the 230kV Hartsel - Tarryall line. The new equipment includes: • Three 230kV 3000A circuit breakers • Nine 230kV 2000A disconnect switches (assume all switch stands will be installed) • Six 230kV CCVTs • Two Line Traps • Six 230kV Surge Arresters • Four Deadends / 2 DE Girder • One Electrical Equipment Enclosure	$15.782

	• Station controls and wiring • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures	
1RSC-2020-1 230kV Switching Station	Install required communications in the EEE at the new switching station	$0.588
PSCo's Hartsel 230kV Bus	Update primary line relaying on line to RSC 2020-1	$0.331
PSCo's Tarryall 230kV Bus	Update primary and secondary line relaying and associated breaker fail on line to RSC 2020-1	$0.616
1RSC-2020-1 230kV Switching Station	Terminate the transmission line into the new switching station	$0.637
	Siting and Land Rights support for substation site acquisition, permitting, and construction	$0.220
	Total Cost Estimate for Network Upgrades for Interconnection	**$18.174**
Time Frame	**Site, design, procure and construct**	**36 Months**

7.2.2 Summary of Interconnection Facilities and Network Upgrades Costs allocated to 1RSC-2020-2

The total cost of the required Upgrades for 1RSC-2020-2 to interconnect at the Tundra Switching Station is **$0.05 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $0.05 Million**
- **The cost of Station Network Upgrades is 0**

The list of improvements required to accommodate the interconnection of 1RSC-2020-2, the Customer's 75MW incremental output in GI-2018-24 hybrid Generating Facility output at the POI are given in Tables 16a and 16b. The work needed to interconnect 1RSC-2020-2 only includes testing of fibre, communication and relaying installed for GI-2018-24 to accommodate the incremental 75MW output. A CPCN will not be required to accommodate 1RSC-2020-2 interconnection, but a CPCN is required for the Tundra 345kV Switching Station construction as identified for GI-2018-24. The interconnection of 1RSC-2020-2 is dependent on the construction of the Tundra 345kV Switching Station.

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

Table 16a – 1RSC-2020-2 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
GI-2018-24's Tundra 345kV Switching Station	Interconnect 1RSC-2020-2 Generating Facility. The new equipment includes: • testing of communications, relays	$0.05
	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	**$0.05**
Time Frame	**Site, design, procure and construct**	**12 Months**

Table 16b – 1RSC-2020-2 Station Network Upgrades

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**

7.2.3 Summary of Interconnection Facilities and Network Upgrades Costs allocated to 1RSC-2020-4

The total cost of the required Upgrades for 1RSC-2020-4 to interconnect at the PSCo's existing Boone 230kV Substation is **$0.05 Million.**

- **The cost of Transmission Provider's Interconnection Facilities is $0.05 Million**
- **The cost of Station Network Upgrades is 0**

The list of improvements required to accommodate the interconnection of 1RSC-2020-4, the Customer's 53MW expansion of GI-2014-8 are given in Tables 17a and 17b. The work needed to interconnect 1RSC-2020-4 only includes testing of fibre, communication and relaying installed for

GI-2014-8 to accommodate the 53MW interconnection. A CPCN will not be required to accommodate 1RSC-2020-4 interconnection. The interconnection of 1RSC-2020-4 is dependent on the construction of the construction of GI-2014-8 and associated Interconnection Facilities and Network Upgrades identified in the GI-2014-8 LGIA.

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

Table 17a – 1RSC-2020-4 Transmission Provider's Interconnection Facilities

Element	Description	Cost Est. (Millions)
GI-2014-8 Boone POI	Interconnect 1RSC-2020-4 Generating Facility. The new equipment includes: • testing of communications, relays	$0.05
	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	**$0.05**
Time Frame	**Site, design, procure and construct**	**12 Months**

Table 17b – 1RSC-2020-4 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	**N/A**
Time Frame	**Site, design, procure and construct**	**N/A**

8.0 Summary of Generation Interconnection Service Results

This report is the Phase 2 study results, if there is a change in status of one or more higher-queued Interconnection Requests due to withdrawal from the queue, a restudy of the power flow analysis will be performed as needed during Phase 3 and study results and costs 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 cost estimates (with no accuracy) for Interconnection Facilities and Network/Infrastructure Upgrades required for the interconnection of the RSC 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.

- There is no accuracy for estimates.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The 1RSC-2020-1, 1RSC-2020-2 and 1RSC-2020-4 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 1RSC-2020-1:

The total estimated cost of the transmission system improvements for 1RSC-2020-1: $19.499 Million (Tables 15a and 15b)

Energy Resource Interconnection Service of 1RSC-2020-1 is: 72MW (after required transmission system improvements in Table 15a and 15b)

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

8.3 1RSC-2020-2:

The total estimated cost of the transmission system improvements for 1RSC-2020-2 are: $0.05 Million (Tables 16a and 16b)

Energy Resource Interconnection Service of 1RSC-2020-2 is: 75MW (after required transmission system improvements in Table 16a and 16b)

Note: the maximum combined output of GI-2018-24 and 1RSC-2020-2 shall not exceed 325MW at any time, which will be limited using the Plant Controller. The GIR output will also be monitored by PSCo operations. Additional monitoring and control requirements will be added to the LGIA to ensure the Interconnection Service amount is not exceeded. The construction of the Tundra 345kV Switching Station for GI-2018-24 will require a CPCN and the estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection facilities is approximately 36 months after authorization to proceed has been obtained. Any delays in obtaining the CPCN may delay the COD of 1RSC-2020-2.

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 3. 1RSC-2020-2 may become part of the mitigations and included in automatic generation adjustments.

8.4 1RSC-2020-4:

The total estimated cost of the transmission system improvements for 1RSC-2020-4 are: $0.05 Million (Tables 17a and 17b)

Energy Resource Interconnection Service of 1RSC-2020-4 is: 53MW (after required transmission system improvements in Table 17a and 17b).

The ERIS assumes GI-2014-12 LGIA is withdrawn if 1RSC-2020-4 moves forward. Also, the combination of GI-2014-8 and 1RSC-2020-4 at the Boone 230kV POI shall not exceed 113MW.

The interconnection of 1RSC-2020-4 is dependent on the construction of the construction of GI-2014-8 and associated Interconnection Facilities and Network Upgrades identified in the GI-2014-8 LGIA.

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 3. 1RSC-2020-4 may become part of the mitigations and included in automatic generation adjustments.

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 Resource Solicitation Cluster GIRs 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. 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 1RSC-2020-1 are as follows:

1. The following unbuilt transmission projects modeled in the Base Case
    - Gilman – Avon 115kV line – ISD 2022
2. Network Upgrades for Interconnection assigned to 1RSC-2020-1 (refer to Table 15a and 15b of this report)

The contingent facilities identified for 1RSC-2020-2 and 1RSC-2020-4 are as follows. See Table 18 for DFAX contribution of each GIR.

1. 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 Daniels Park – Prairie1 230kV line to 576MVA
    - TSGT's planned project to uprate the Fuller – Vollmer – Black Squirrel 115 kV line to 173 MVA
    - CSU's project to close Tesla - Cottonwood 34.5kV line and open the Kettle Creek – Tesla 34.5kV line
    - 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 Daniels 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
    - Fuller 230/115kV transformer project
    - BCHE's West Station - Pueblo West - North Penrose planned project
    - BCHE's Boone - South Fowler 115 kV planned project
2. Interconnection Facilities for each GIR identified in this report

    See Table 16a and 16b for Interconnection Facilities assigned to 1RSC-2020-2

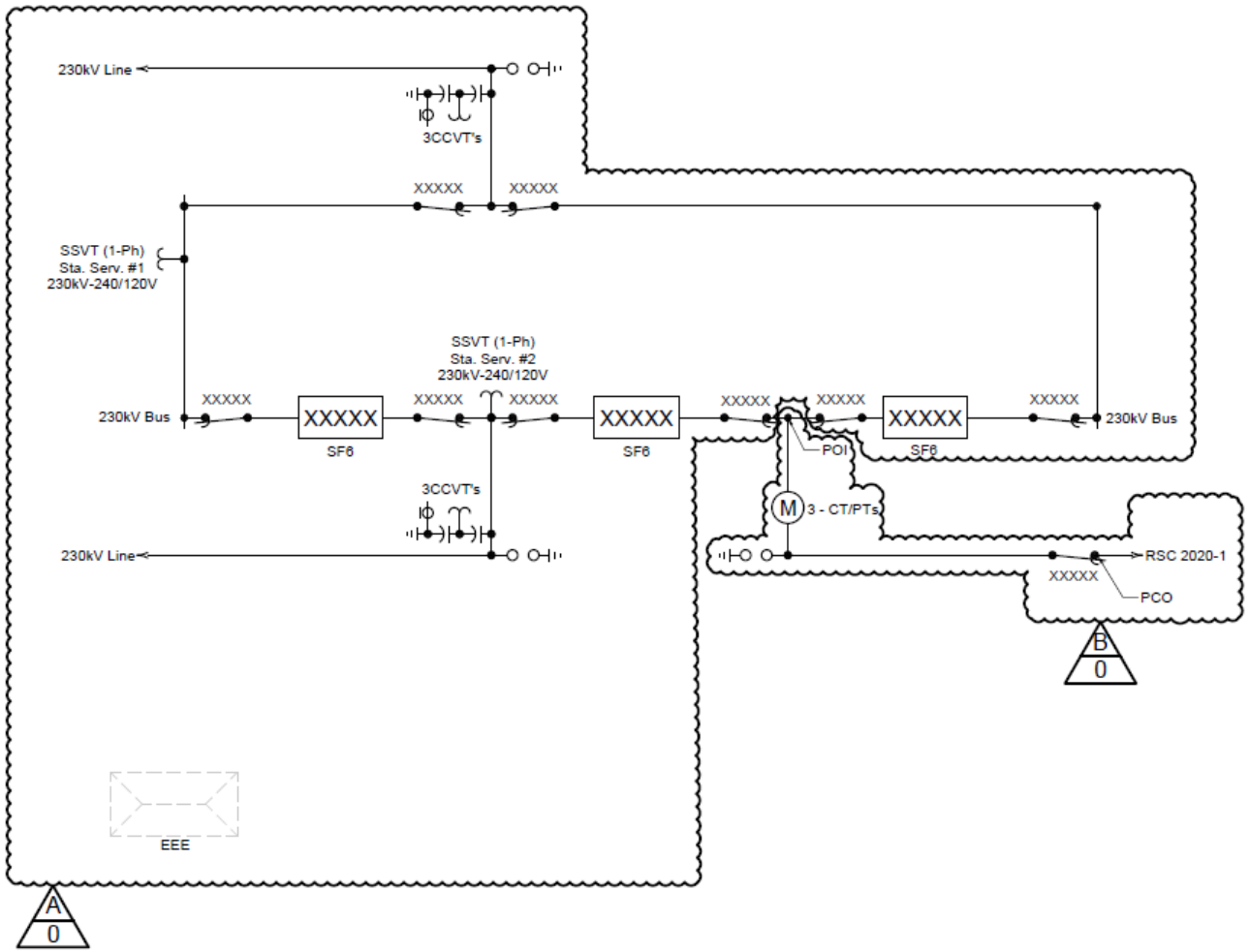
    See Table 17a and 17b for Interconnection Facilities assigned to 1RSC-2020-4
3. Upgrades identified for higher-queued GIRs
    - 1RSC-2020-2 is dependent on the interconnection of GI-2018-24
    - 1RSC-2020-4 is dependent on the interconnection of GI-2014-8

Table 18 DFAX Contribution of 1RSC-2020-2 and 1RSC-2020-4 to Contingent Facilities

Contingent Facility	DFAX for 1RSC-2020-2	DFAX for 1RSC-2020-4	Contingency
PSCo's Monument – Flying Horse 115kV Series Reactor project	0.0668	0.1008	Daniels Park -fuller 230 KV line (Overload on the Palmer-Monument 115kV line)
PSCo's terminal upgrade project to uprate the Daniels Park – Prairie3 230kV line to 576MVA	0.1761	0.1699	Daniels Park – Prairie1 230 KV line (Overload on Daniels Park – Prairie3 230kV line)
PSCo's terminal upgrade project to uprate the Daniels Park – Prairie1 230kV line to 576MVA	0.1761	0.1699	Daniels Park – Prairie3 230 KV line (Overload on Daniels Park – Prairie1 230kV line)
PSCo's upgrade project to uprate the MidwayPS – GI-2014-9 POI 230kV line to 478MVA	0.1403	0.0667	Daniels Park - Tundra 345 KV line (Overload on MidwayPS – GI-2014-9 230kV line)
TSGT's planned project to uprate the Fuller – Vollmer – Black Squirrel 115 kV line to 173 MVA	0.0408	0.0597	Daniels Park -Fuller 230 KV line (Overload on the Fuller – Vollmer – Black Squirrel 115kV line)
CSU's project to close Tesla - Cottonwood 34.5kV line and open the Kettle Creek – Tesla 34.5kV line	0.039	0.0583	Briargate S -Briargate N 115 KV line (Overload on CTTNWD N - KETTLECK S 115kV line)
PSCo's Upgrade Greenwood – Priarie1 230kV line to 576MVA – ISD 2021 478 to 576	0.1749	0.1688	Daniels Park – Prairie3 230 KV line (Overload on Greenwood – Prairie1 230kV line)
PSCo's Upgrade Greenwood – Priarie3 230kV line to 576MVA – ISD 2021 478 to 576	0.175	0.1688	Daniels Park – Prairie1 230 KV line (Overload on Greenwood – Prairie3 230kV line)
PSCo's Upgrade Dainels Park 345/230kV # T4 to 560MVA – ISD 2021 478 to 560	0.1372	0.0718	Daniels Park 230/345 KV transformer T3 (Overload on Daniels Park 345/230kV # T4)
Fuller 230/115kV, 100MVA #2 transformer – ISD 2023	0.0176	0.026	MidwayBR – Rancho 115 KV line (Overload on FULLER 230/115 kV transformer #1)
BCHE's West Station - Pueblo West - North Penrose planned project	0.0395	0.0393	Daniels Park - Tundra 345 KV line (Overload on MidwayPS 230/115 kV transformer)
BCHE's Boone - South Fowler 115 kV planned project	0.0254	0.0305	Boone - Lajuntaw 115 KV line (Overload on MidwayPS 230/115 kV transformer)

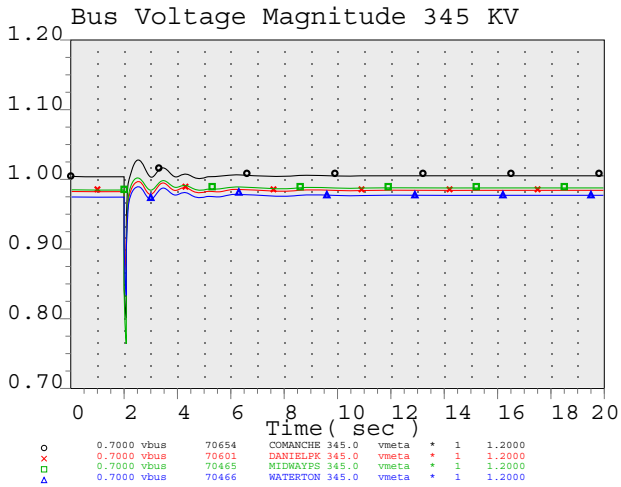
Briargate S 115/230kV transformer with the high end tapping the Cottonwood – Fuller 230kV line – ISD 2023	0.0139	0.0209	Cottonwood N – Kettleck S 115kV line (Overload on Briargate S – Cottonwood S 115kV line)

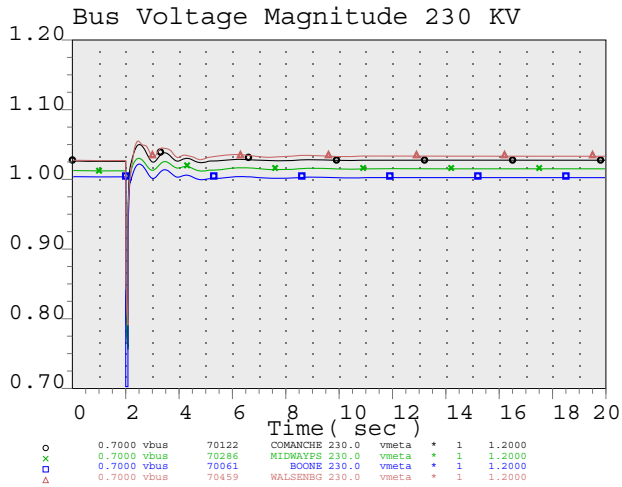
Figure 2 – Preliminary One-line of the 1RSC-2020-1 POI at the 1RSC-2020-1 230kV Switching Station

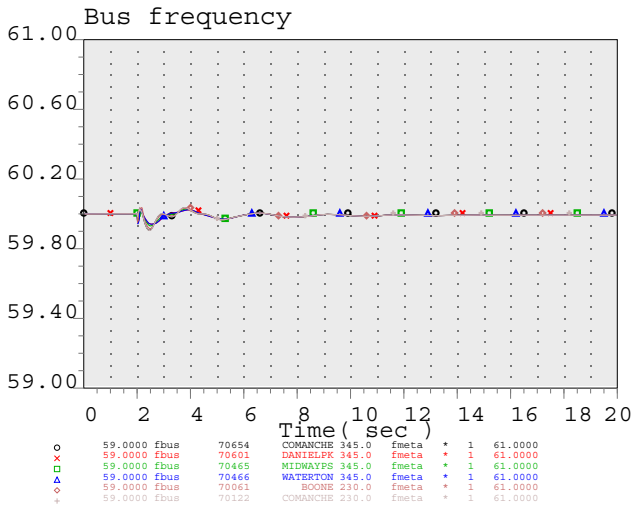


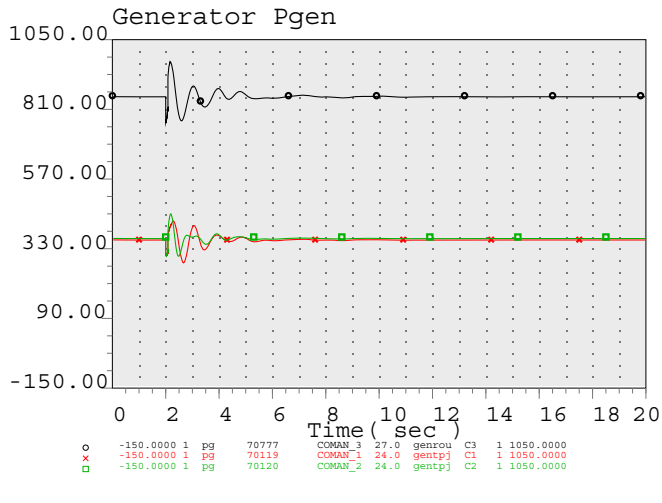
Appendix A-1

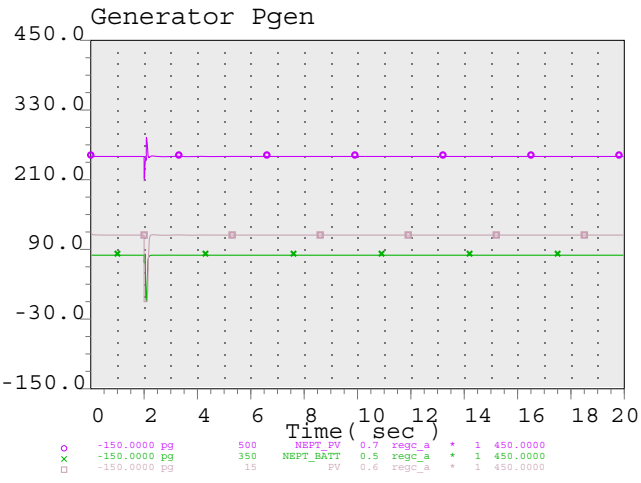
Transient Stability Plots – Southern Colorado Study Pocket

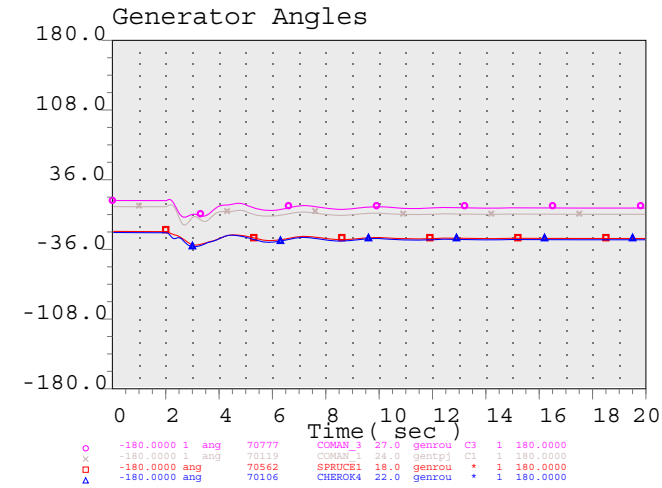




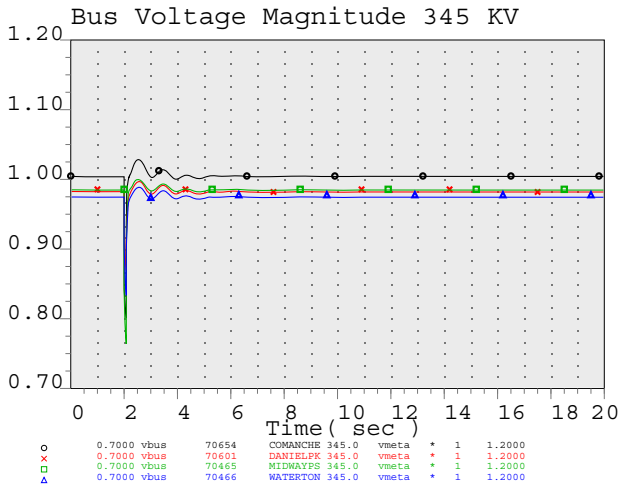


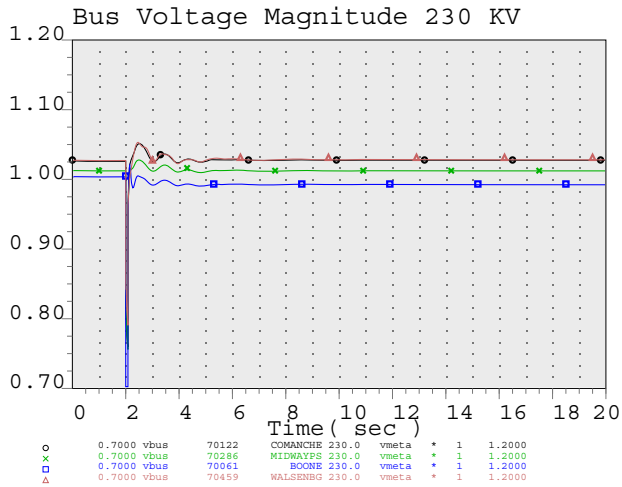


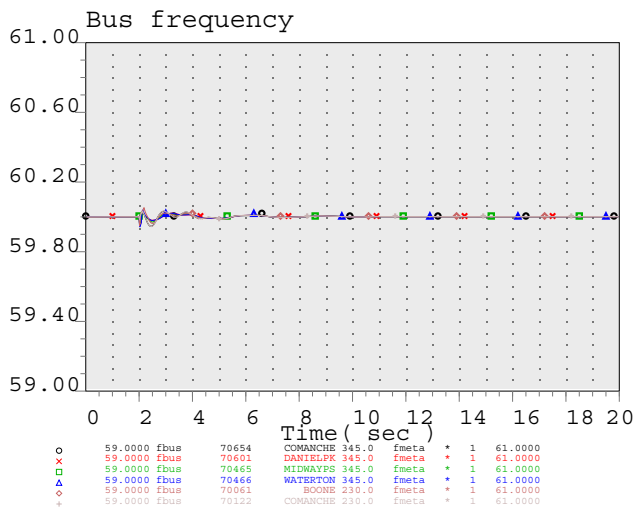


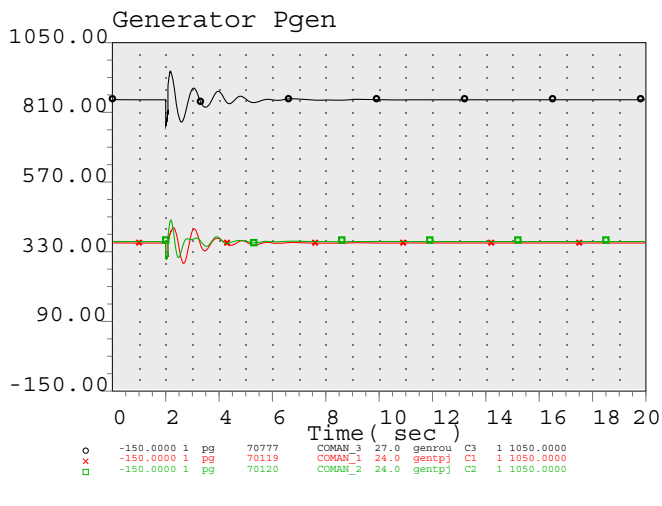


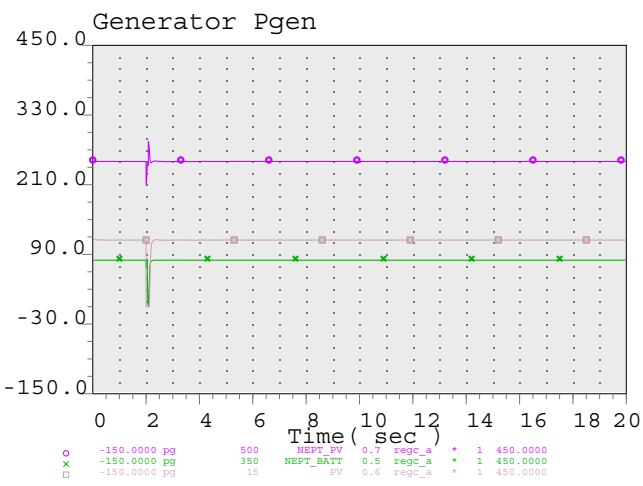
Fault:5-cycle bus fault at Boone 230kV
Outage:Lamar - Boone 230kV line and all generation at Lamar

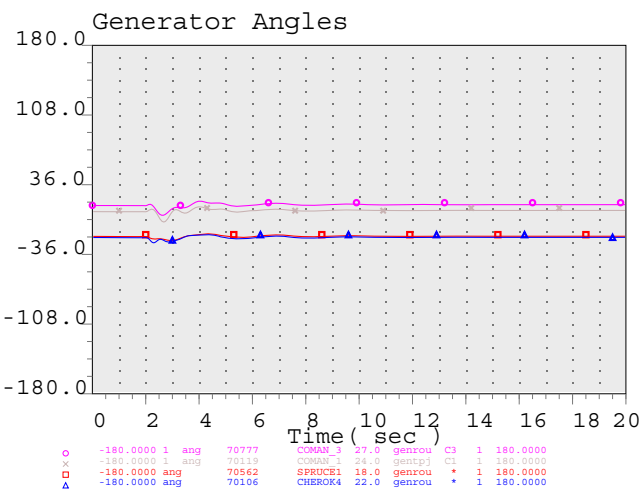




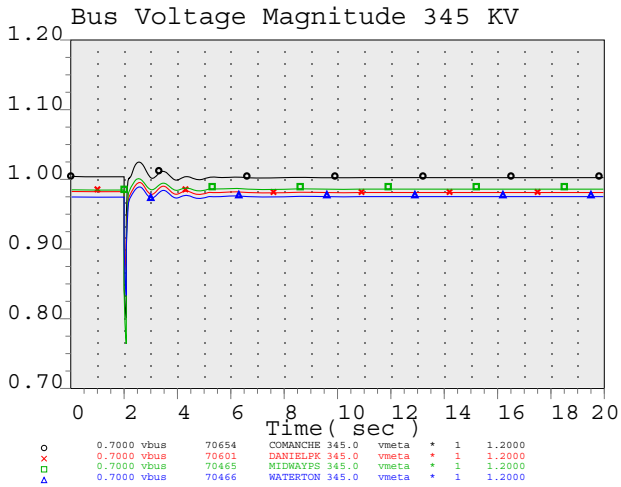


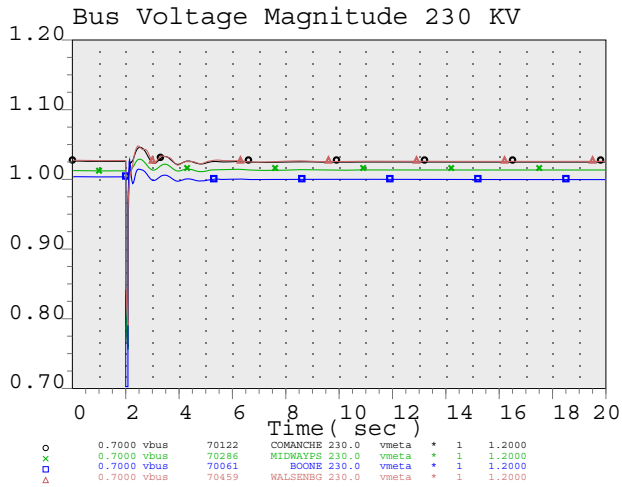


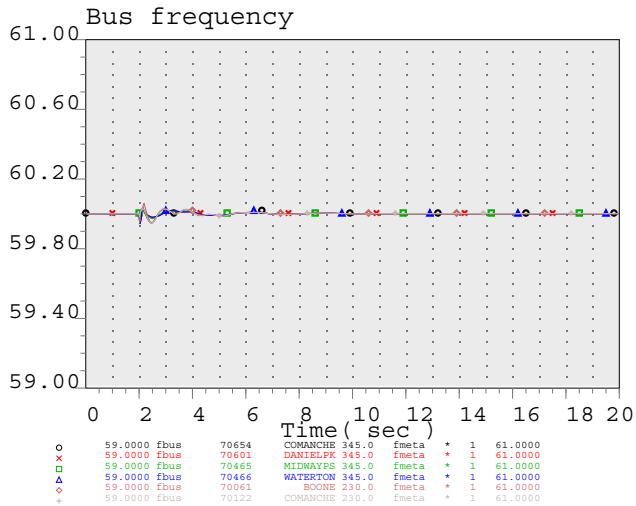


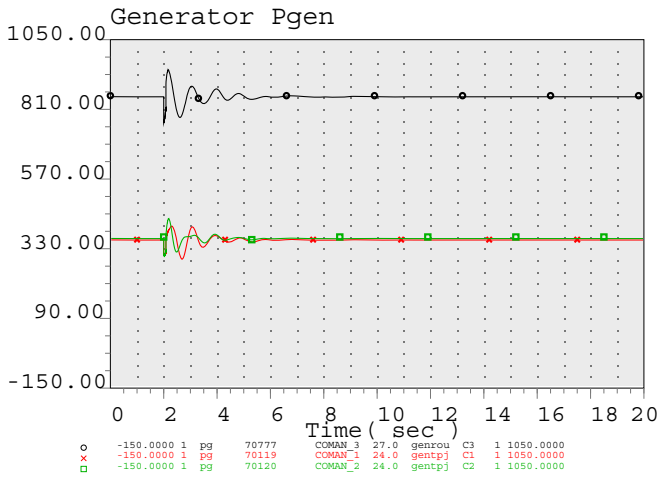


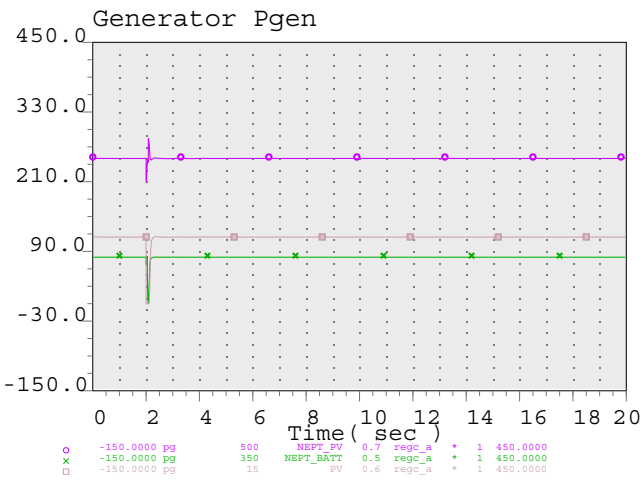
Fault:5-cycle bus fault at Boone 230kV
Outage:Boone - Comanche 230kV line

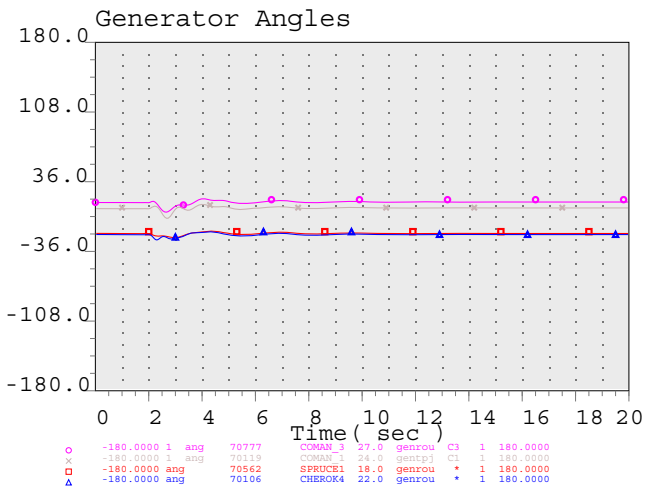




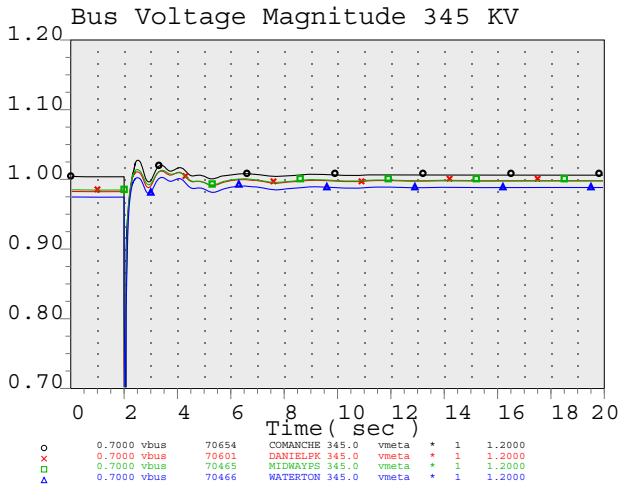


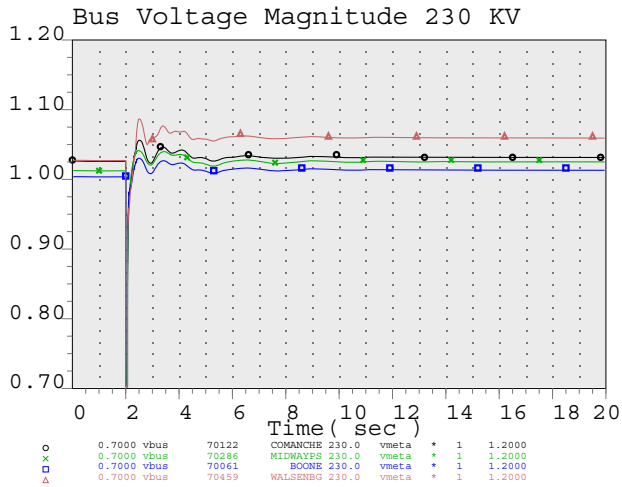


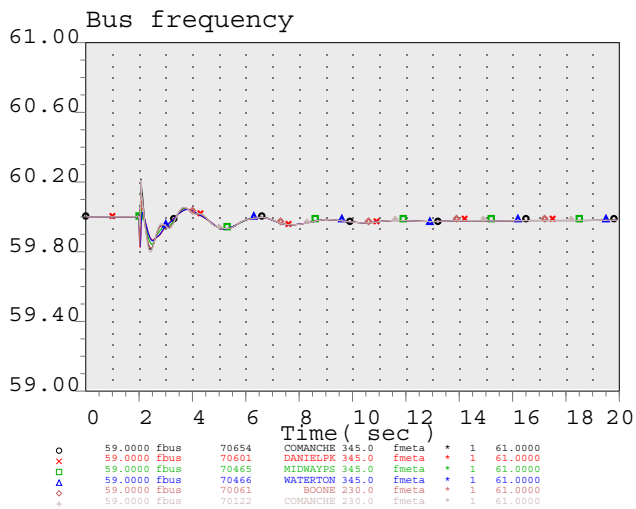


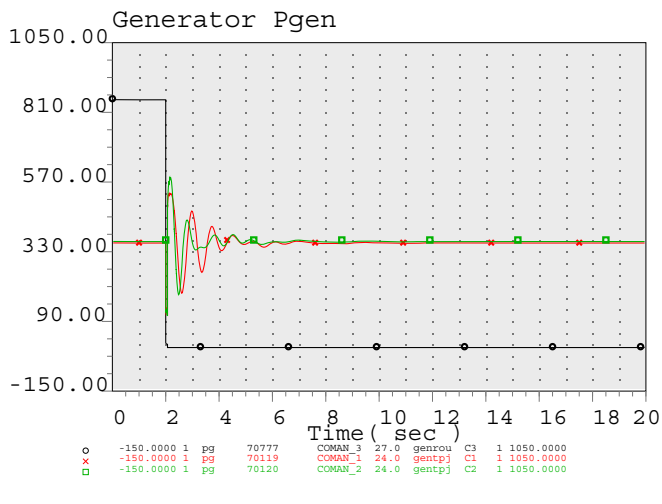


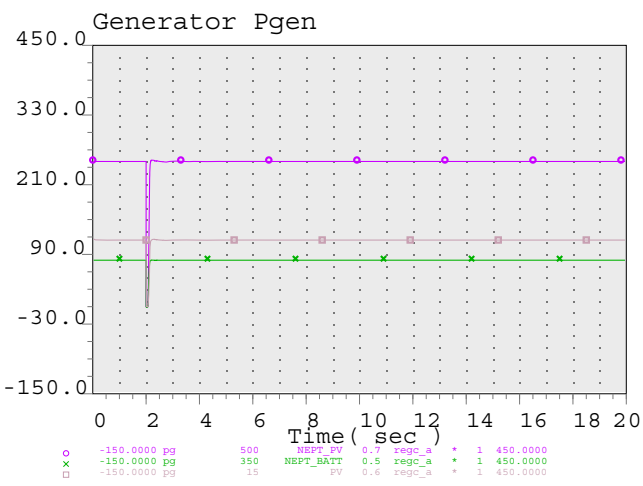
Fault:5-cycle bus fault at Boone 230kV
Outage:Boone - Midway 230kV line

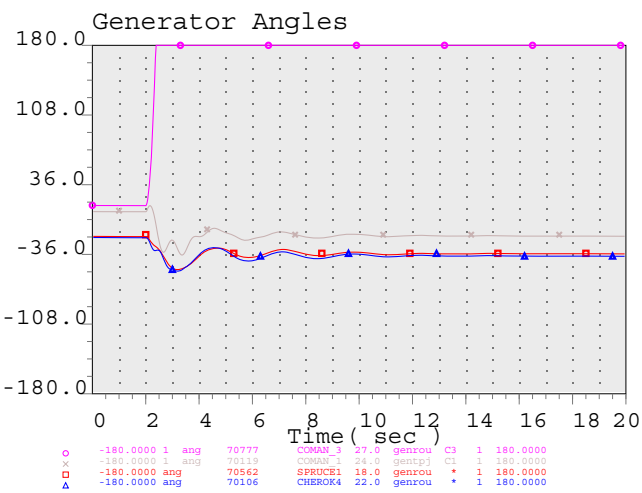




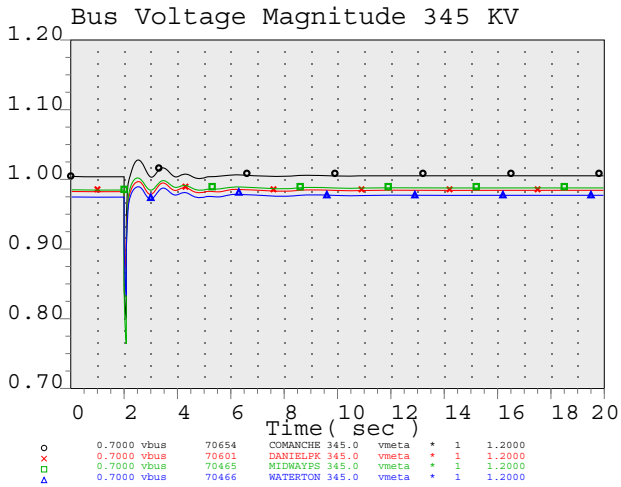


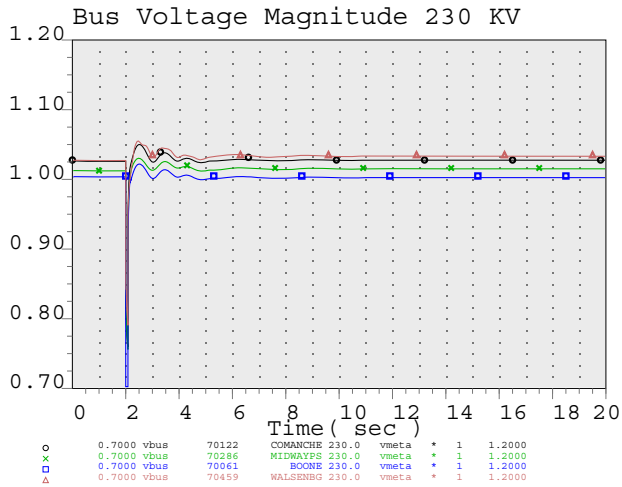


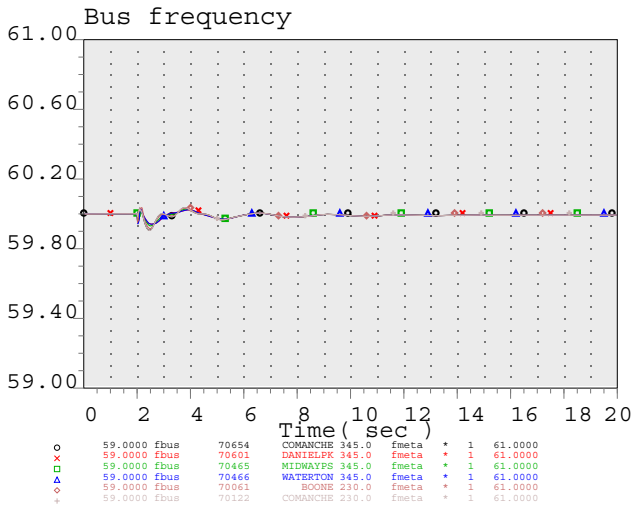


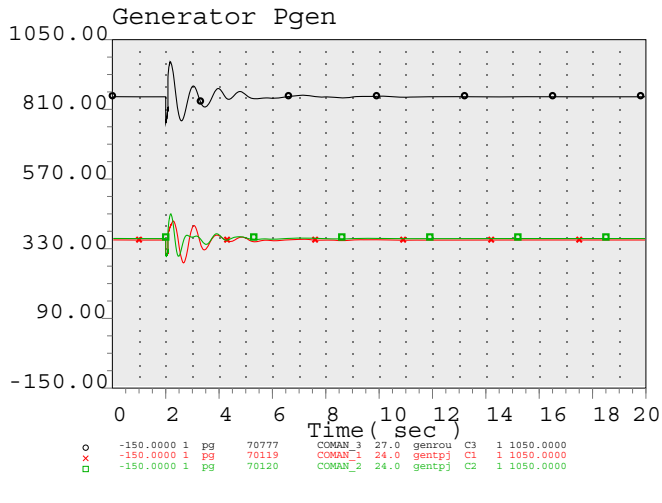


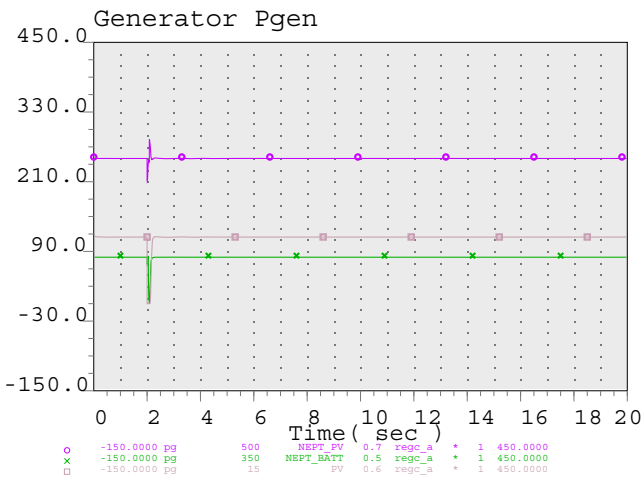
Fault:4-cycle bus fault at Comanche 345kV
Outage:Comanche#3 generator

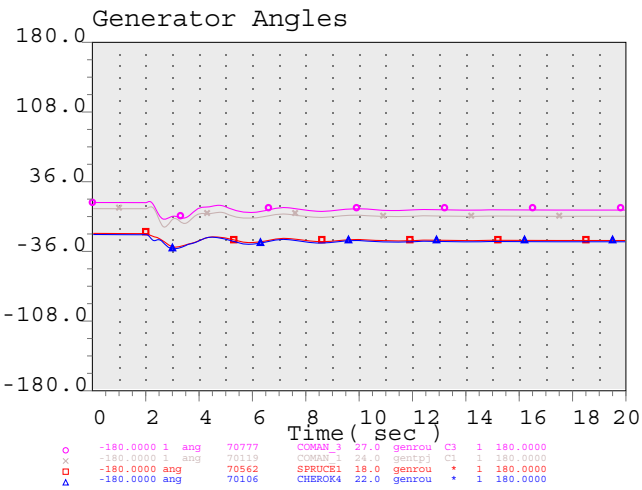




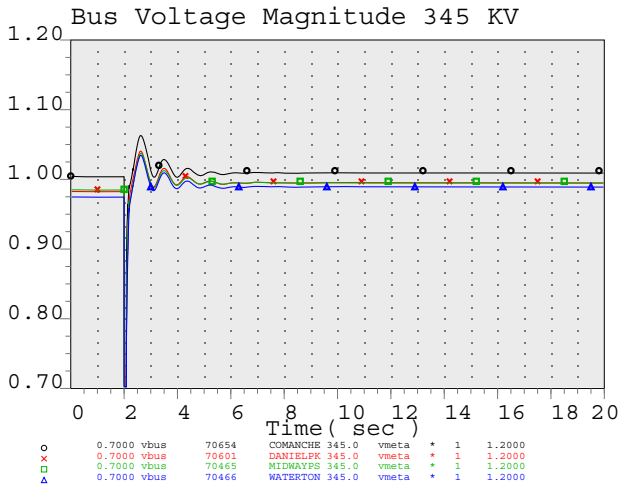


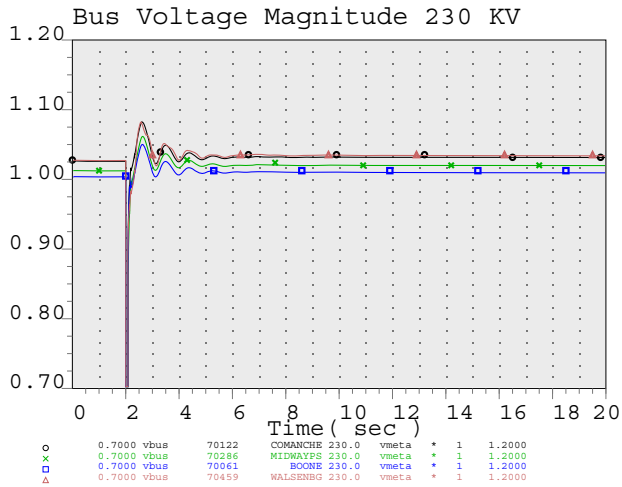


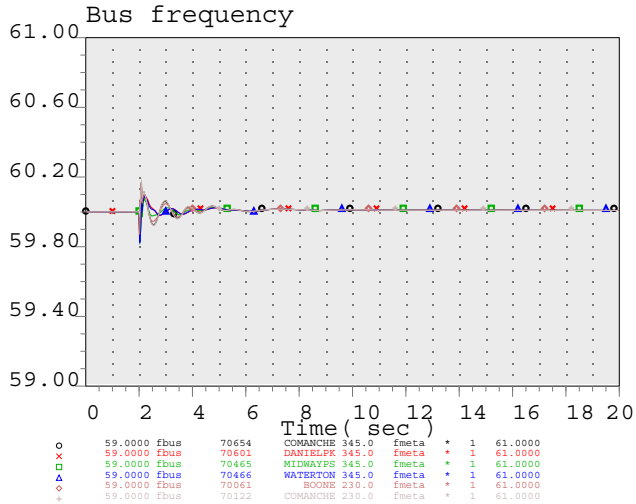


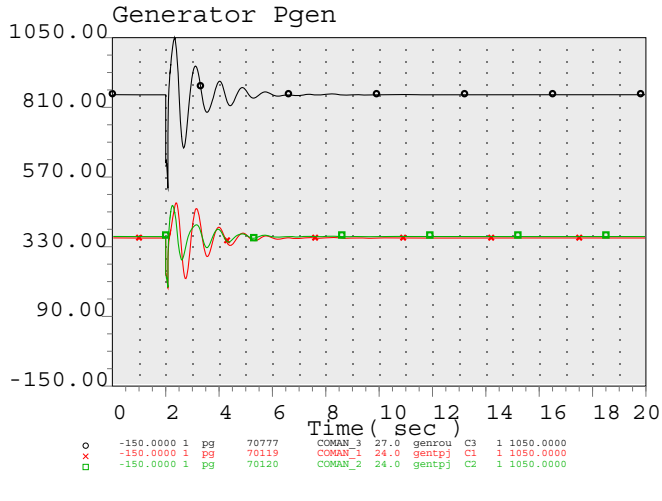


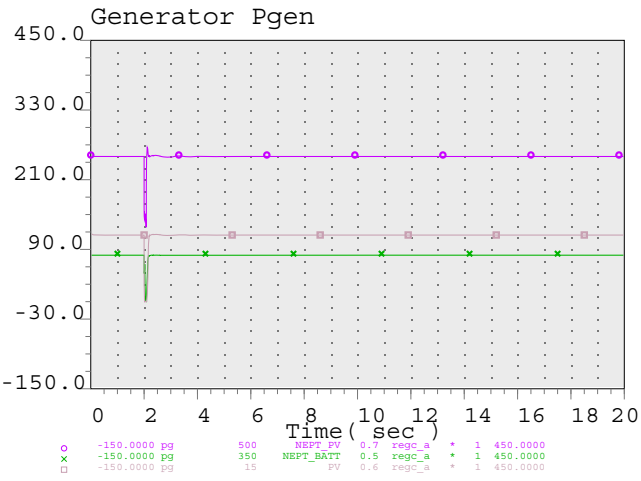
Fault:5-cycle bus fault at Lamar 230kV
Outage:Lamar - Boone 230kV line and all generation at Lamar

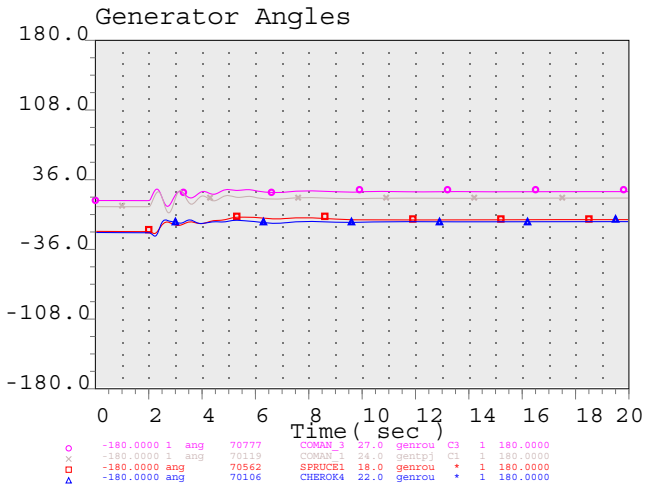




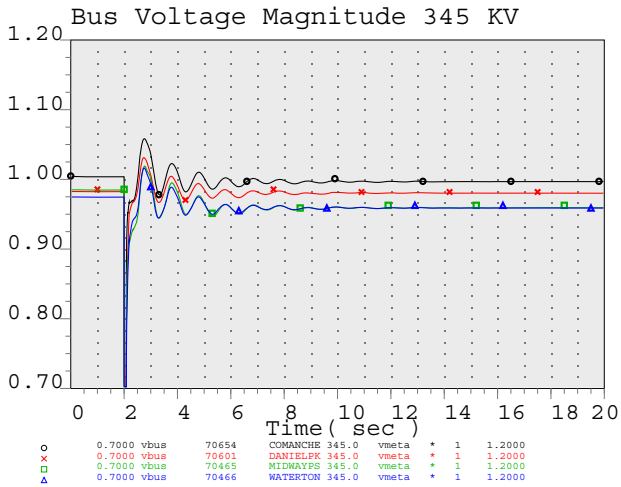


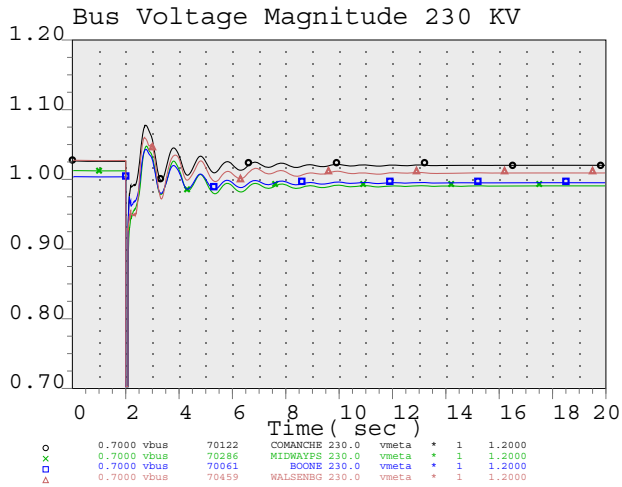


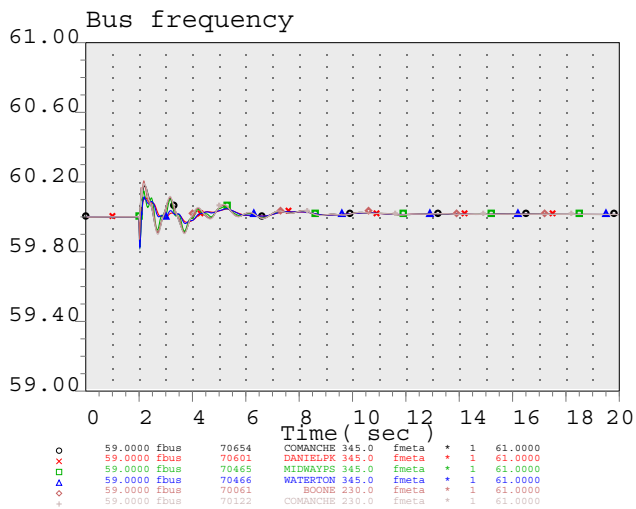


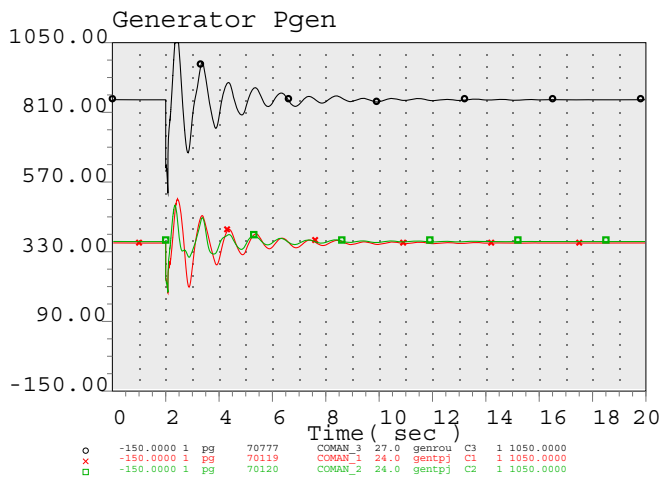


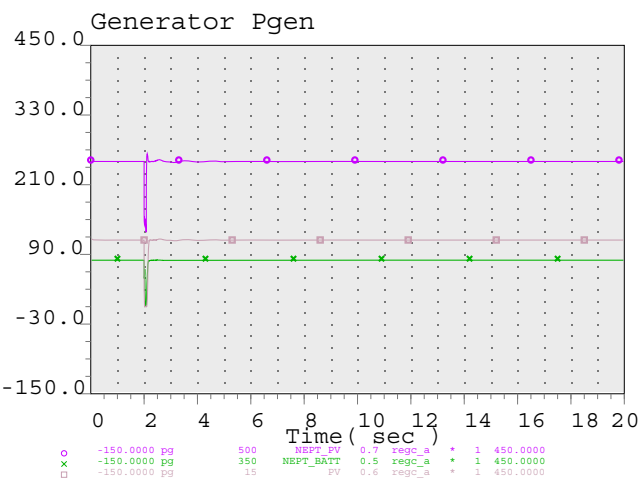
Fault:5-cycle bus fault at MidwayPS 230kV
Outage:All Fountain Valley gas units

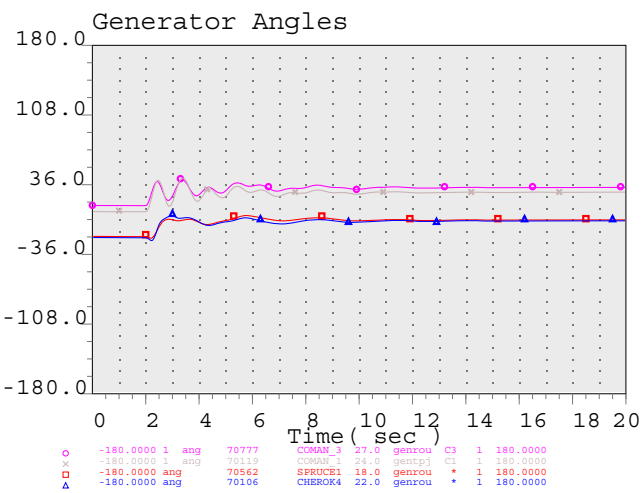




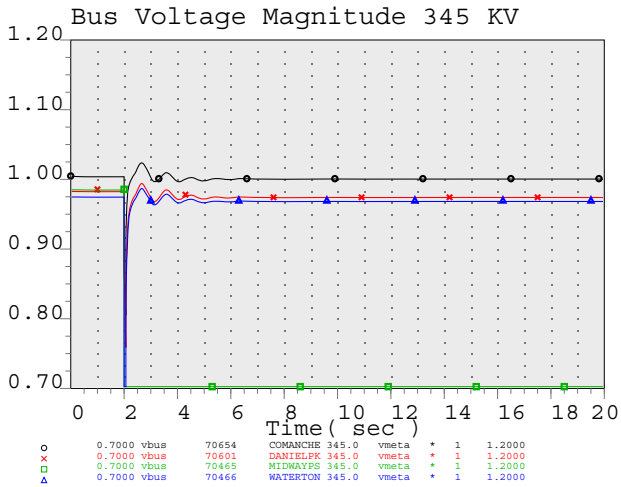


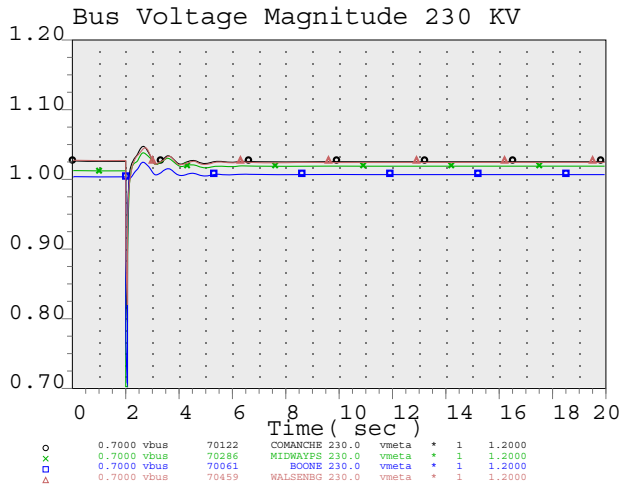


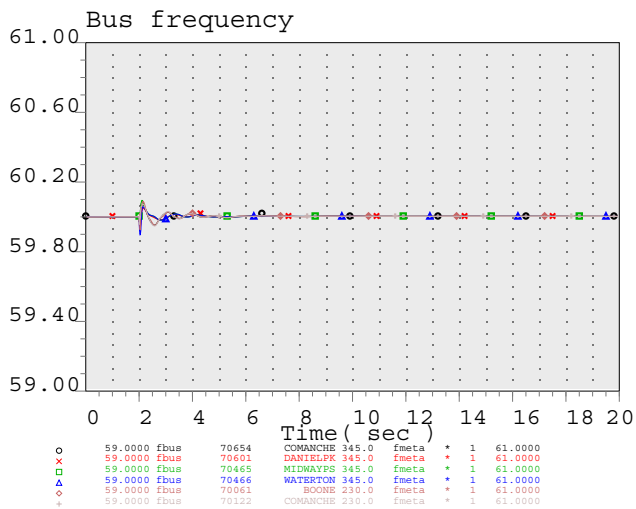


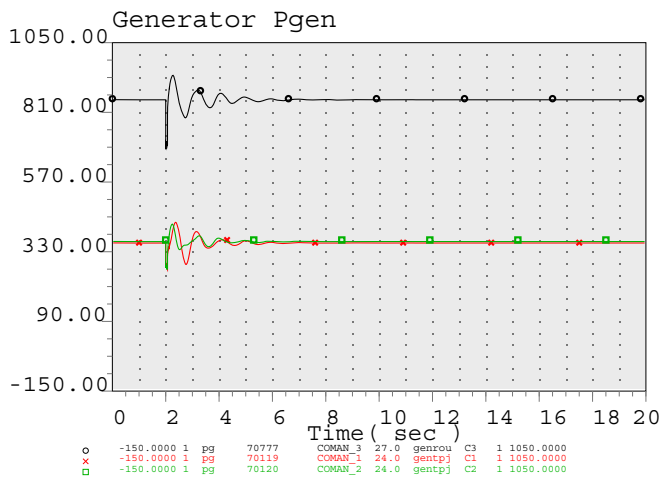


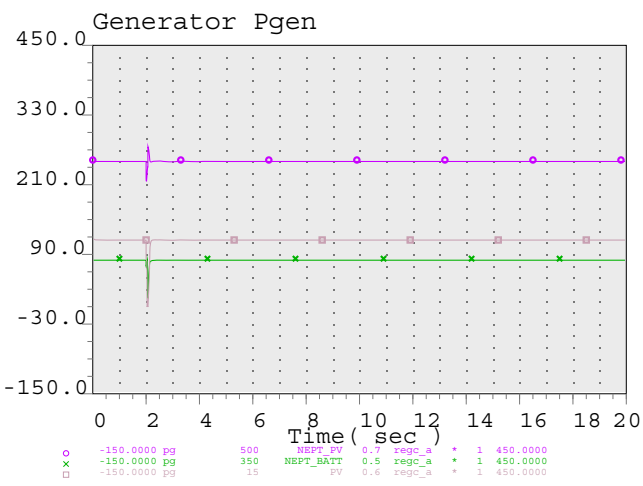
Fault:5-cycle bus fault at MidwayPS 230kV
Outage:Lose MidwayPS - Fuller 230kV and MidwayBR 115kV and 230kV lines

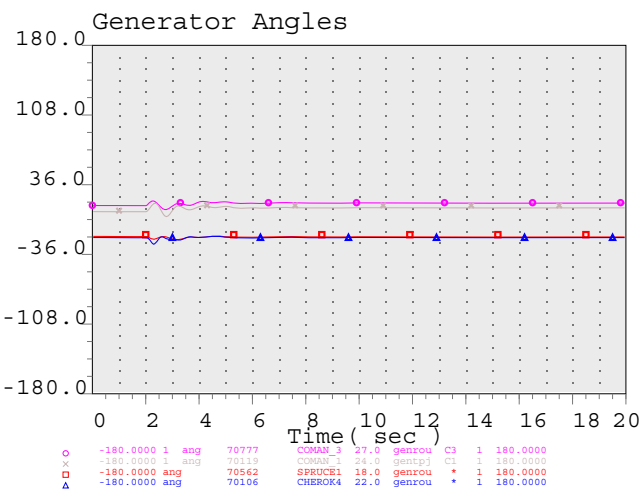




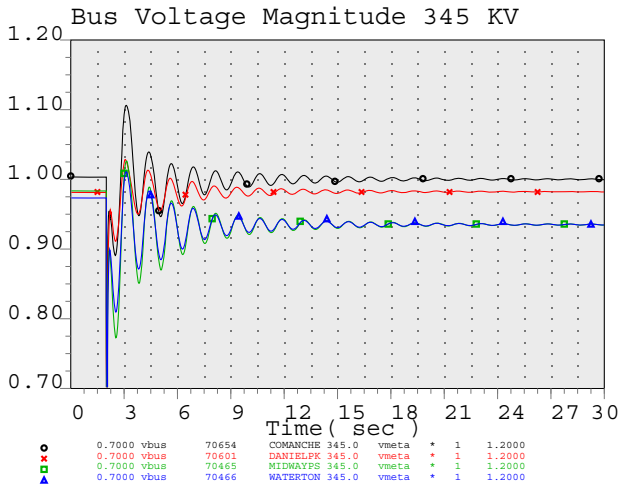


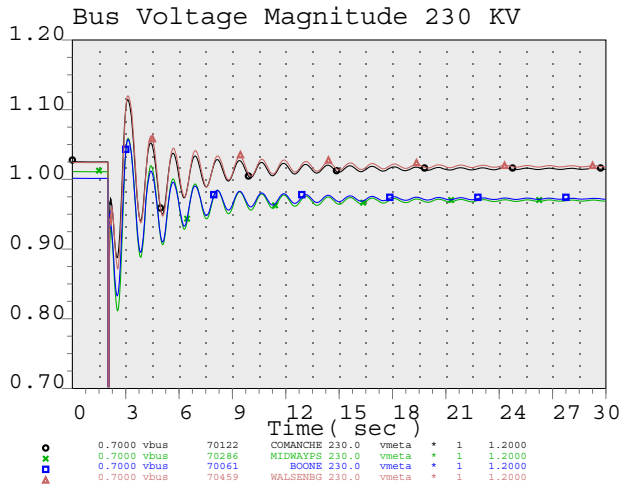


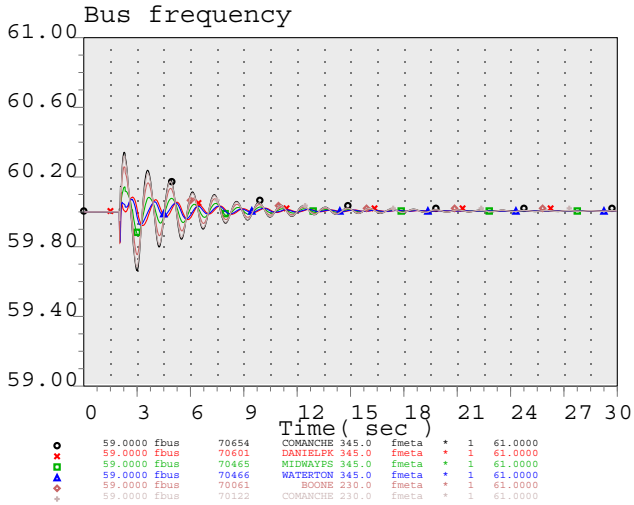


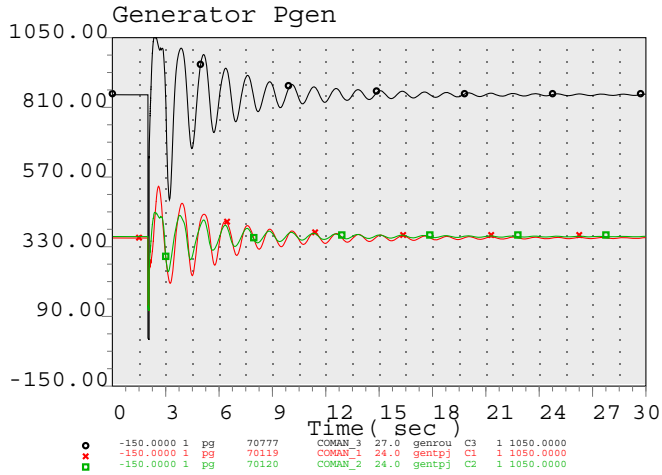


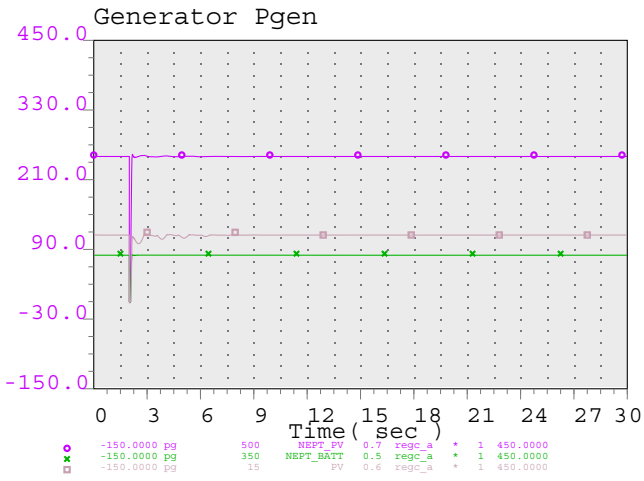
Fault:4-cycle bus fault at MidwayPS 345kV
Outage:Lose MidwayPS - Waterton 345kV line and Midway 230/345kV transformer

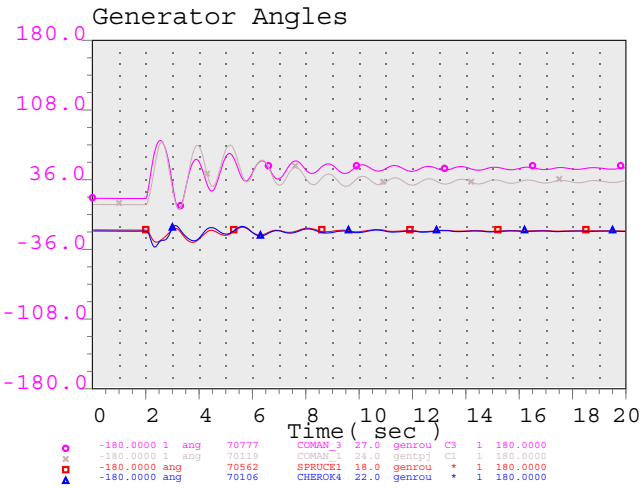




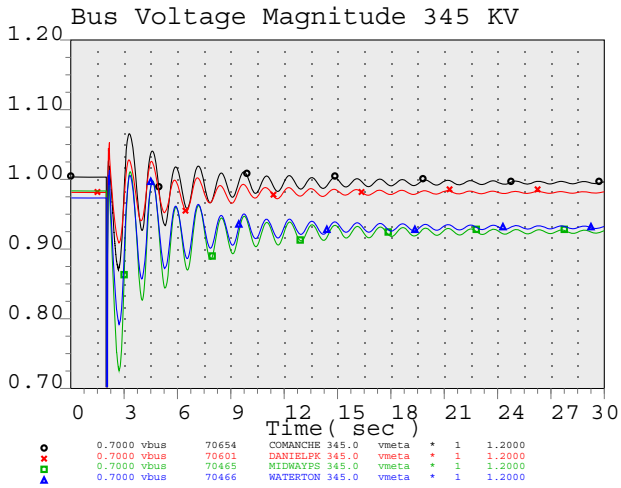


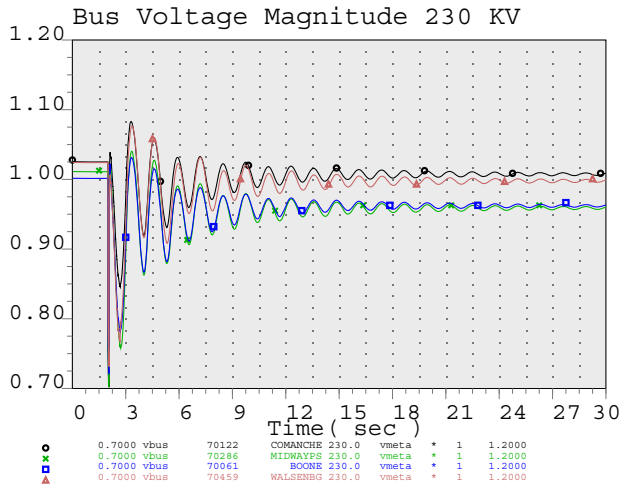


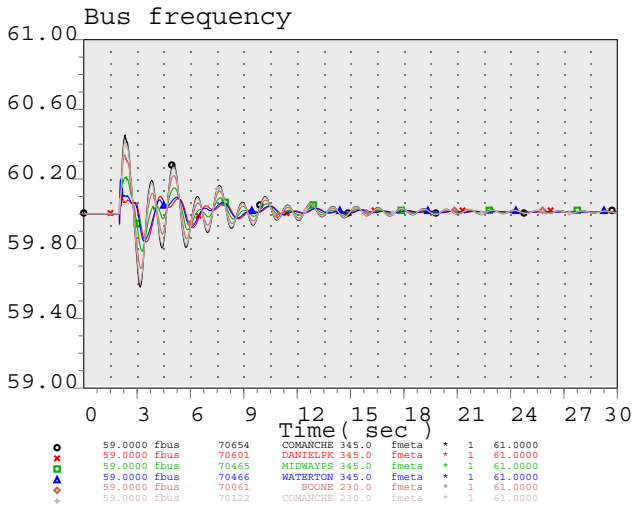


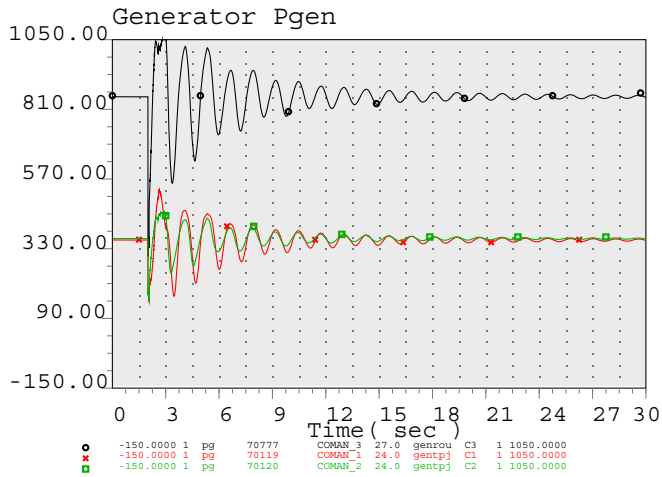


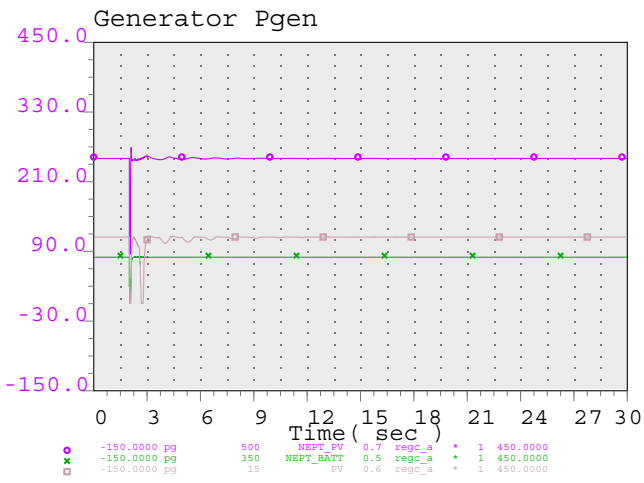
Fault:4-cycle bus fault at Comanche 345kV
Outage:Lose Comanche - Daniels Park 345kV and Comanche - Tundra 345kV lines

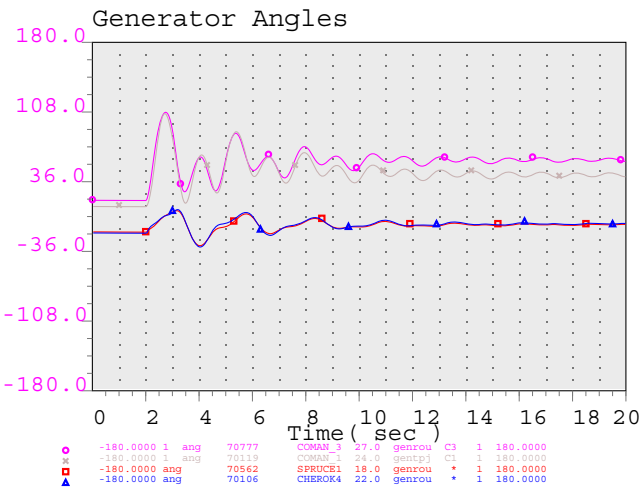








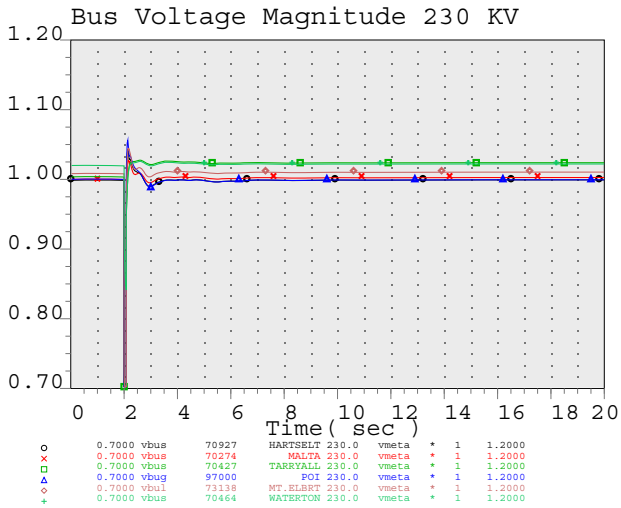


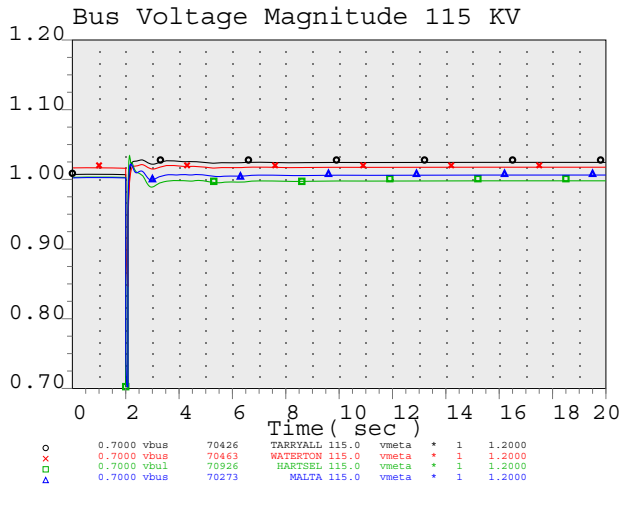


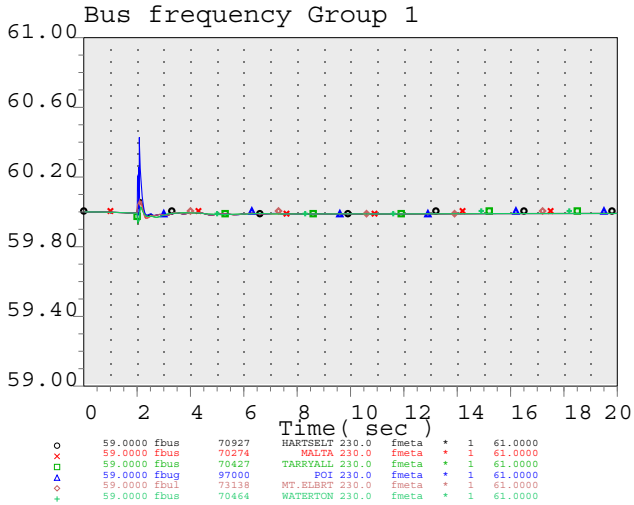
Fault:4-cycle bus fault at Comanche 345kV
Outage:Lose Comanche - Daniels Park 345kV and Daniels Park - Tundra 345kV lines

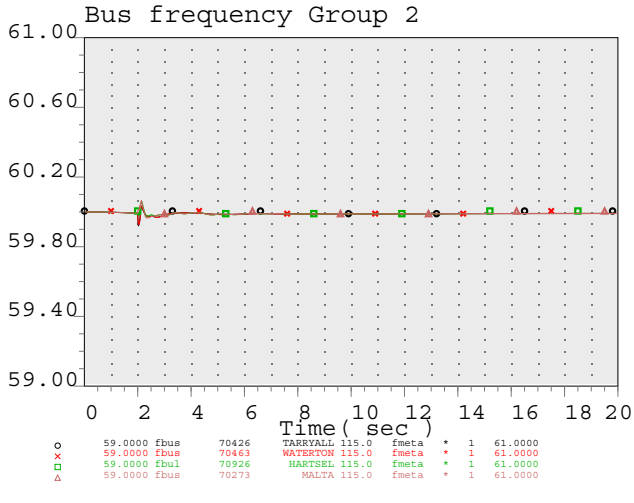
Appendix A-2

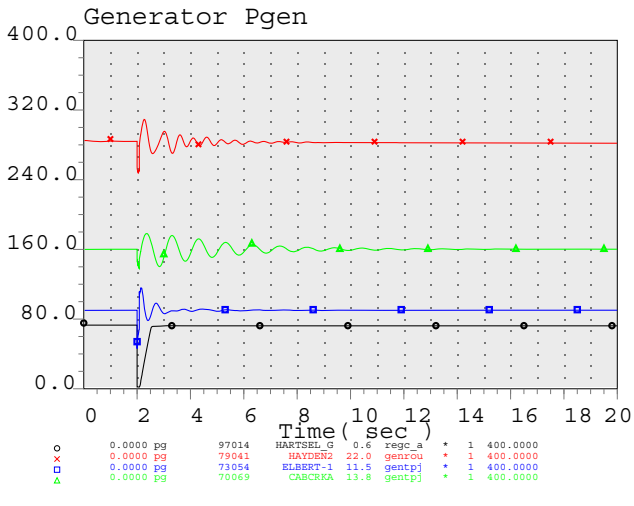
Transient Stability Plots – Western Slope Study Pocket

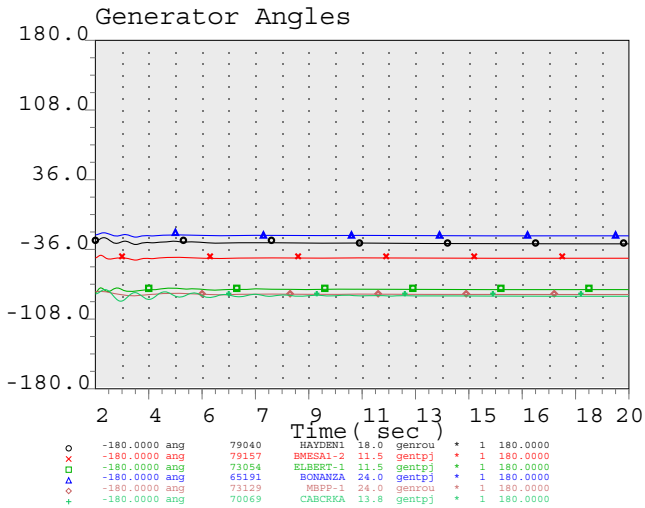






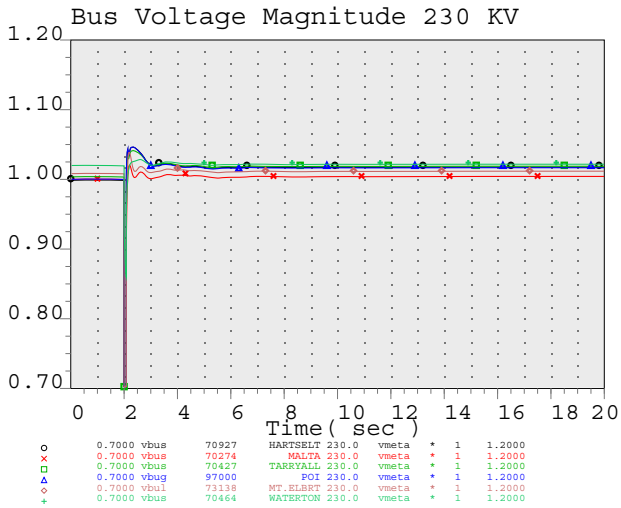


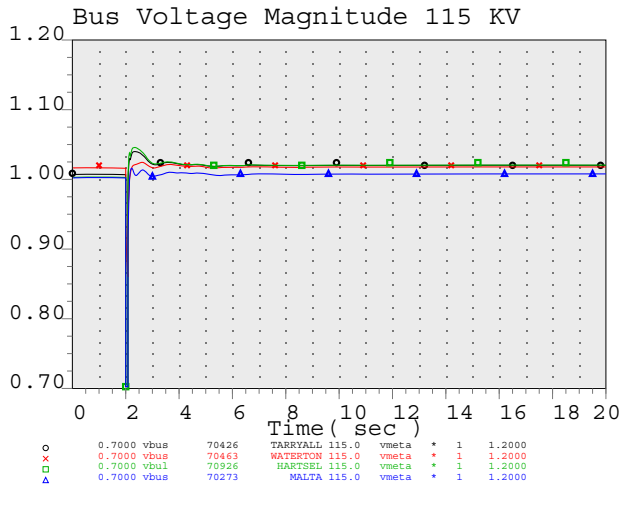


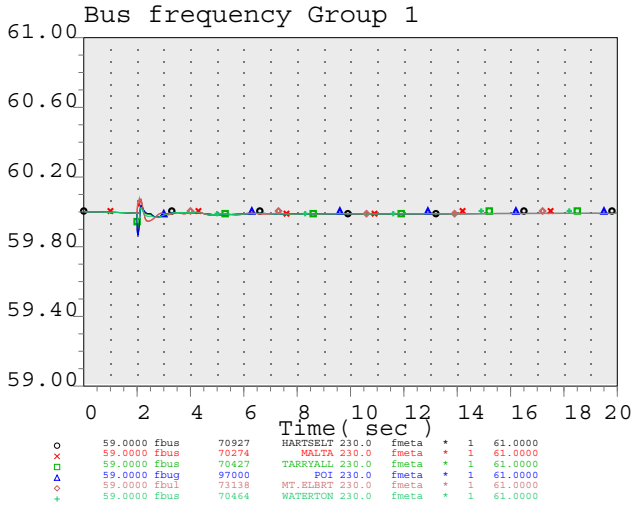


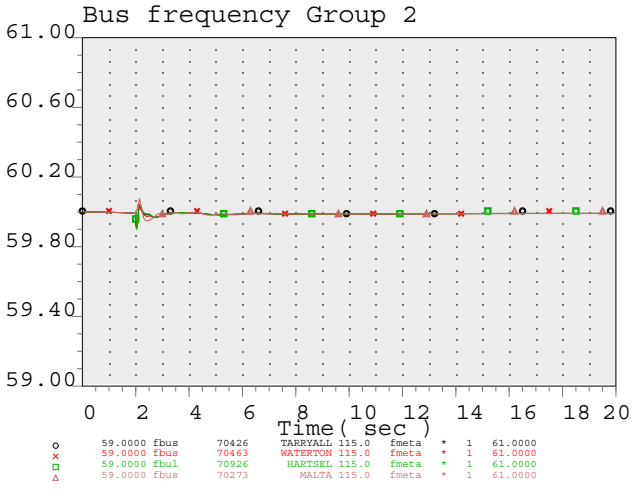
Solar PV - 72 MW

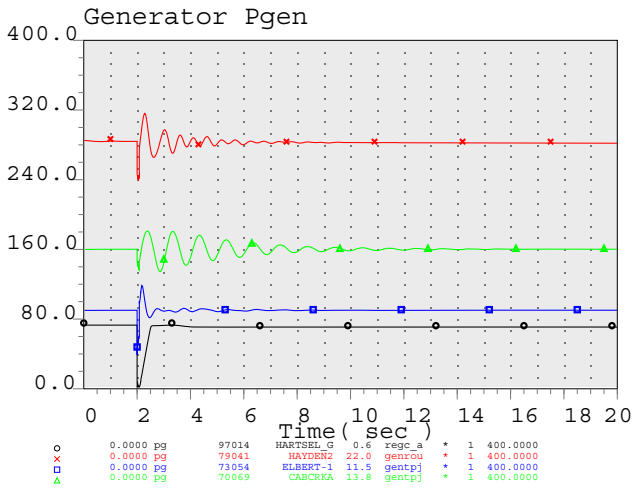
Fault: 3-ph 5 cycle line end fault on Tarryall - PI-2019-7 POI 230kV line at PI-2019-7 POI 230kV
Outage: Tarryall - PI-2019-7 POI 230kV line

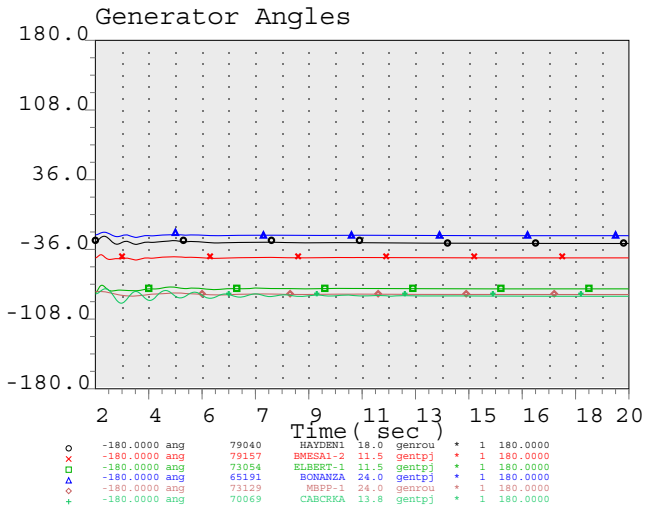






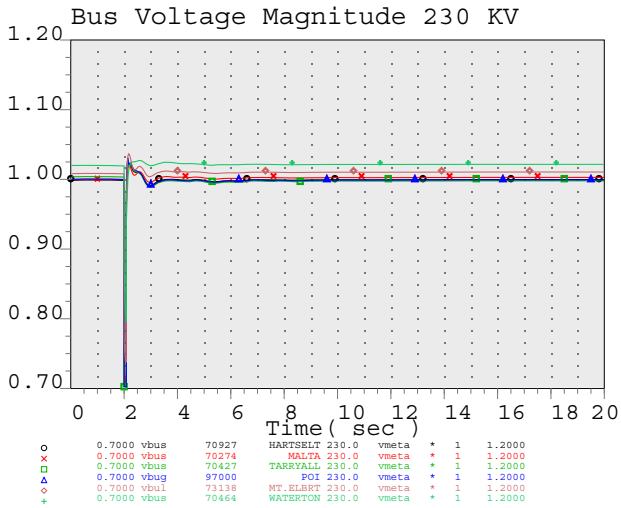


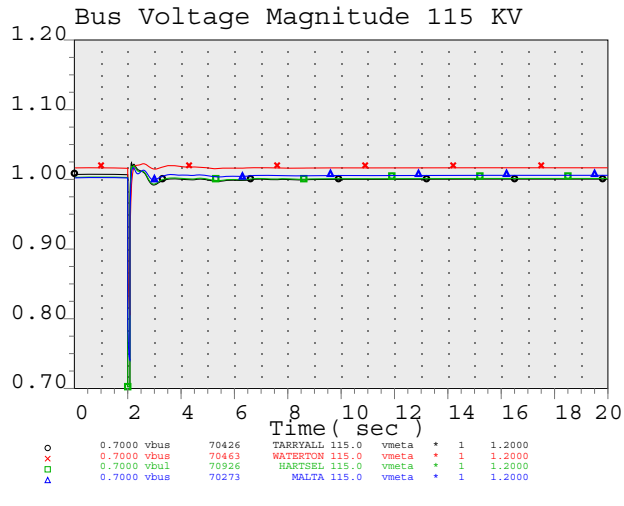


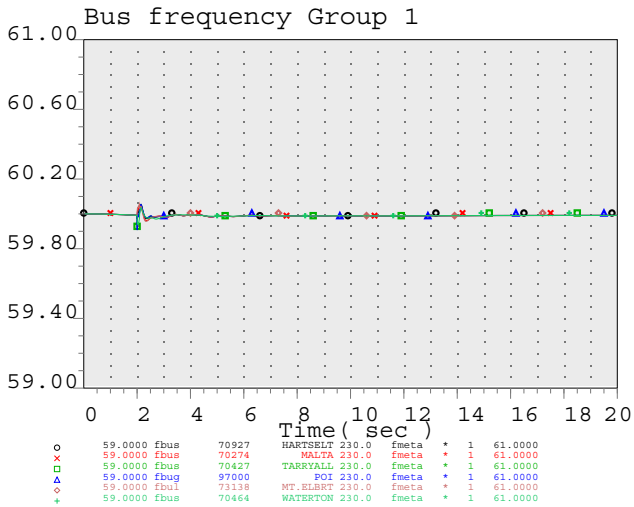


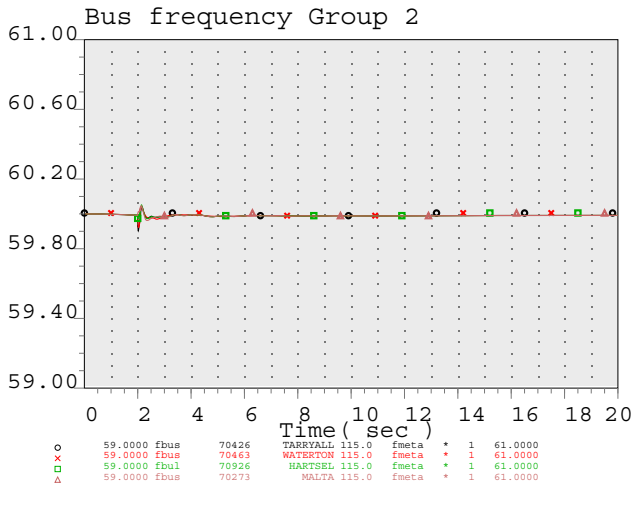
Solar PV - 72 MW

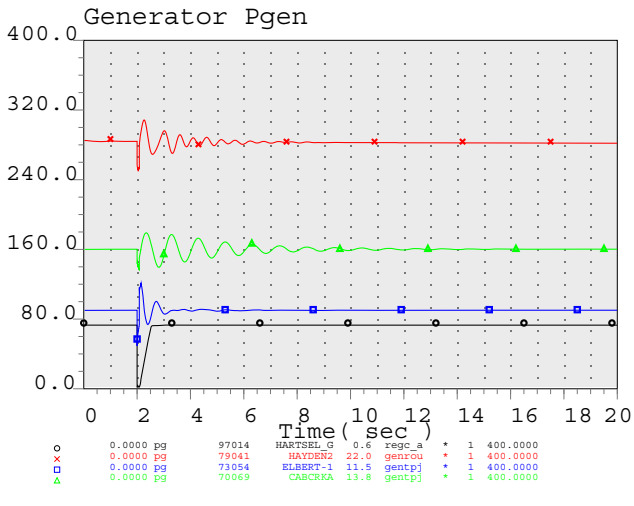
Fault: 3-ph 5 cycle line end fault on Malta - Hartsel 230kV line at Hartsel 230kV
Outage: Malta - Hartsel 230kV line

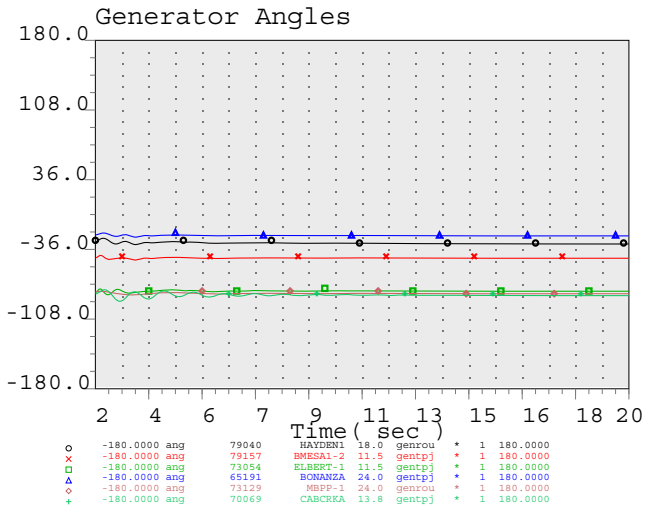






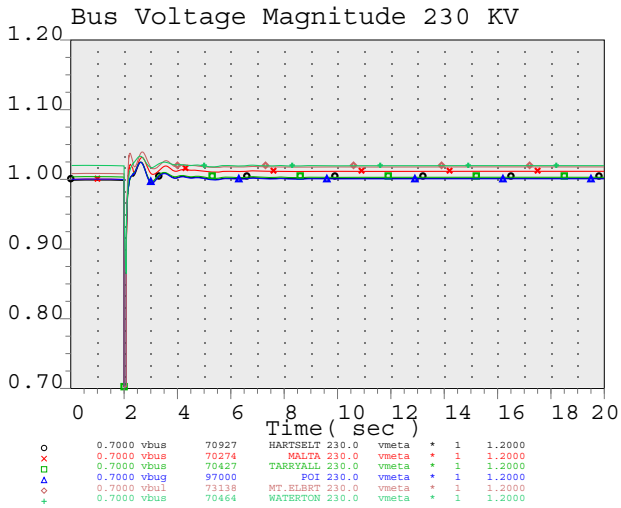


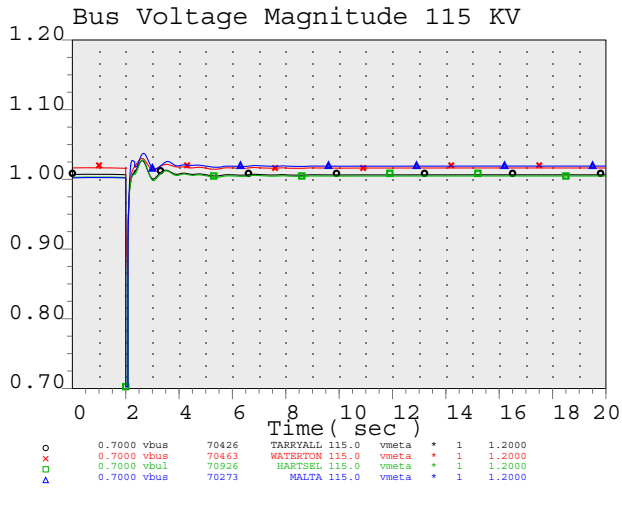


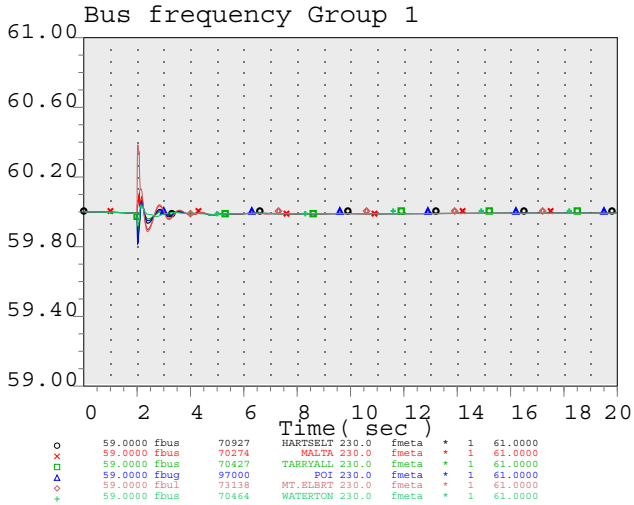


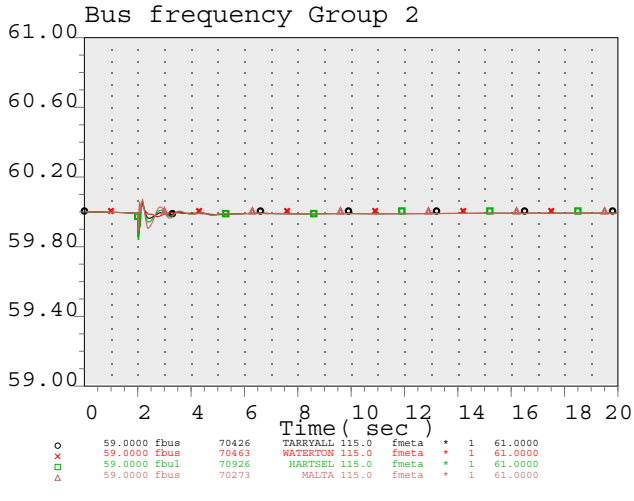
Solar PV - 72 MW

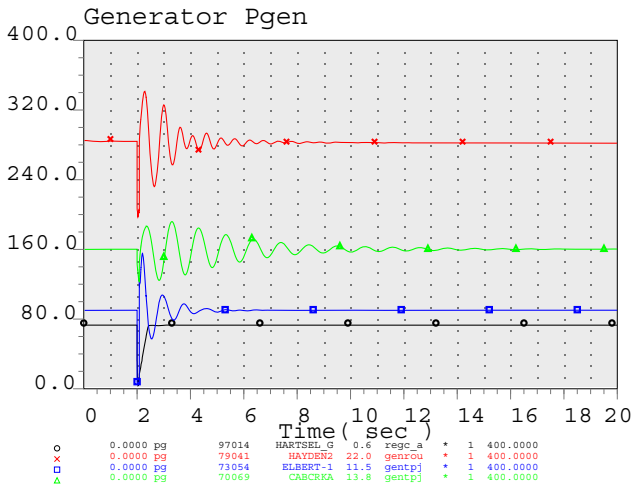
Fault: 3-ph 5 cycle line end fault on Tarryall - Waterton 230kV line
at Tarryall 230kV
Outage: Tarryall - Waterton 230kV line

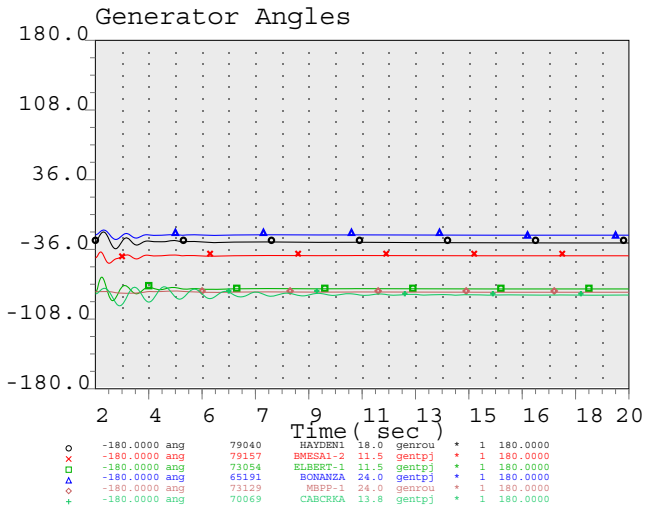






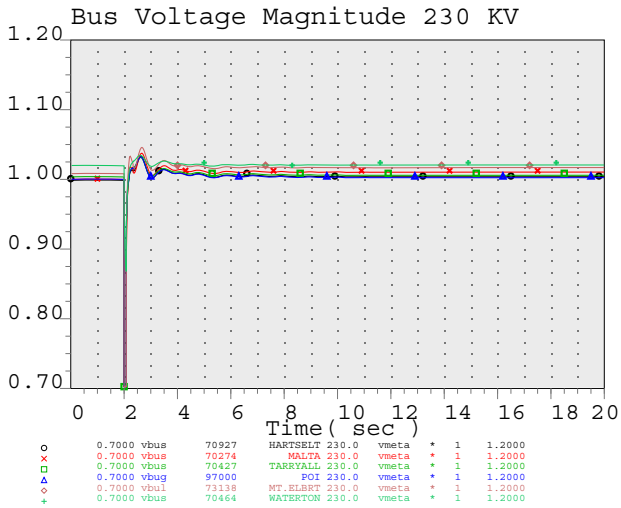


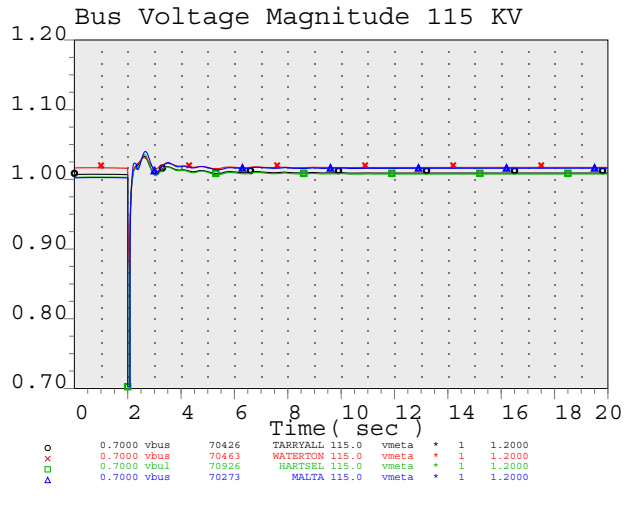


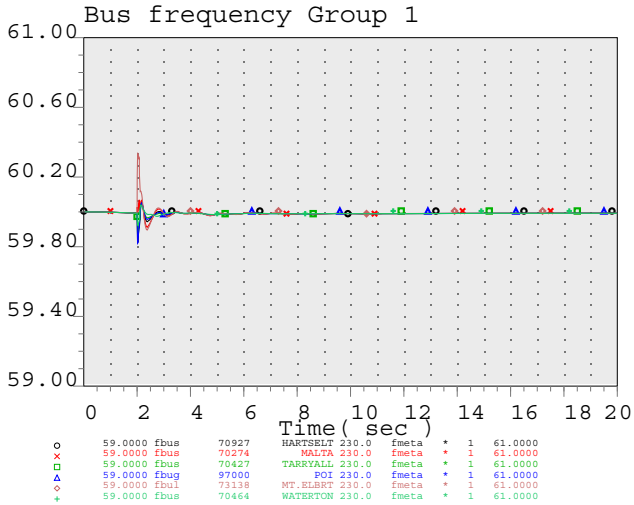


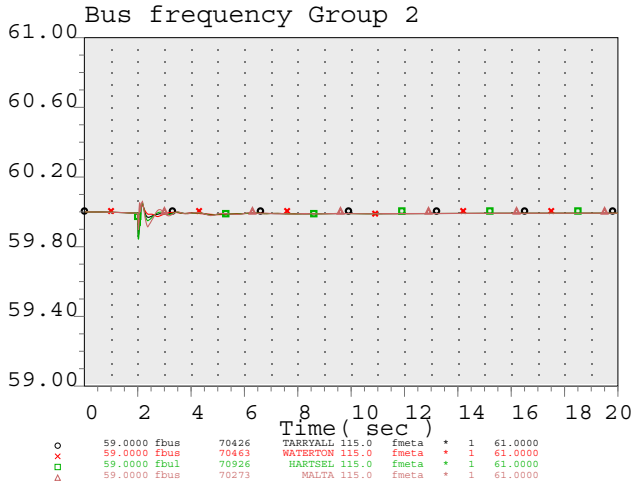
Solar PV - 72 MW

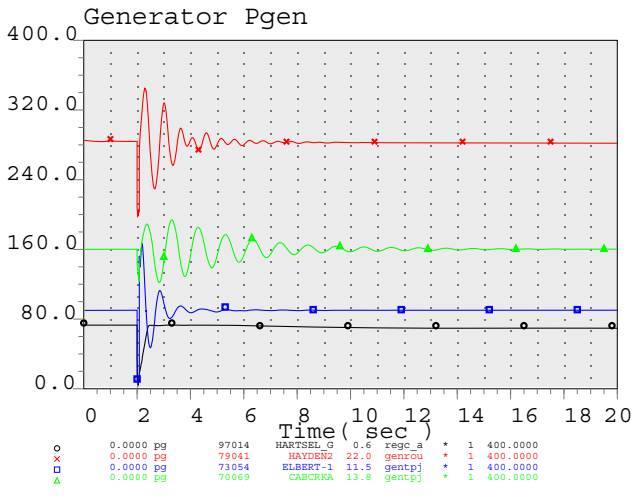
Fault: 3-ph 5 cycle line end fault on Malta - Alma 230kV line
at Malta 230kV
Outage: Malta - Alma 230kV line

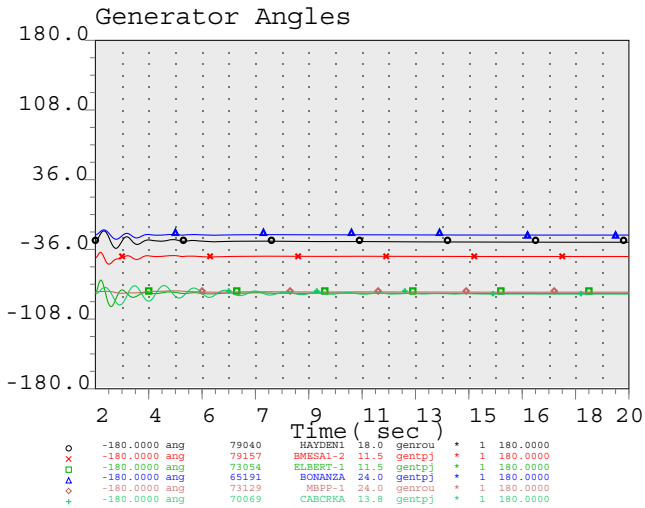






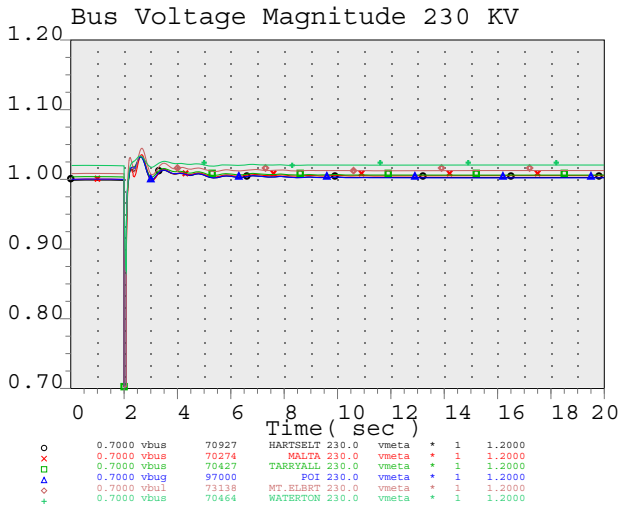


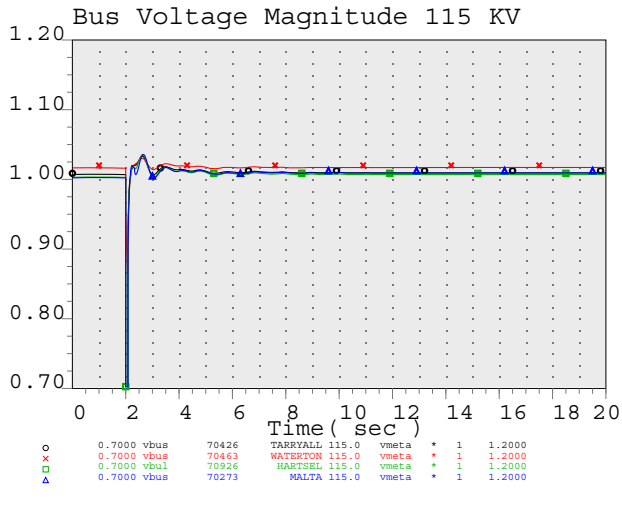


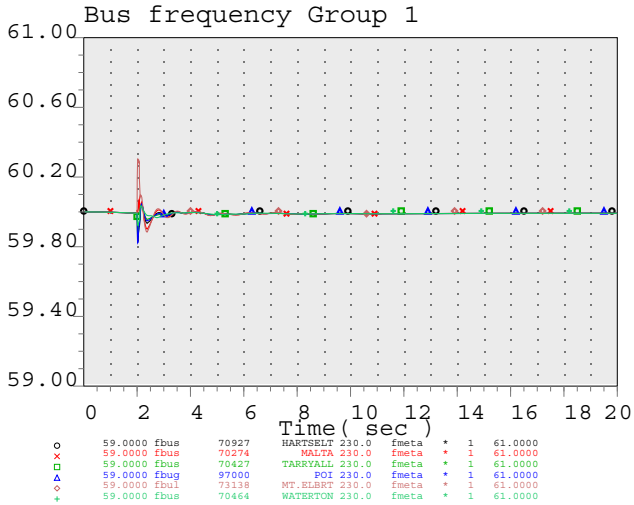


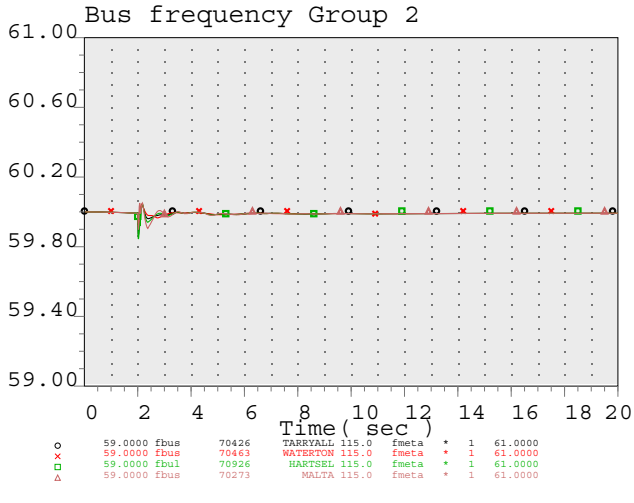
Solar PV - 72 MW

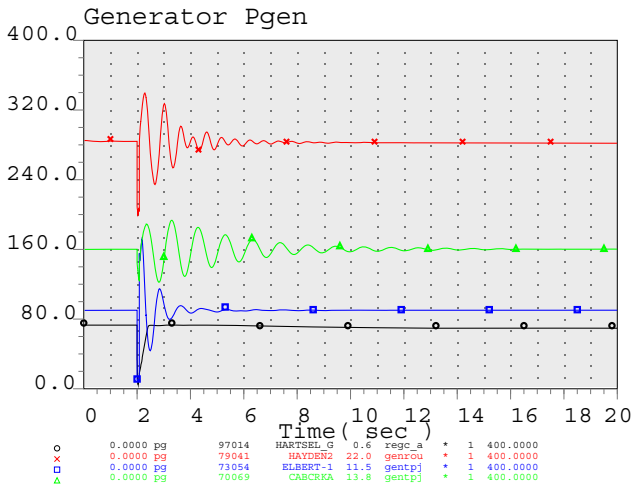
Fault: 3-ph 5 cycle line end fault on Malta - Basalt 230kV line
at Malta 230kV
Outage: Malta - Basalt 230kV line

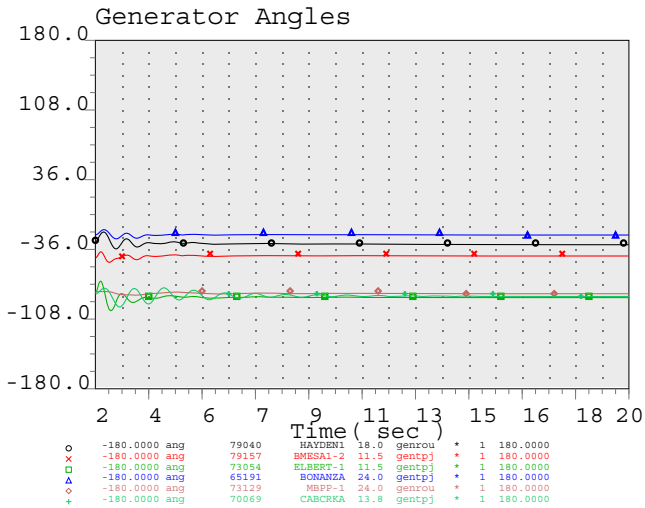






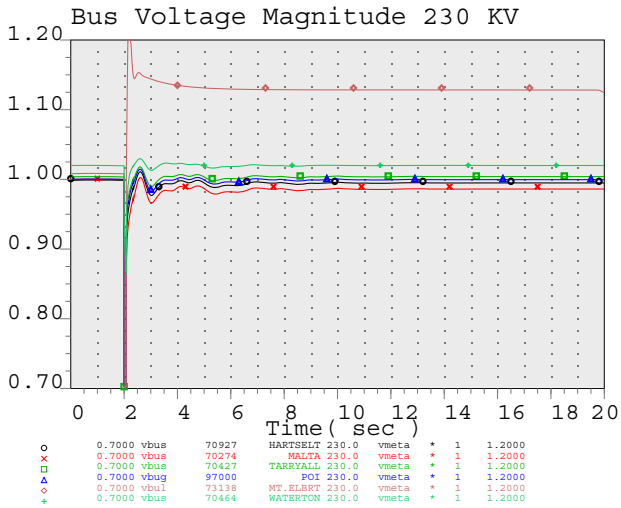


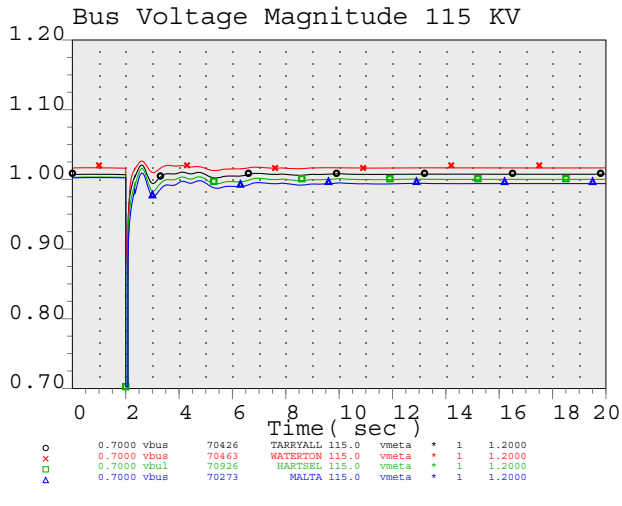


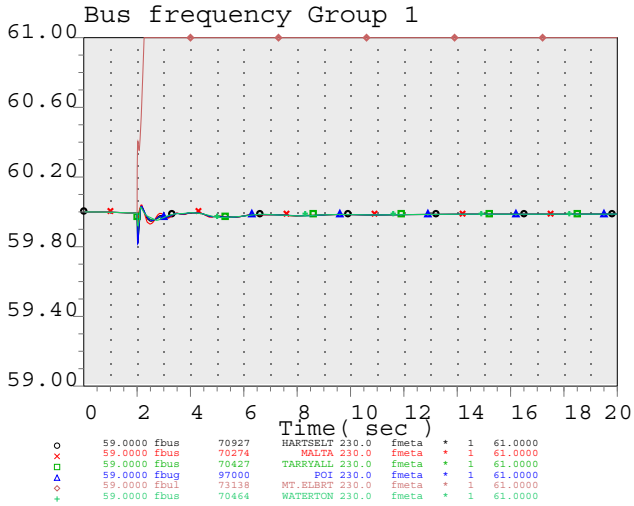


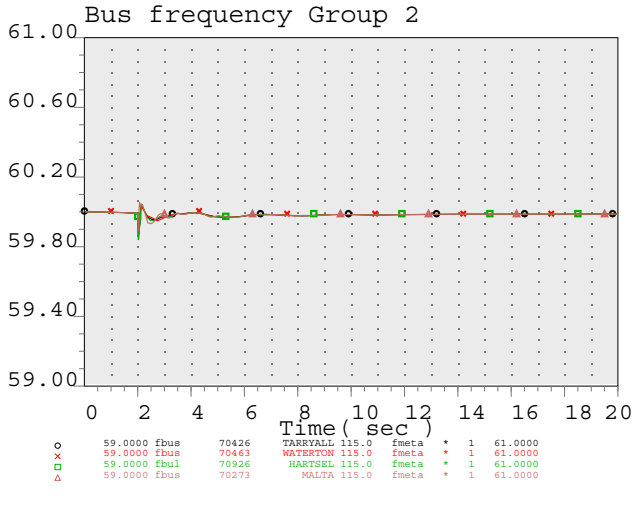
Solar PV - 72 MW

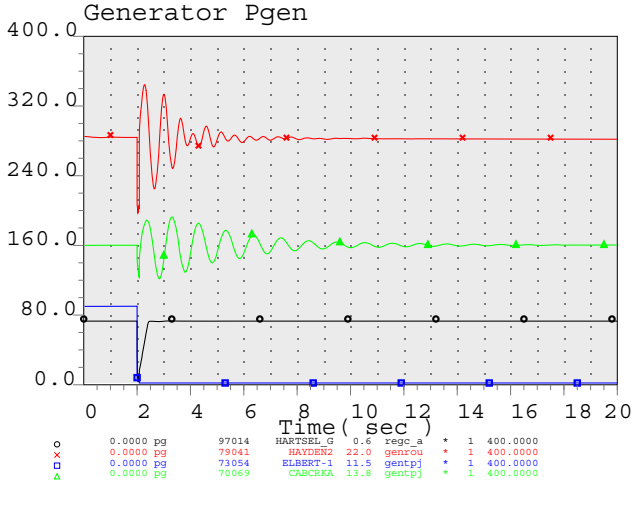
Fault: 3-ph 5 cycle line end fault on Malta - Hopkins 230kV line
at Malta 230kV
Outage: Malta - Hopkins 230kV line

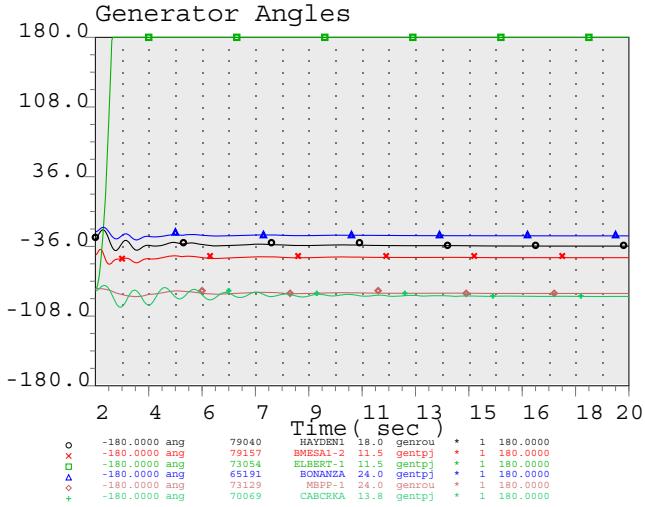






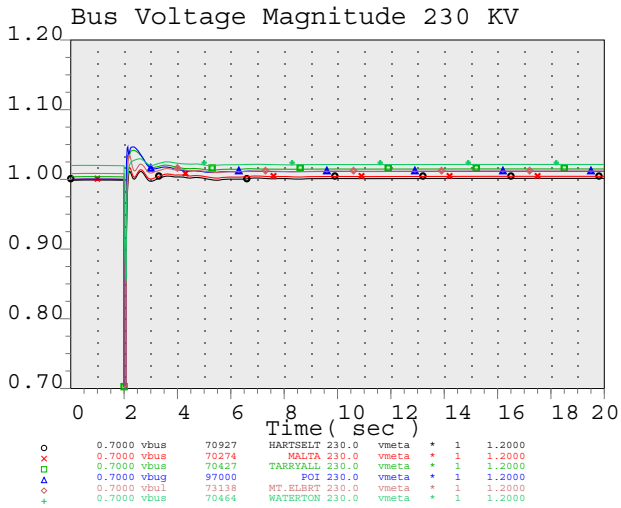


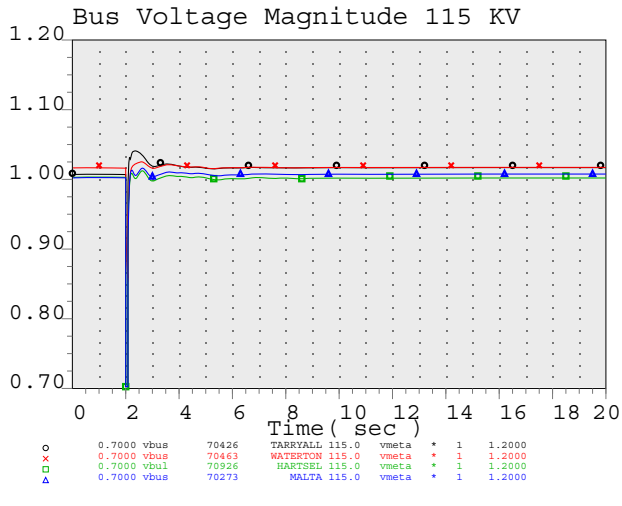


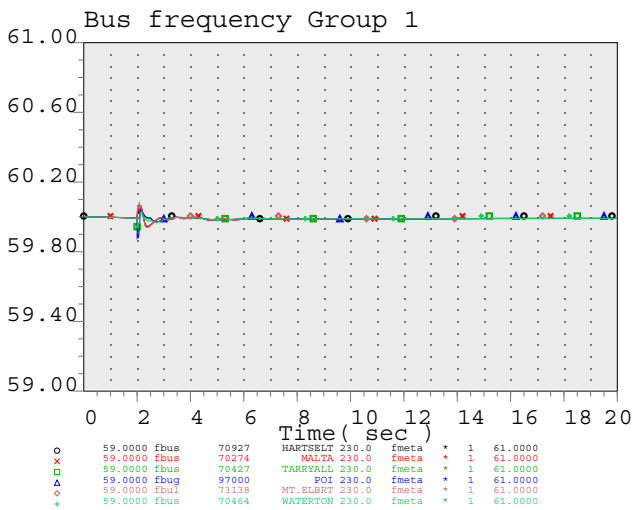


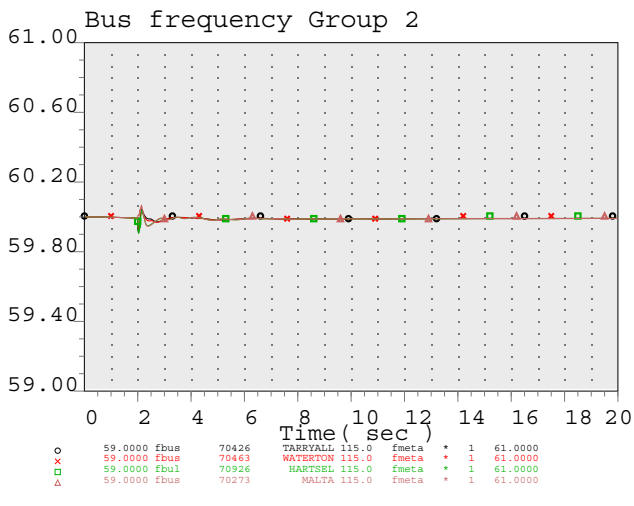
Solar PV - 72 MW

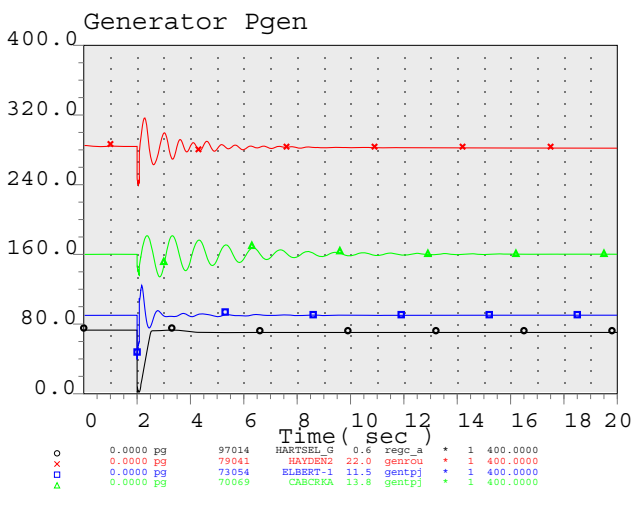
Fault: 3-ph 5 cycle line end fault on Malta - Mt. Elbert 230kV line at Malta 230kV
Outage: Malta - Mt. Elbert 230kV line

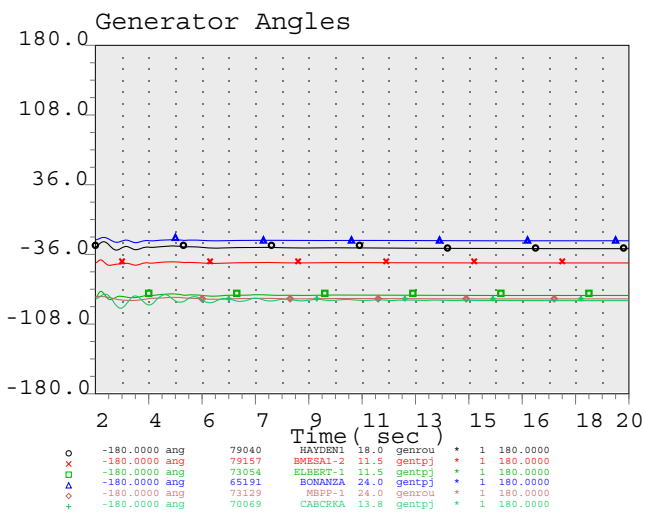












Solar PV - 72 MW

Fault: 3-ph 5 cycle line end fault on Hartsel - PI-2019-7 POI 230kV line at Hartsel 230kV
Outage: Hartsel - PI-2019-7 POI 230kV line