Surplus Interconnection Study Report for GI-2014-6

52.2MW Battery Energy Storage Generating Facility
Midway 115kV Substation
Pueblo County, Colorado

Xcel Energy - Transmission Planning West
March 17, 2020

Executive Summary

Public Service Company of Colorado (PSCo) received the request for evaluating a 52.2MWac Battery Energy Storage (BES) for Surplus Interconnection Service for GI-2014-6. GI-2014-6 is a 100.2MW Solar Photovoltaic (PV) Generation facility request with a Point of Interconnection (POI) at Midway 115kV Substation.

The final configuration of GI-2014-6 after the inclusion of the BES for Surplus interconnection will make it an AC-coupled hybrid Generation Facility. The expected operating modes of the Generating Facility are:

I. 100.2MW rated generation output at the POI via combination of PV and BES
II. 52.2MW when the PV output is zero.

The BES shall only expected to charge from the PV Generating Facility.

As stated in the study agreement, the Surplus Interconnection selected Network Resource Interconnection Service (NRIS). This study assumed that the underlying generator is in-service and has a Interconnection Agreement. Note that at this time, the underlying generator is not constructed and the LGIA is in suspension. If the underlying interconnection agreement is terminated or if changes to the generating facility assumptions result in a Material Modification, the results of this Surplus Interconnection Study are invalid.

The study did not find any impact to the stability or short circuit analysis performed due to the addition of the 52.2MW BES as Surplus Interconnection Service to GI-2014-6.

Surplus Interconnection Service = 52.2MW

The Surplus Interconnection Service will be made available 24/7, all days of the year, for as long as: 1) the LGIA associated with GI-2014-6 is in effect, and 2) the battery storage facility is in operation and adheres to the terms of its future Surplus agreement.

The Interconnection 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.

The Interconnection Customer shall use the Plant Controller to limit the output of GI-2014-6 hybrid generating facility at all times, not to exceed 100.2MW. The output shall also be monitored by PSCo operations.

Introduction

Public Service Company of Colorado (PSCo) received the request for evaluating a 52.2MWac Battery Energy Storage (BES) for Surplus Interconnection Service for GI-2014-6. GI-2014-6 is a 100.2MW Solar Photovoltaic (PV) Generation facility request with a Point of Interconnection (POI) at Midway 115kV Substation. The LGIA for GI-2014-6 was signed on 8/6/2017 and it is currently under suspension. The Interconnection Customer has made 52.2MW of Surplus Interconnection Service available for itself, starting 12/1/2022. Coincident with the start of the Surplus Interconnection Service, the expected COD of BES is 12/1/2022.

The 100.2MW Solar PV facility will consist of twenty-seven (27) TMEIC NINJA 840-PCS 3750kW/3975KVA inverters, each with its own 630V/34.5kV, 4200KVA, Z=6.3% pad-mounted generator step-up transformer. The 52.2MW BES facility will consist of eighteen (18) Freemaq PCSK P300k inverters rated 2900kW/3120KVA, each with its own 600V/34.5kV, 3120KVA pad-mounted step-up transformer. The collector systems of the PV and BES will interface with one 34.5/115kV, 70/93/116MVA wye-grounded/wye-grounded/buried delta main step-up transformer which in turn will connect to PSCo's Midway 115kV Substation.

The Surplus Interconnection Service will be made available 24/7, all days of the year, for as long as: 1) the LGIA associated with GI-2014-6 is in effect, and 2) the battery storage facility is in operation and adheres to the terms of its future Surplus GIA.

The final configuration of GI-2014-6 after the inclusion of the BES for Surplus interconnection will make it an AC-coupled hybrid Generation Facility. The expected operating modes of the Generating Facility are:

III. 100.2MW rated generation output at the POI via combination of PV and BES
IV. 52.2MW when the PV output is zero.

The BES is only expected to charge from the PV Generating Facility.

The main purpose of this study is to determine the system impact of interconnecting 52.2MW of BES generation for Surplus Interconnection[1] for GI-2014-6. As stated in the study agreement, the Surplus Interconnection selected Network Resource Interconnection Service (NRIS)[2].

Study Scope and Analysis Criteria

The scope of this report includes reactive power analysis at the POI, transient stability analysis and short circuit analysis for the following modes of the operation of the hybrid facility:

[1] **Surplus Interconnection Service** shall mean any unneeded portion of Interconnection Service established in a Large Generator Interconnection Agreement, such that if Surplus Interconnection Service is utilized the total amount of Interconnection Service at the Point of Interconnection would remain the same.

[2] **Network Resource Interconnection Service** shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission system (1) in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an RTO or ISO with market based congestion management, in the same manner as all other Network Resources. Network Resource Interconnection Service in and of itself does not convey transmission service.

1. 47.2MW PV and 52.2MW BES
2. 52.2MW BES
3. 100MW PV (The GI-2014-6 studies are six years old and the generation mix in the Southern Colorado has changed since the completion of the studies due to retirement of Comanche and new resources added as part of the 2016 Electric Resource Plan. This operating mode is only studied to benchmark the results of the BES operating mode and to identify the Surplus Interconnection Service evaluation results)

The reactive power analysis identifies the Generating Facility's ability to maintain at least unity voltage at the POI while maintaining ±0.95PF at the high-side of the main step-up transformer.

The transient stability analysis evaluates the ability of the Generating Facility to demonstrate satisfactory performance for select single and multiple contingencies.

The short circuit analysis determines that the maximum available fault current at the POI does not exceed the rating of the POI breaker identified as part of GI-2014-6 LGIA and identifies if any circuit breaker(s) within the PSCo station(s) exceed their breaker duty ratings.

PSCo adheres to applicable NERC Reliability Standards and WECC Reliability Criteria, as well as its internal transmission planning criteria for studies. 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 the Surplus Interconnection.

System Impact Study Power Flow Case Creation

Since the COD of the Surplus Interconnection Request is 12/1/2022, a 2023HS case was used for the analysis. The Base Case originated from the 2023HS case built for the 2018 TPL1 Work Group of the Colorado Coordinated Planning Group (CCPG). The case was reviewed and updated 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 closed and Smelter Town – West Canyon 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
- Briargate 230/115kV Transformer – ISD 2022

The Base Case model includes the existing PSCo generation resources and planned retirement of Comanche 1 in 2022.

The Benchmark Case for evaluating the system impact of the Surplus Interconnection Service 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
BAC_MSA GEN1 13.800	G1	1	90	90	BHE
BAC_MSA GEN2 13.800	G1	1	90	90	BHE
BAC_MSA GEN4 13.800	G1	1	35	40	BHE
BAC_MSA GEN4 13.800	G2	1	35	40	BHE
BAC_MSA GEN4 13.800	S1	1	20	24.8	BHE
BAC_MSA GEN5 13.800	G1	1	30	40	BHE
BAC_MSA GEN5 13.800	G2	1	30	40	BHE
BAC_MSA GEN5 13.800	S1	1	20	24.8	BHE
BAC_MSA GEN6 13.800	G1	0	0	40	BHE
BUSCHRNCH_LO0.7000	1	0	0	60	BHE
BUSCHRWTG1 0.7000	G1	1	20	28.8	BHE
RTLSNKWNDLO 0.7000	G1	1	14	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	200	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	6.1	30	TSGT
TBII_GEN 0.6900	W	1	64.8	76	TSGT
TSGT_0809 0.6200	PV	1	80	100	TSGT

A Study case was created from the Benchmark Case by adding the GI-2014-6 hybrid interconnection facility at the proposed Point of Interconnection (Midway 115kV). The output from GI-2014-6 was sunk pro-rata to the PSCo units outside the study area. The study generators were modeled using data supplied by the customer.

The Reactive Power at the POI analysis and the transient stability analysis was performed using General Electric's PSLF Ver.21.0_07 program. The stability behavior of the BES only and BES plus PV operating modes are compared to the PV only operating mode to identify the Surplus Interconnection Service of GI-2014-6. The transient stability analysis is studied by simulating three phase faults for selected single and multiple contingencies using standard clearing times. PSLF's DYTOOLS EPCL program was used to simulate the disturbances.

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 the regulating voltage of the POI.

According to the modeling data provided by the Customer, the Generating Facility has the following modeling parameters:

- Solar PV: Pmax =100MW, Pmin =0, Qmax = 33.46Mvar, Qmin = -33.46Mvar
- BES: Pmax =52.2MW, Pmin=-52.2MW, Qmax=20.79Mvar, Qmin=-20.79Mvar

Table 2 - Reactive Capability Evaluation

	Shunt	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	Lead/Lag
PV	0Mvar	100.2MW, 0MW / -33.46Mvar, 0Mvar	0.957/0.973	1.01	98.8	-50.6	0.890	Lead	1.01	98.8	-50.7	0.889	Lead
	0Mvar	100.2MW, 0MW / 33.46Mvar, 0Mvar	1.076/1.055	1.027	99.1	20.2	0.980	Lag	1.027	99.1	20.2	0.980	Lag
	7Mvar	100.2MW, 0MW / 33.46Mvar, 0MVar	1.085/1.064	1.029	99.1	27.9	0.962	Lag	1.029	99.1	27.9	0.962	Lag
PV+ BES	0Mvar	47.8MW, 52.2MW / -33.5Mvar, -20.8Mvar	0.926/0.925	1.003	98.5	-73.4	0.802	Lead	1.003	98.5	-73.5	0.801	Lead
	0Mvar	47.8MW, 52.2MW / 33.5Mvar, 20.8Mvar	1.095/1.099	1.028	98.9	41.1	0.923	Lag	1.028	98.9	41	0.923	Lag
	8.1Mvar	47.8MW, 52.2MW / 33.5Mvar, 20.8Mvar	1.1/1.104	1.026	98.9	48.6	0.897	Lag	1.026	98.9	48.5	0.898	Lag
BES	0Mvar	0MW, 52.2MW / -0Mvar, -20.8Mvar	0.996/0.978	1.017	51.7	-26	0.893	Lead	1.017	51.7	-26.1	0.893	Lead
	0Mvar	0MW, 52.2MW / -0Mvar, 20.8Mvar	1.049/1.072	1.029	51.8	16.7	0.952	Lag	1.029	51.8	16.7	0.952	Lag
	7.7Mvar	0MW, 52.2MW / -0Mvar, 20.8Mvar	1.053/1.077	1.027	51.8	24.2	0.906	Lag	1.027	51.8	24.2	0.906	Lag
PV+ BES	0Mvar	0MW, 0MW/ 0Mvar, 0Mvar	1.024/1.024	1.023	0	1.3	N/A	Lag	1.023	0	1.3	N/A	Lag
	7.5Mvar	0MW, 52.2MW / -0Mvar, 20.8Mvar	1.033/1.033	1.025	0	8.7	N/A	Lag	1.025	0	8.7	N/A	Lag

From the analysis in Table 2, the Generating Facility is capable of maintaining at least nominal voltage at the POI in the BES and PV+BES operating modes. It should be noted that the Generating Facility is not capable of meeting 0.95 lagging power factor at the high-side of the main step-up transformer for the BES only operating mode and voltage at the generator terminals is outside the normal voltage operating range of 0.95-1.05 p.u. The Interconnection Customer must address these issues in the detailed design of the Generating Facility and capture the updates surplus agreements.

Transient Stability Study Results

Table 3 Transient Stability Analysis Results

Stability Scenarios						
#	**Fault Location**	**Fault Type**	**Facility Tripped**	**Clearing Time (cycles)**	**Post-Fault Voltage Recovery**	**Angular Stability**
1	Midway 115kV	3ph	None	5.0	Maximum transient voltage dips within criteria	Stable with positive damping
2	Midway – Fuller 115kV Breaker Failure	3ph	Midway – Fuller 230kV line, Midway WAPA 230kV bus and Midway WAPA 115kV bus	5.0	Maximum transient voltage dips within criteria	Stable with positive damping

The stability analysis studied the following operating modes of the hybrid facilities:

1. 47.2MW PV and 52.2MW BES (see note below)
2. 52.2MW BES
3. 100MW PV (The GI-2014-6 studies are six years old and the generation mix in the Southern Colorado has changed since the completion of the studies due to retirement of Comanche and new resources added as part of the 2016 Electric Resource Plan. This operating mode is only studied to benchmark the results of the BES operating mode and to identify the Surplus Interconnection Service evaluation results)

The results of the transient stability analysis are given in Table 3. The interconnection of the 52.2MW BES Surplus Generating facility produced satisfactory stability performance. For all the disturbances analyzed, the following results were observed:

- ✓ No transient voltage drop violations were observed
- ✓ Machine rotor angles displayed positive damping

Note: The PV Generating Facility in the PV+BES operating mode did not recover to the pre-fault generation output for both faults studied. The PV Generating Facility Plant Controller and Excitation model parameters should be fine tuned to remedy this behavior. The corrections need to be identified and captured before the execution of the Surplus Interconnection Agreement.

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 additional fault current contributions from the BES as seen at Midway 115kV POI is not significant.

A preliminary breaker duty study did not identify any circuit breakers that became over-dutied"[3] as a result of adding the BES generation. Also, the breaker at the POI is adequately rated to handle the additional fault current contribution from the BES facility.

Conclusion:

The study did not find any impact to the stability or short circuit analysis performed due to the addition of the 52.2MW BES as Surplus Interconnection Service to GI-2014-6.

Surplus Interconnection Service = 52.2MW

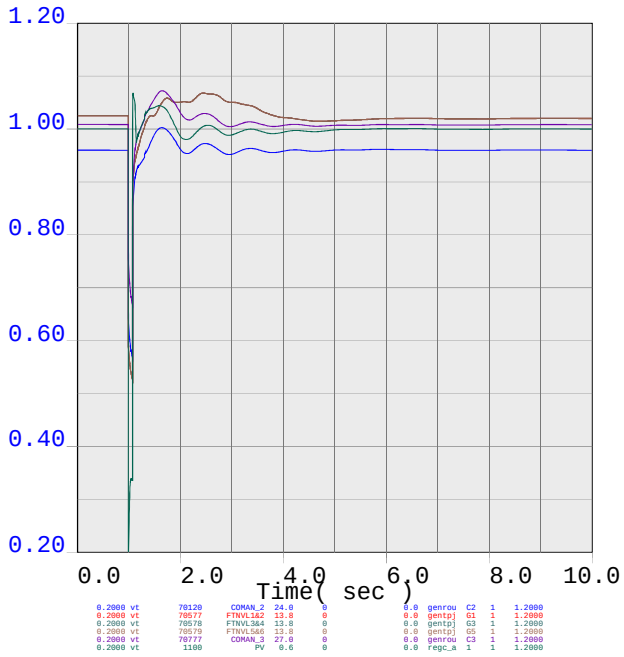
The Surplus Interconnection Service will be made available 24/7, all days of the year, for as long as: 1) the LGIA associated with GI-2014-6 is in effect, and 2) the battery storage facility is in operation and adheres to the terms of its future Surplus GIA.

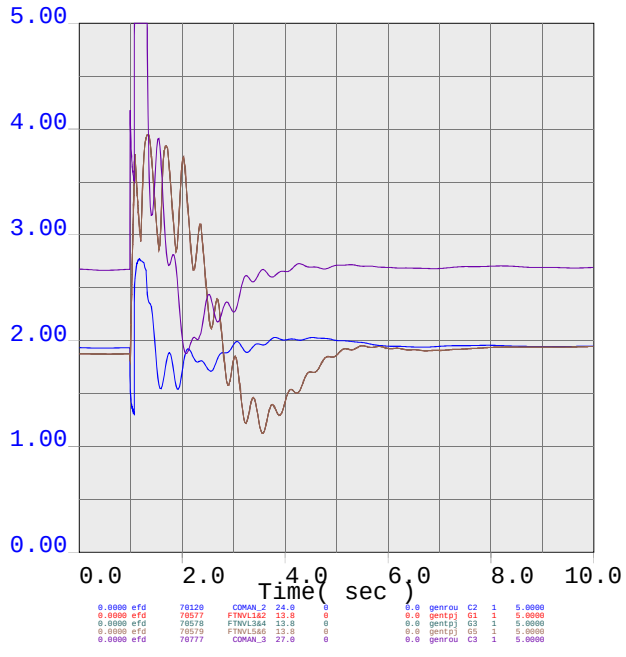
This study assumed that the underlying generator is in-service and has a Interconnection Agreement. Note that at this time, the underlying generator is not constructed and the LGIA is in suspension. If the underlying interconnection agreement is terminated or if changes to the generating facility assumptions result in a Material Modification, the results of this Surplus Interconnection Study are invalid.

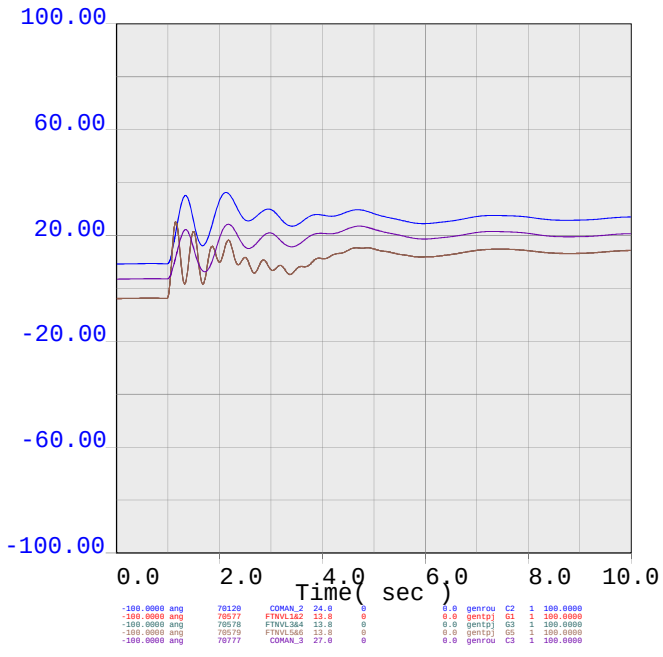
The Interconnection Customer is required to design and build the Generating Facility to mitigate for any potential inverter interactions with the neighboring inverter based Generating Facility(ies) and/or the inverters of the hybrid Generating Facility.

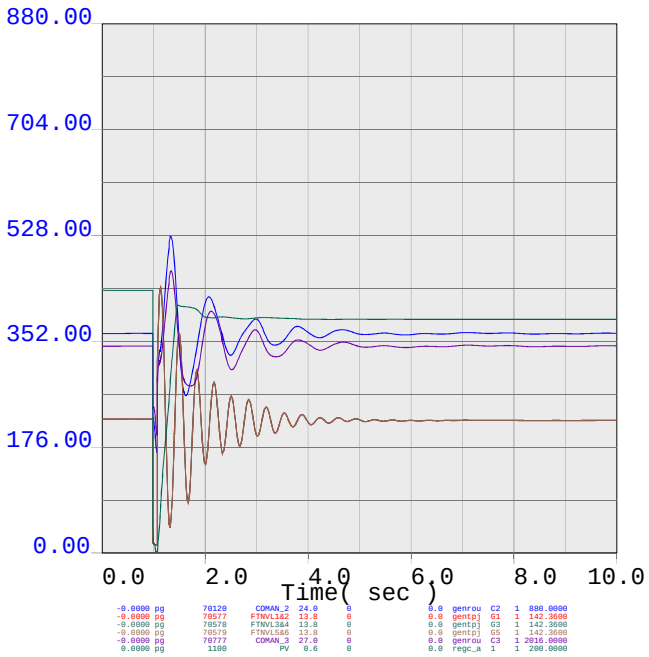
The Interconnection Customer shall use the Plant Controller to limit the output of GI-2014-6 hybrid generating facility at all times, not to exceed 100.2MW. The output shall also be monitored by PSCo operations.

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

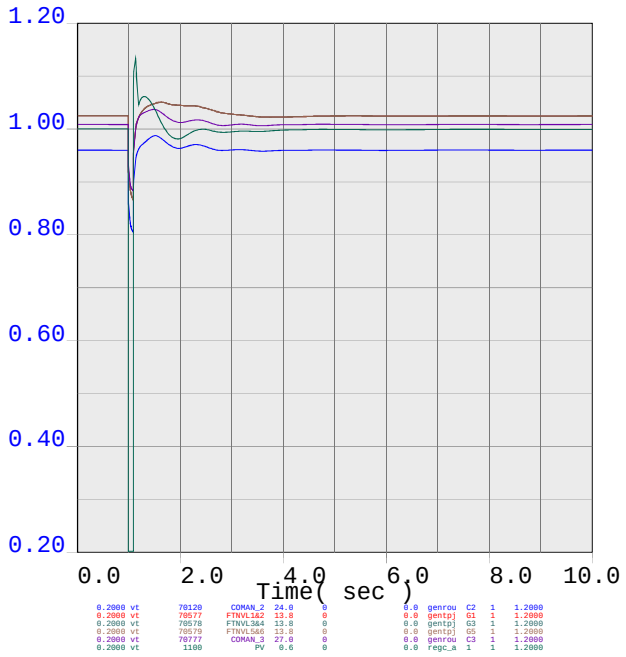


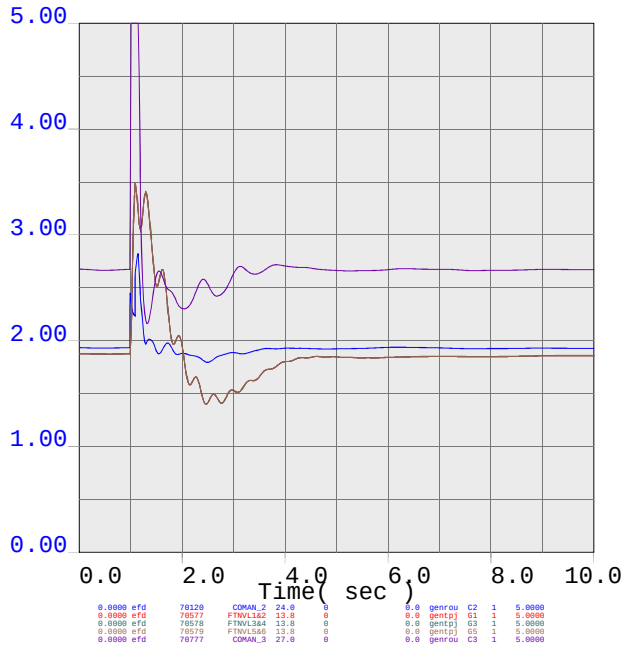


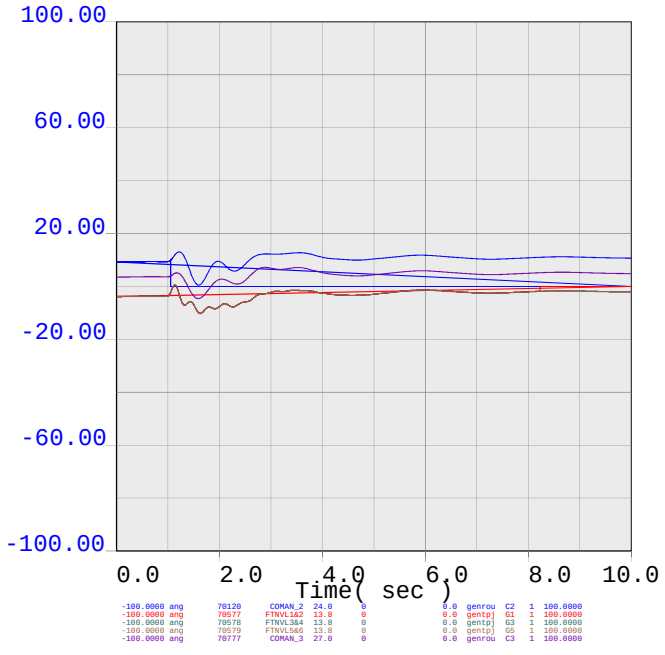


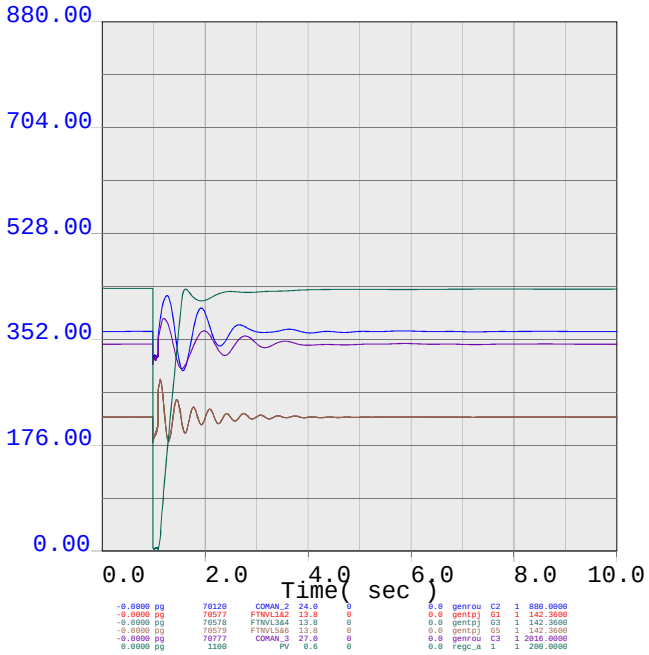


Fault_2
MIDWAYPS-Fuller 230kV Breaker Failure, Lose Mid-Ful and Midway WAPA 115kV and 2







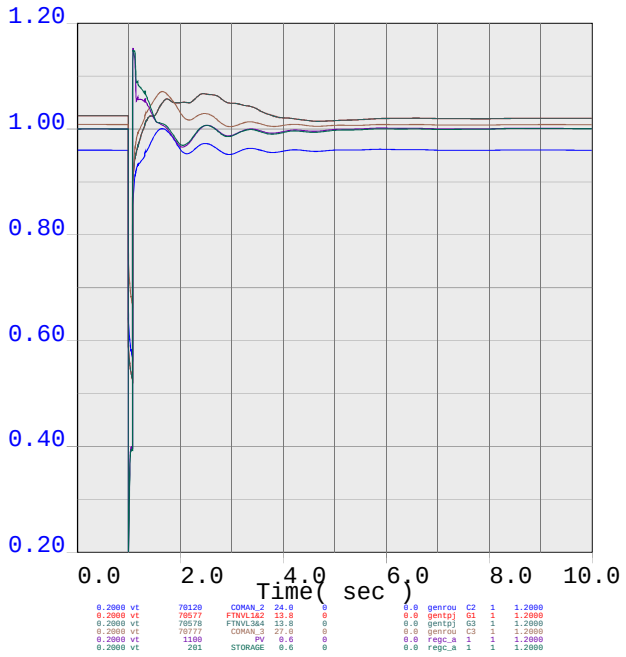


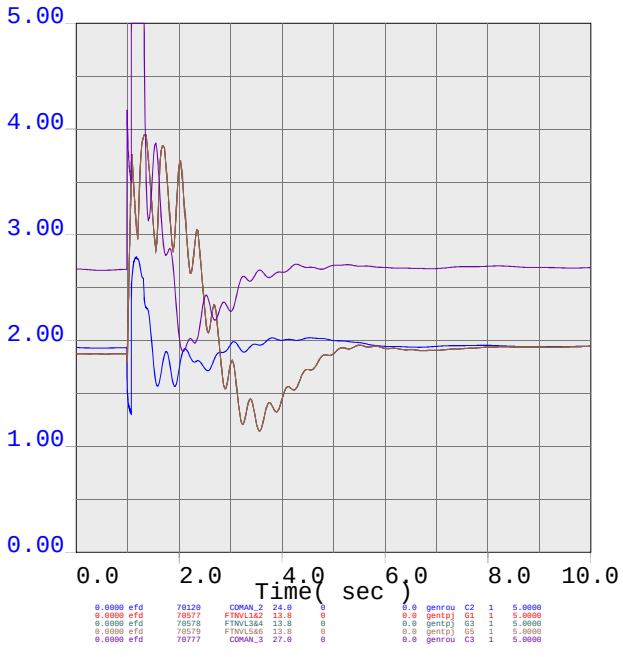
Fault_1
Midway 115kV bus fault, no contingency

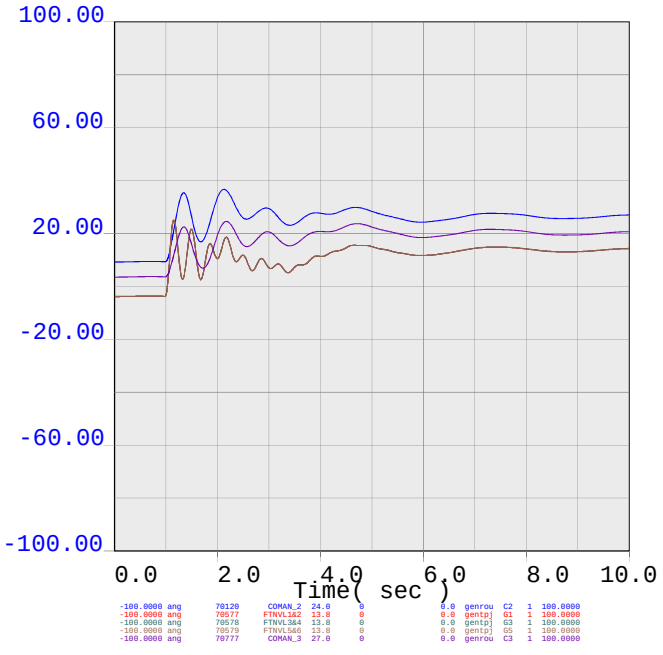
psec-run-gi-2014-6-PV-Fault_1.chf

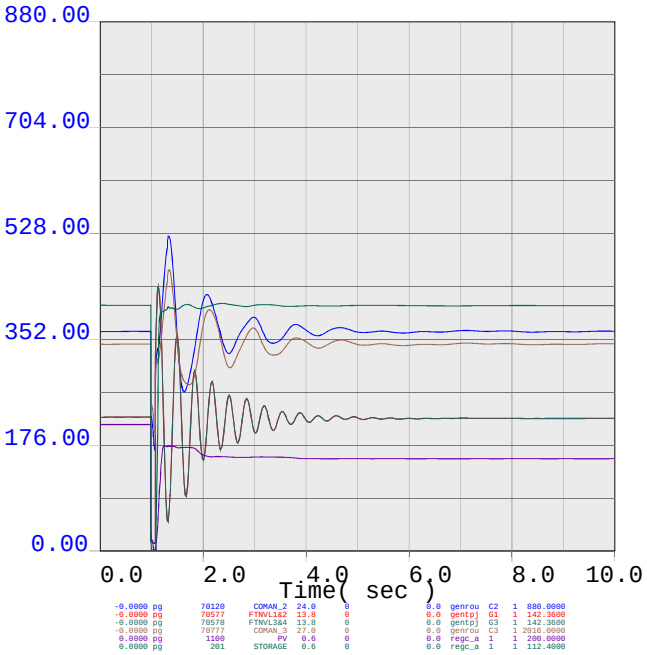
lus_TCR\Surplus\SIS\chans

Mon Mar 16 10:17:24 2020

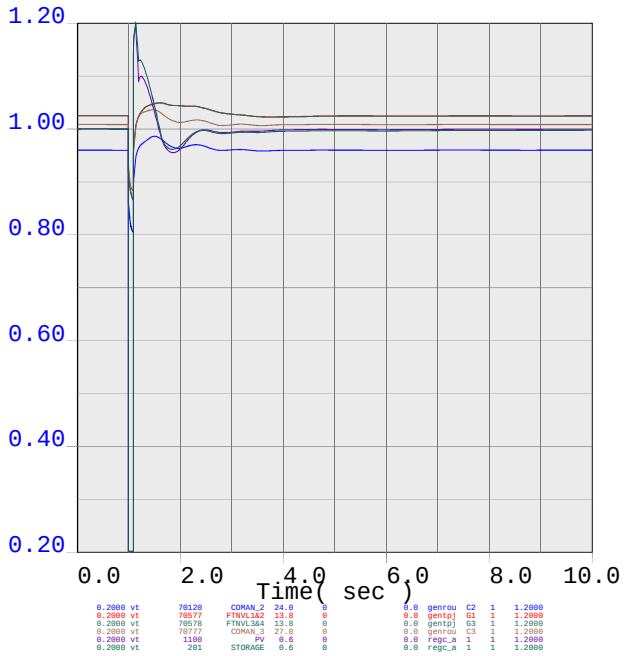


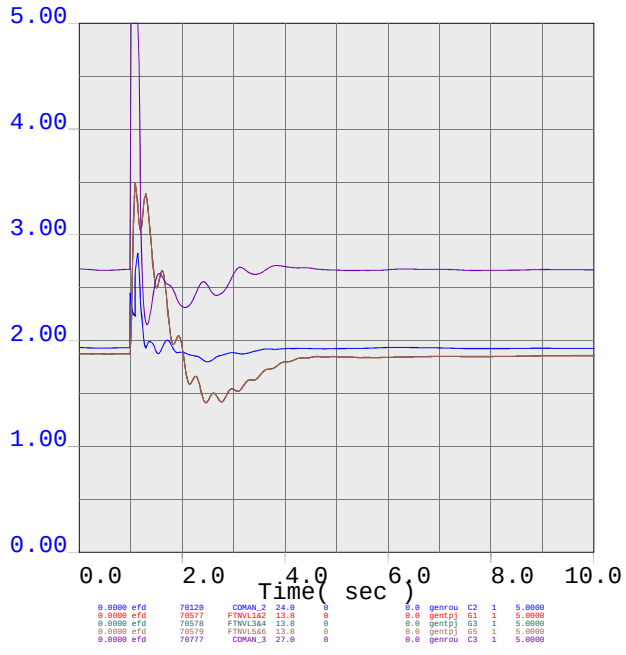


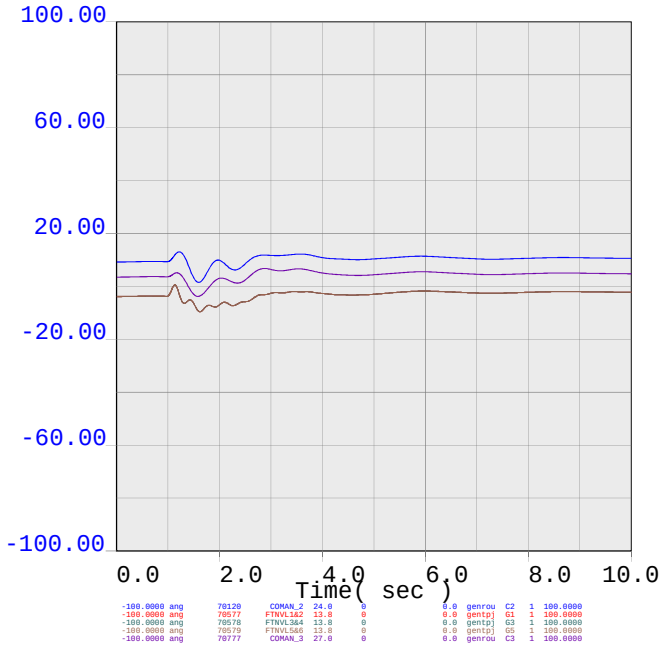




Fault_2
MIDWAYPS-Fuller 230kV Breaker Failure, Lose Mid-Ful and Midway WAPA 115kV and 2





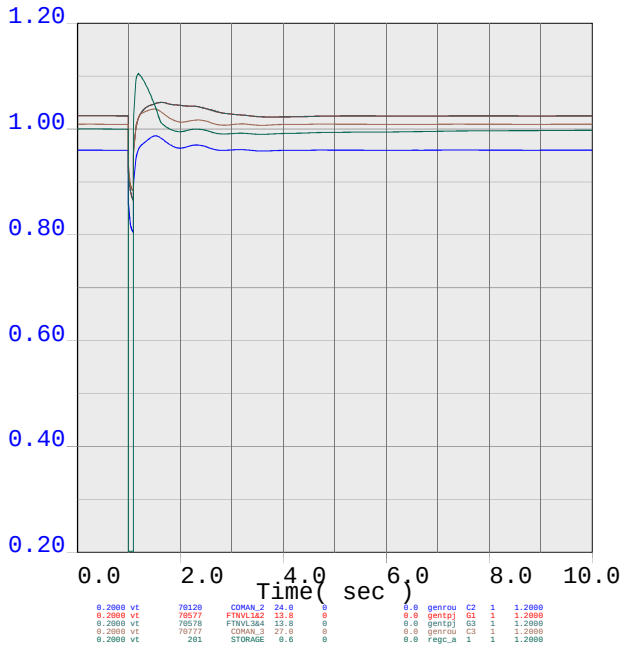


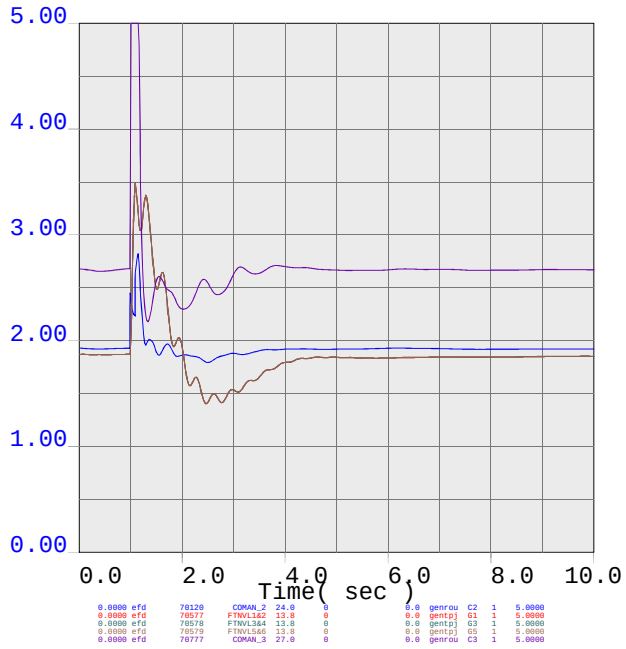
Fault_1
Midway 115kV bus fault, no contingency

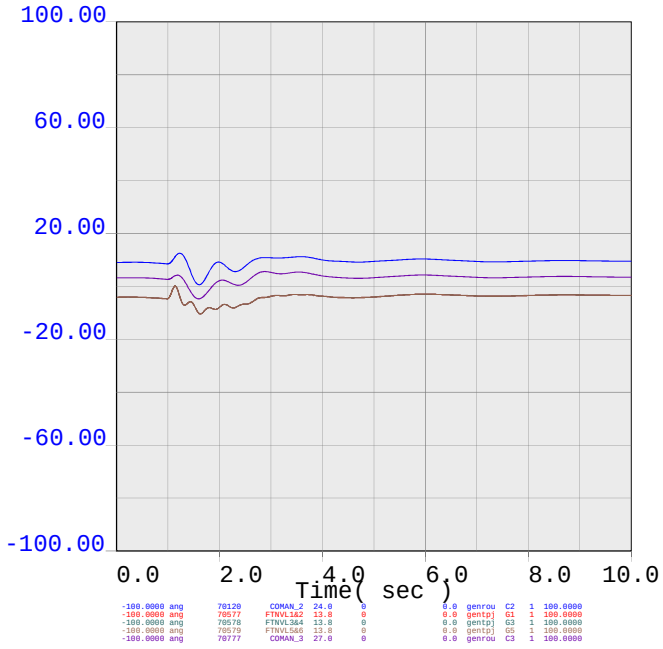
psec-run-gi-2014-6-PV-BES-Fault_1.chf

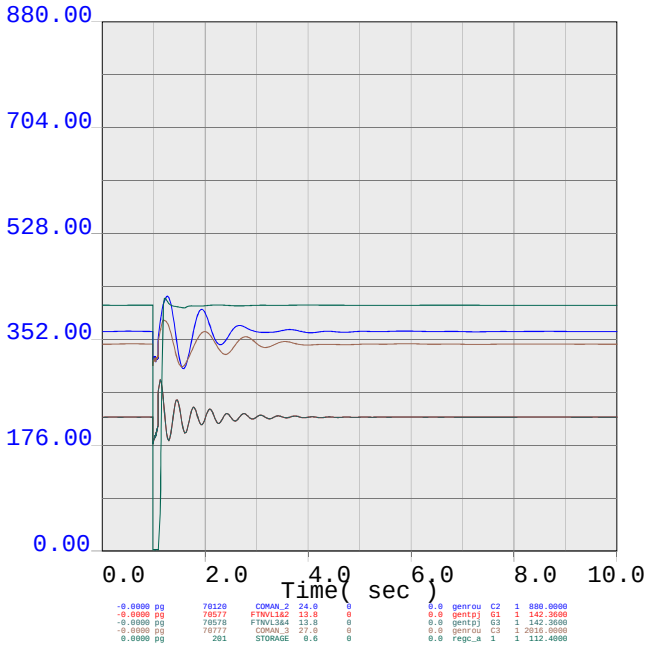
lus_TCR\Surplus\SIS\chans

Mon Mar 16 10:29:23 2020







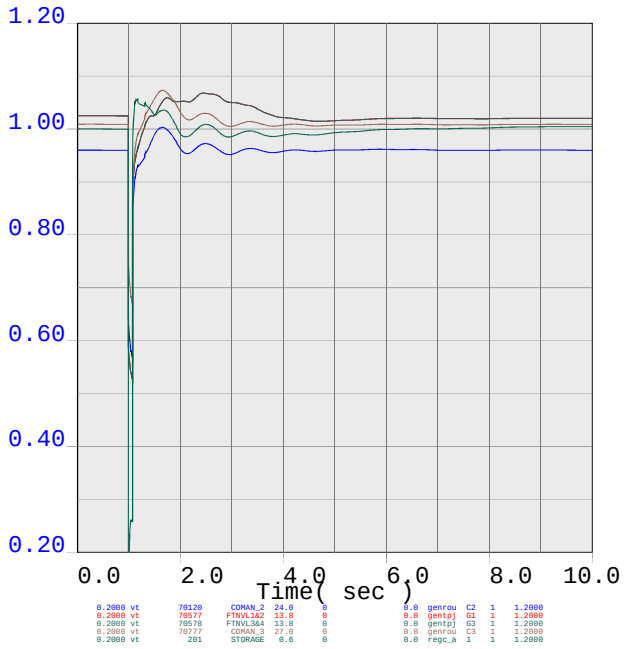


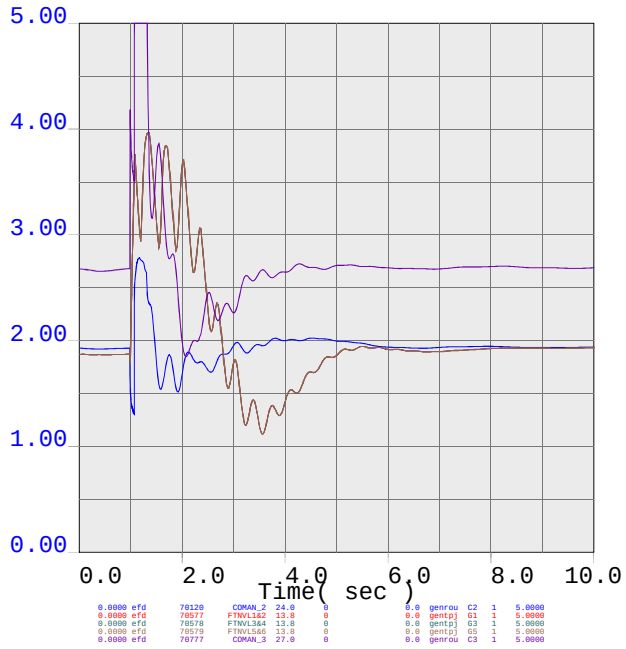
Fault_1
Midway 115kV bus fault, no contingency

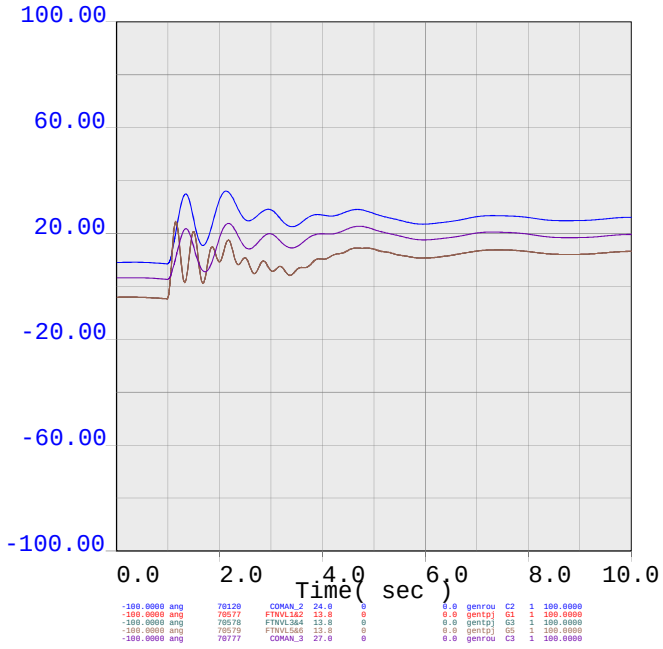
psec-run-gi-2014-6-BES-Fault_1.chf

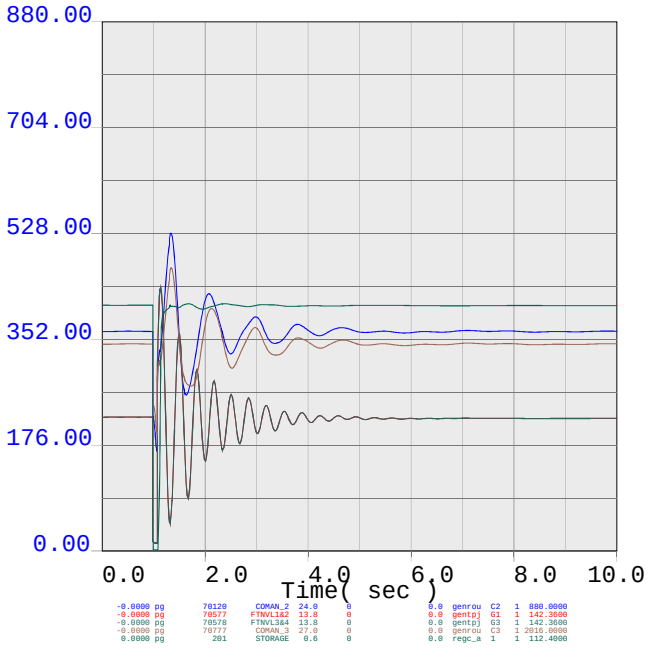
lus_TCR\Surplus\SIS\chans

Mon Mar 16 10:30:06 2020









Fault_2
MIDWAYPS-Fuller 230kV Breaker Failure, Lose Mid-Ful and Midway WAPA 115kV and 2