



Interconnection System Impact Study Report Request # GI-2012-6

**30 MW Solar Photovoltaic Generating Facility
Missile Site 230 kV Station, Colorado**

**Public Service Company of Colorado
Transmission Planning
August 8, 2014**

Executive Summary

Public Service Company of Colorado (PSCo) received an interconnection request for a 30 MW solar photovoltaic generating facility on October 26, 2012 that was assigned GI-2012-6 as the queue number. The proposed generating facility will be located on 545 acres of currently farmed land approximately 0.5 miles away from PSCo's Missile Site 345/230 kV Station. The primary point of interconnection (POI) requested for GI-2012-6 is the Missile Site 230 kV bus and the generating facility will interconnect to the POI using a new 230 kV, 0.5-mile long transmission line. The in-service date (ISD) requested for GI-2012-6 generating facility is December 31, 2016, and the request will be studied as both a Network Resource and Energy Resource*.

This request was studied as a stand-alone generator interconnection that excluded any other new generation requests existing in the PSCo Generator Interconnection Request queue, except for the generator interconnection projects that are already planned to be in service by the winter of 2016. The main purpose of this System Impact Study was to evaluate the potential impact on the interconnected transmission system of PSCo and its neighboring utilities (the affected parties) due to an additional 30 MW of generation injected into the Missile Site 230 kV bus. The results of each transient stability run were analyzed to determine whether any violation of transient voltage dip criteria, violation of transient frequency dip, or loss of generator synchronism occurred in the Western Electricity Coordinating Council (WECC) system before or after the generation project was interconnected. It should be noted that PSCo studied the interconnection using the provided detailed project model. The Interconnection Customer is responsible to provide an equivalent model upon modeling the generation project within official WECC base cases.

* Energy Resource Interconnection Service allows Interconnection Customer to connect the Large Generating Facility to the Transmission System and be eligible to deliver the Large Generating Facility's output using the existing firm or non-firm capacity of the Transmission System on an "as available" basis. Energy Resource Interconnection Service does not in and of itself convey any right to deliver electricity to any specific customer or Point of Delivery.

The transient stability analysis found **no criteria violations** in the pre-project or post-project bases for any of the studied outages in the heavy summer peak base case. Therefore, this project is determined to cause no violations and to produce no adverse impacts for existing violations related to the transient behavior of the WECC system. The following list tabulates the results obtained for the benchmark and project cases analyzed:

- No machines lost synchronism with the system
- No transient voltage dip violations were observed
- No transient frequency dip violations were observed

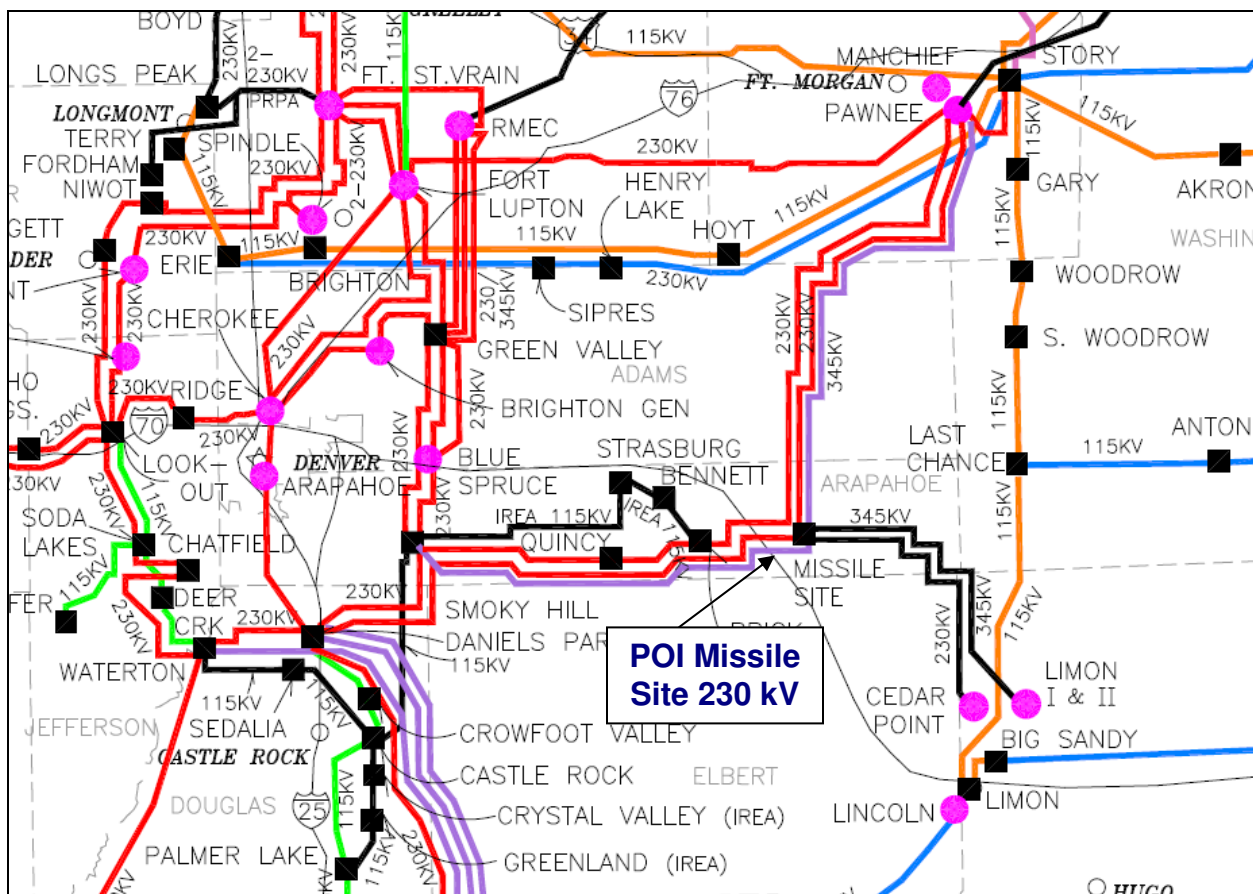


Figure 1 Missile Site, Pawnee, Daniels Park, and Surrounding Transmission System

Introduction

Public Service Company of Colorado (PSCo) received an interconnection request for a 30 MW solar photovoltaic generating facility on October 26, 2012 that was assigned GI-2012-6 as the queue number. The proposed generating facility will be located on 545 acres of currently farmed land approximately 0.5 miles away from PSCo's Missile Site 345/230 kV Station. The primary point of interconnection (POI) requested for GI-2012-6 is the Missile Site 230 kV bus and the generating facility will interconnect to the POI using a new 230 kV, 0.5- mile long transmission line. The in-service date (ISD) requested for GI-2012-6 generating facility is December 31, 2016.

Study Scope and Analysis

The System Impact Study evaluated the transmission impacts associated with the proposed generation project. The study consisted of transient stability analysis only. Power flow and short circuit analyses were conducted as a part of the Feasibility Study and published in the report dated April 2, 2014. The analysis identified any dynamic or transient stability problems associated with the new generation.

PSCo adheres to NERC & WECC Reliability Criteria, as well as internal Company criteria for planning studies. During system intact conditions, criteria are to maintain transmission system bus voltages between 0.95 and 1.05 per unit of nominal, and steady-state power flows below the thermal ratings of all facilities. Operationally, PSCo attempts to maintain a transmission system voltage profile ranging from 1.02 per unit or higher at regulating (generation) buses to 1.0 per unit or higher at transmission load buses. Following a single contingency, transmission system steady state bus voltages must remain within 0.90 per unit to 1.10 per unit, and power flows within 100% of the facilities' continuous thermal ratings. Also, voltage deviations should not exceed 5%.

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

- Following fault clearing for single contingencies:
 - Voltage may not drop more than 25% of the pre-fault voltage at load buses, more than 30% at non-load buses, or more than 20% for more than 20 cycles at any bus.
 - Frequency may not drop below 59.6 Hz for 6 cycles or more at load buses.
- Following fault clearing for double contingencies:
 - Voltage may not drop more than 30% of the pre-fault voltage at any bus or more than 20% for more than 40 cycles at any bus.

- Frequency may not drop below 59.0 Hz for 6 cycles or more at load buses.

Power Flow Study Models

The GI-2012-6 System Impact Study was performed using a WECC 2019 heavy summer (2019HS) power flow base case with associated dynamic modeling data in GE PSLF format – the latest available base case nearest to the interconnection in-service date. The study includes transient stability analyses for the Benchmark case (Before GI-2012-6) and the Study case (After GI-2012-6). The 2019HS base case assumes the TOT-3 major path flow (north-south) at 670 MW and was updated to dispatch the existing and planned wind generation interconnected at Pawnee and Missile Site stations at their maximum expected coincident output (based on 2012-13 winter operating data). The resulting Benchmark case was then used to create the Study case by adding GI-2012-6 at the Missile Site 230kV bus and dispatching the generator at 30 MW rated output. The wind and solar generation dispatch used at Pawnee and Missile Site stations in the two cases is as follows:

- ✓ Peetz Logan (Pawnee 230kV) = 80% of rated capacity = 461 MW
- ✓ Limon I and Limon II (Missile Site 345kV) = 97% of rated capacity = 392 MW
- ✓ Cedar Point (Missile Site 230kV) = 96% of rated capacity = 240 MW
- ✓ Planned Limon III (Missile Site 345kV) = 97% of rated capacity = 196 MW
- ✓ Proposed GI-2012-6 (Missile Site 230kV) = 100% of rated capacity = 30 MW

The study also assumed generation dispatch changes in other areas of the PSCo system to accommodate wind and solar dispatch and to more accurately represent the generation available in 2019. The changes to the two cases are as follows:

- ✓ Manchief Units 1 and 2 (Pawnee 230kV) = 0% of rated capacity = 0 MW
- ✓ Ft. St. Vrain Units 2-5 (Ft. St. Vrain 230 kV) = 0% of rated capacity = 0 MW
- ✓ Valmont Unit 5 (Valmont 115 kV) = 0% of rated capacity = 0 MW
- ✓ Spruce Units 1-2 (Spruce 230 kV) = 93% of rated capacity = 260 MW

Study Process

Transient stability analysis was completed on the reference models and the models with the proposed new generation using GE's PSLF Ver. 18.1_02 program. NERC Category B & C contingencies were considered as part of the analysis, including standard clearing and delayed clearing single events. Bus voltage, bus frequency, and generator angle were recorded and compared to the WECC allowable criteria. Also, any generators that went out of synchronism were recorded. WECC's ALLDYNS.p EPCL program was used to simulate the disturbances.

Disturbances Studied

Eight transient stability disturbances were simulated for the benchmark and project cases, including the following:

A. NERC/WECC Category B Disturbances

(Three-phase, close-in faults at * with normal clearing of 6 cycles)

1. Missile Site* - Daniels Park 230 kV Line
2. Missile Site* - Pawnee 230 kV Line
3. Missile Site* - Smoky Hill 345 kV Line
4. Missile Site* - Pawnee 345 kV Line
5. Daniels Park* - Greenwood 230 kV Line
6. Pawnee* - Story 230 kV Line

B. NERC/WECC Category C Disturbances

(Single-line-to-ground, close-in faults at * with delayed clearing of 21 cycles)

7. Missile Site* - Daniels Park 230 kV Line
8. Missile Site* - Pawnee 230 kV Line

Study Results

The transient stability analysis for the GI-2012-6 System Impact Study simulated each of the eight disturbances listed for both of the two study cases. The results of each transient stability run were then analyzed to determine whether the voltage and frequency performed within the WECC criteria and whether generators continued in synchronism before or after the proposed generation was interconnected. As noted previously, a case was studied using the detailed model provided by the Interconnection Customer.

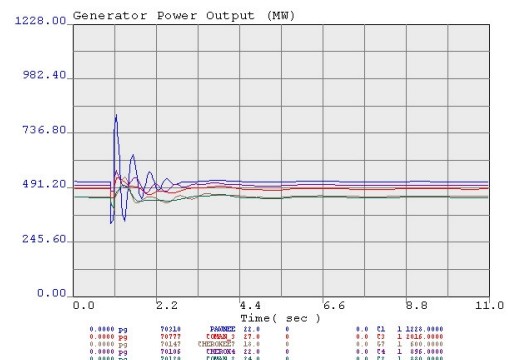
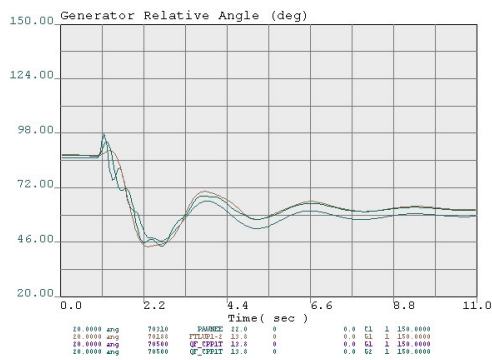
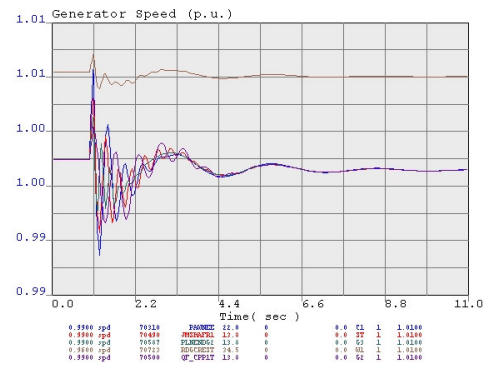
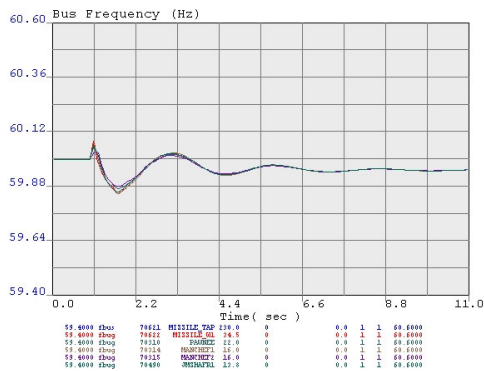
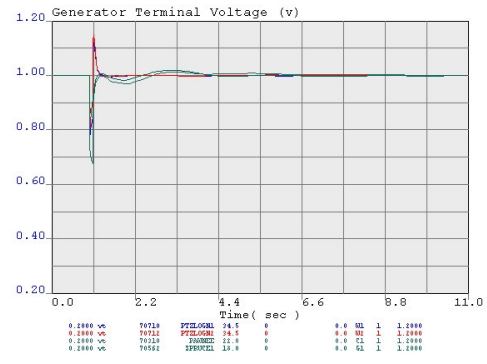
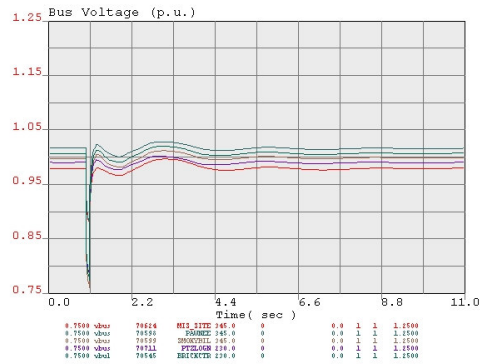
The GI-2012-6 transient stability analysis found no criteria violations in the pre-project and post-project cases for any of the studied outages. Therefore, this project is determined to cause no violations and to produce no adverse impacts for existing violations related to the transient behavior of the WECC system. The following results were obtained for every case and disturbance analyzed:

- ✓ No machines lost synchronism with the system
- ✓ No transient voltage drop violations were observed
- ✓ No transient frequency drop violations were observed

Transient stability plots showing surrounding bus voltages, bus frequencies, generator terminal voltages, generator relative angles, generator speeds, and generator power output for each of the disturbances run for each study scenario have been created and documented in Appendix A.



Appendix A Transient Stability Plots



19hs21 BASE CASE
 Benchmark case
 GI-2012-6 stability analysis
 Fault on Missile 230 kV bus - clear in 6 cycles
 Element removed: Missile Site - Daniels Park 230 kV
 ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.

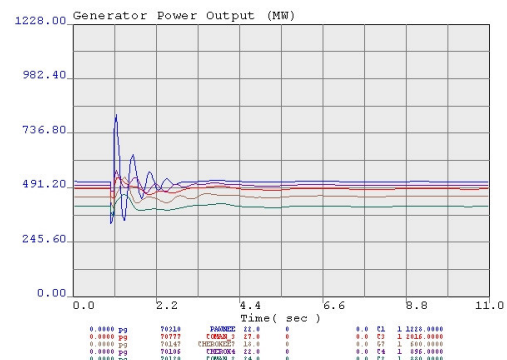
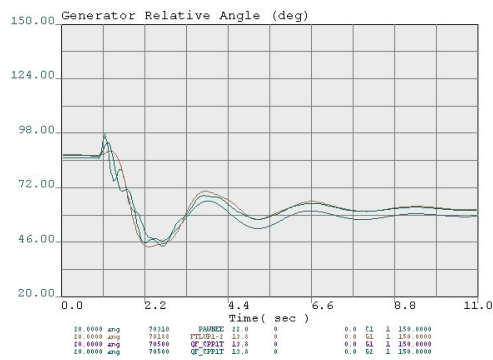
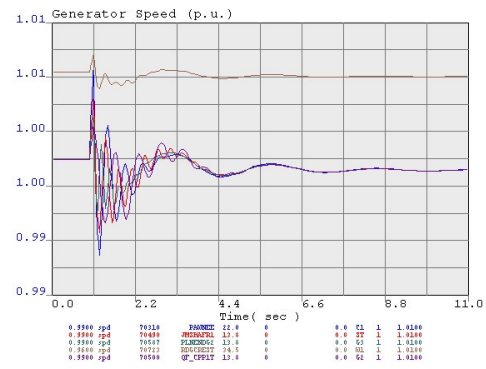
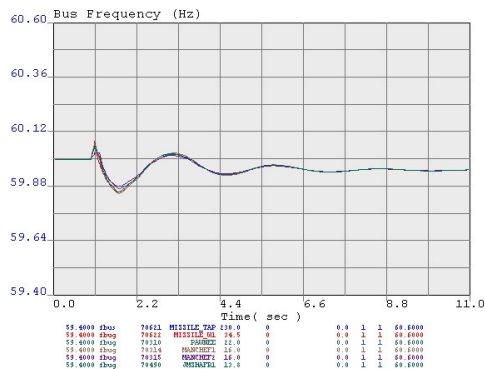
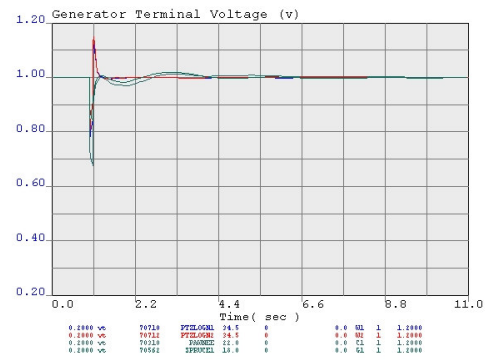
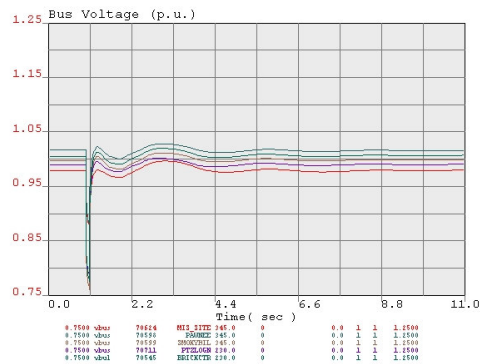


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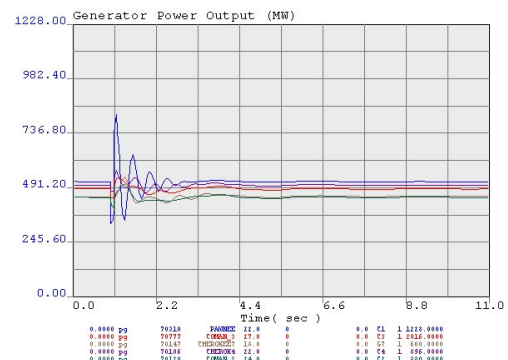
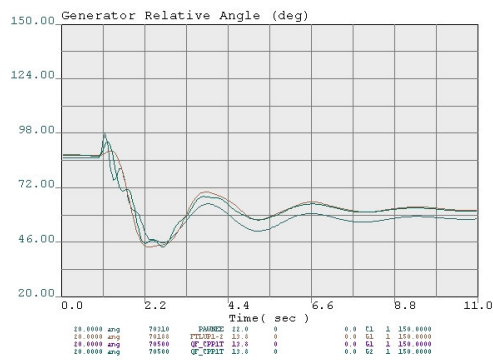
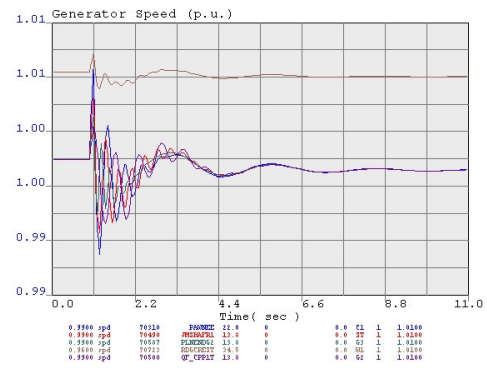
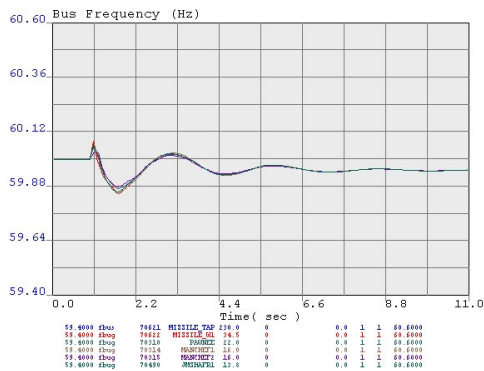
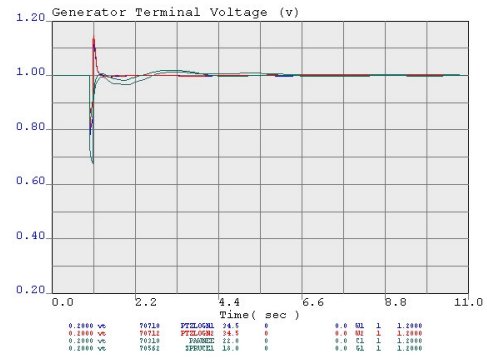
Page 1

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19hs21_GI-2012-6 BASE CASE
30MW solar PV generation at Missile Site 230 kV bus
GI-2012-6 stability analysis
Fault on Missile 230 kV bus - clear in 6 cycles
Element removed: Missile Site - Daniels Park 230 kV
ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.



19hs21 BASE CASE
 Benchmark case
 GI-2012-6 stability analysis
 Fault on Missile 230 kV bus - clear in 6 cycles
 Element removed: Missile Site - Pawnee 230 kV
 ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.

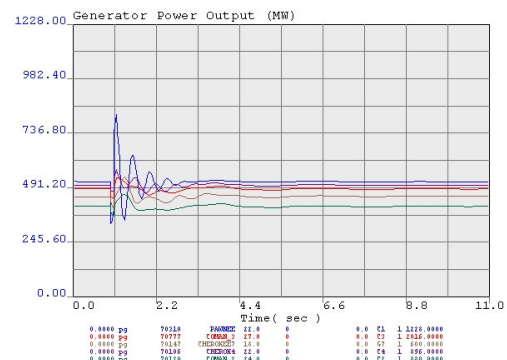
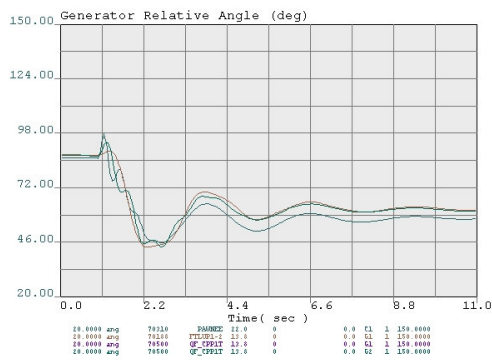
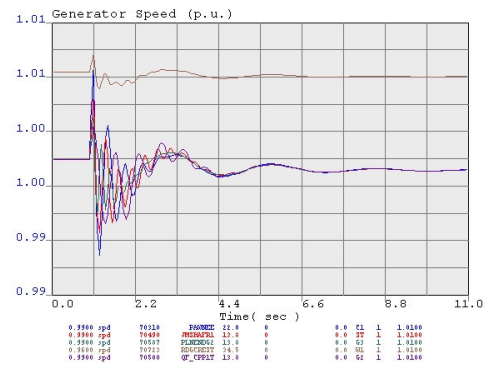
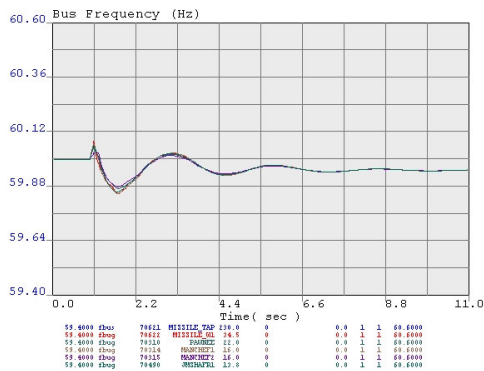
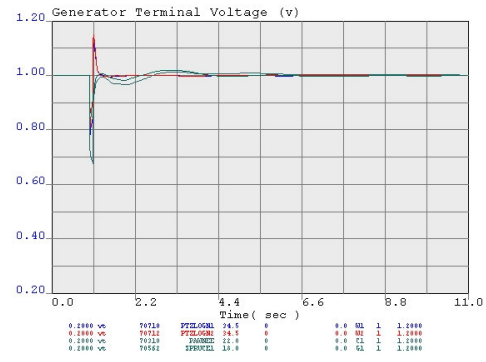
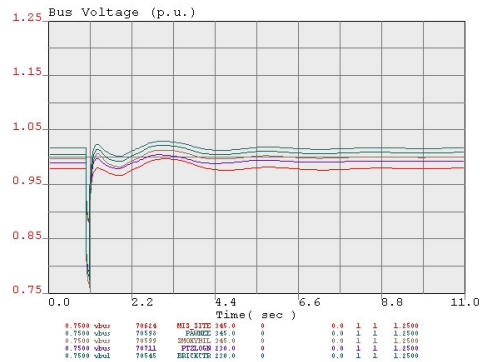


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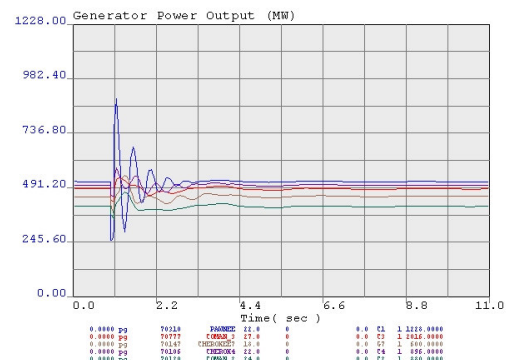
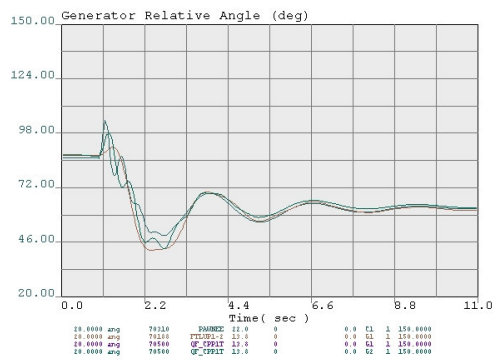
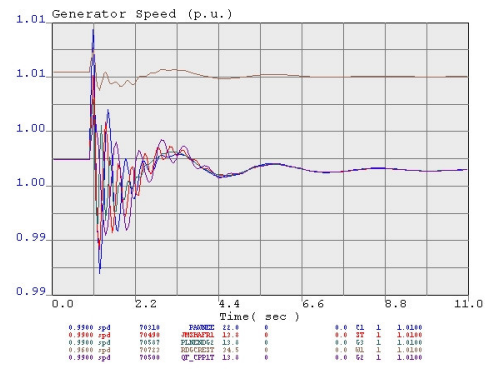
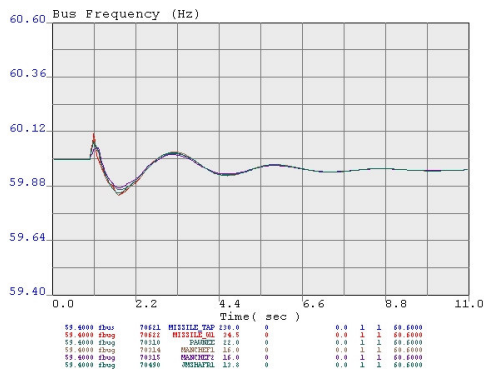
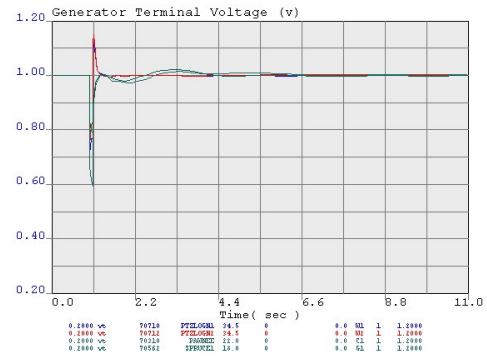
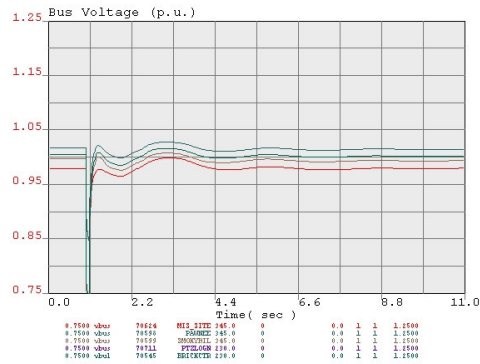
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 GI-2012-6 stability analysis
 Fault on Missile 230 kV bus - clear in 6 cycles
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 ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.



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19hs21_GI-2012-6 BASE CASE
 30MW solar PV generation at Missile Site 230 kV bus
 GI-2012-6 stability analysis
 Fault on Missile 345 kV bus - clear in 6 cycles
 Element removed: Missile Site - Smoky Hill 345 kV
 ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.

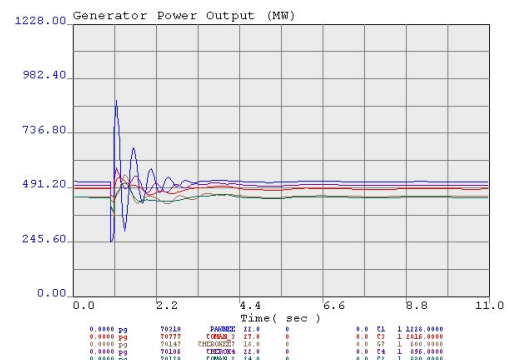


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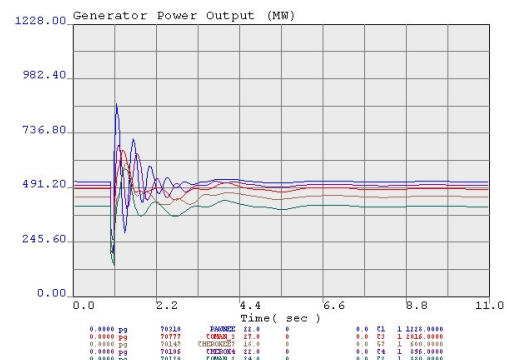
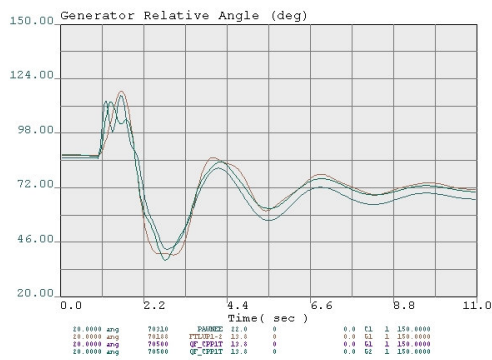
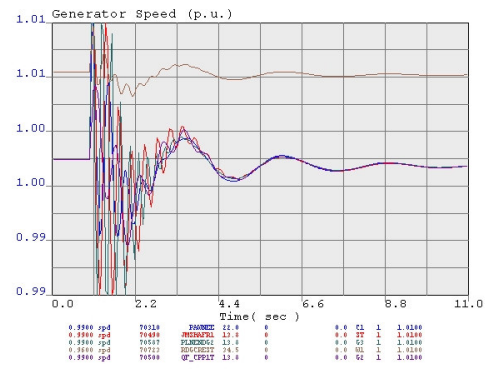
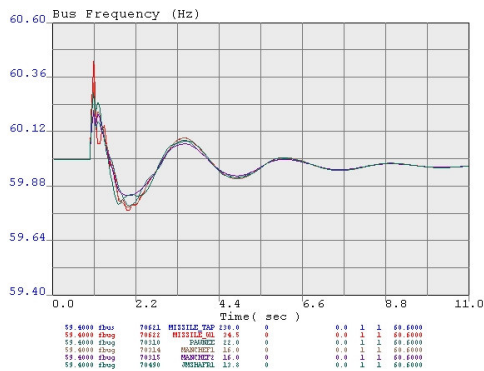
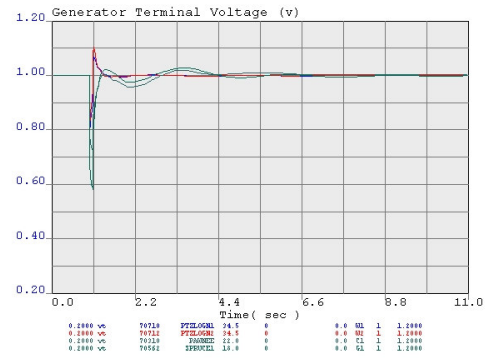
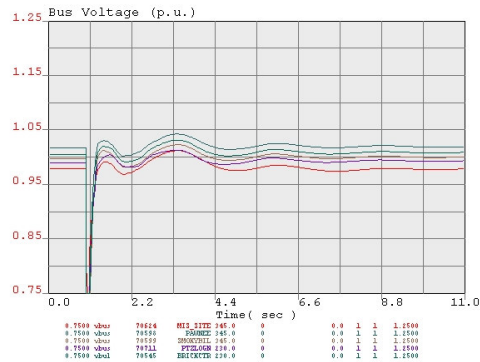
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 GI-2012-6 stability analysis
 Fault on Daniels Park 230 kV bus - clear in 6 cycles
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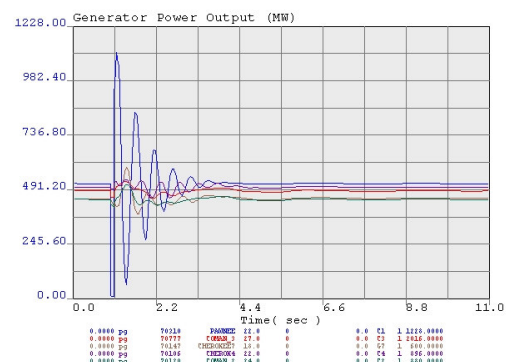
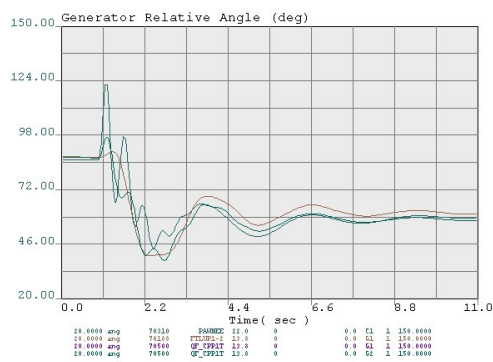
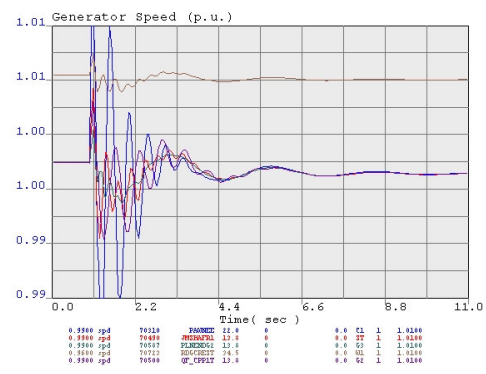
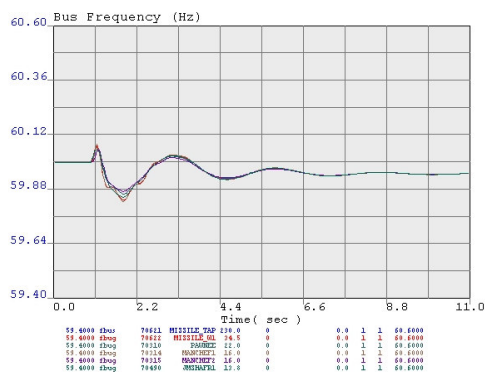
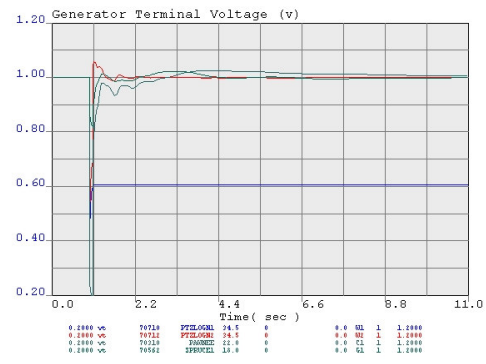
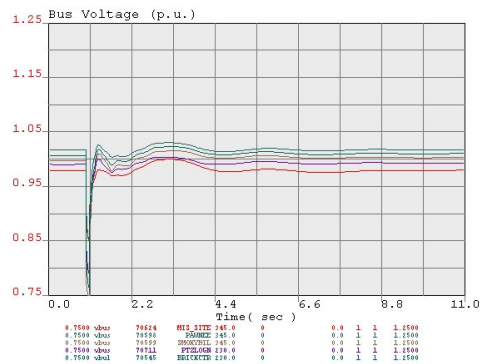


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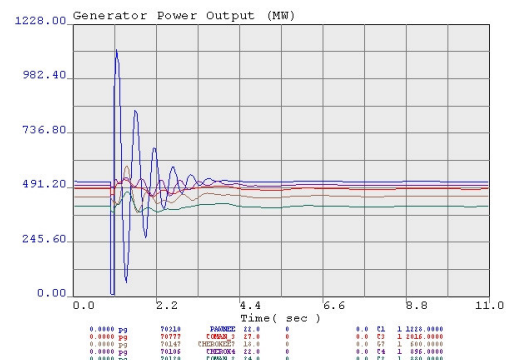
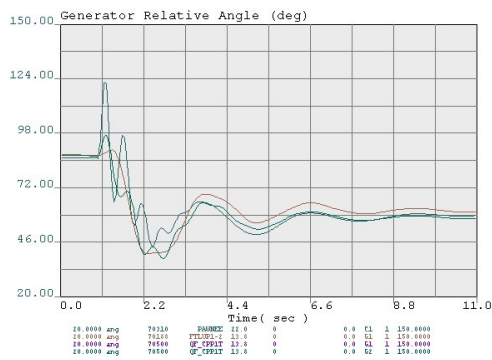
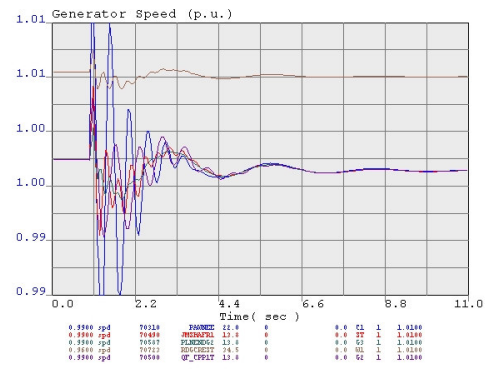
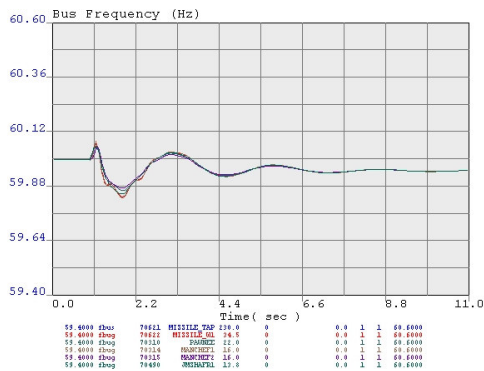
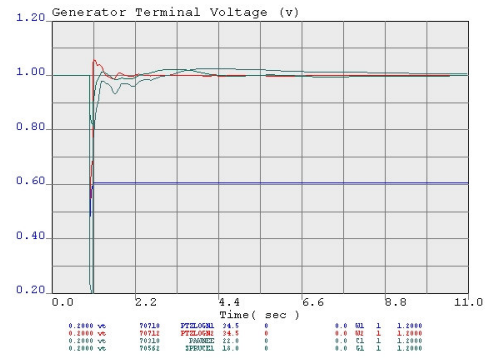
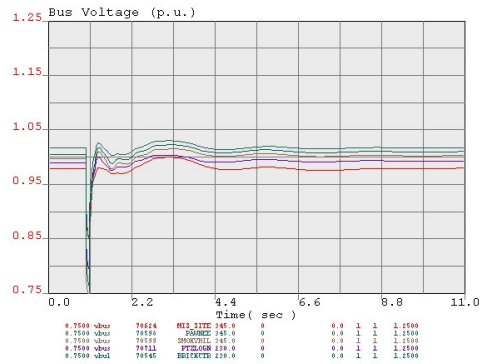
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Benchmark case
GI-2012-6 stability analysis
Fault on Pawnee 230 kV bus - clear in 6 cycles
Element removed: Pawnee - Story 230 kV
ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.



19hs21_GI-2012-6 BASE CASE
 30MW solar PV generation at Missile Site 230 kV bus
 GI-2012-6 stability analysis
 Fault on Pawnee 230 kV bus - clear in 6 cycles
 Element removed: Pawnee - Story 230 kV
 ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.

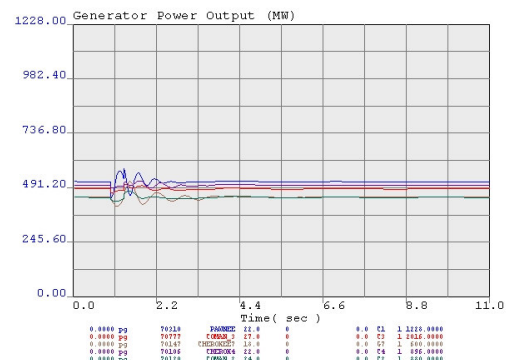
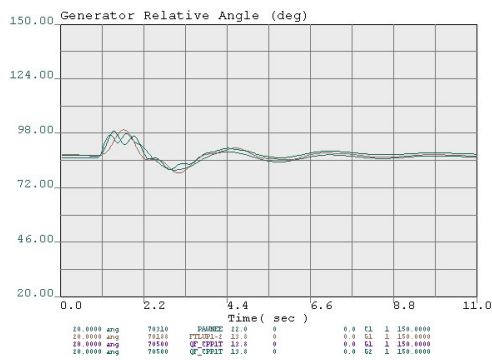
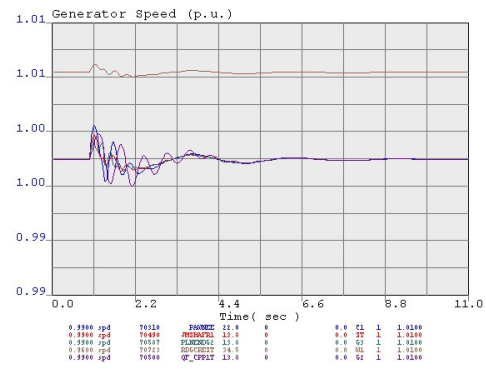
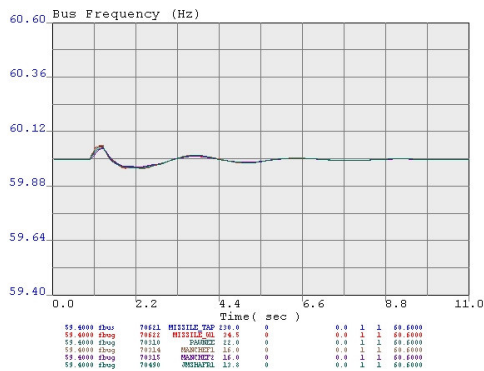
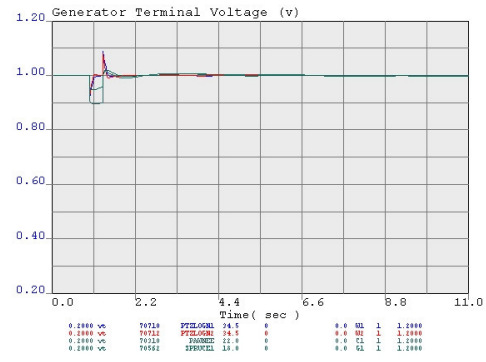
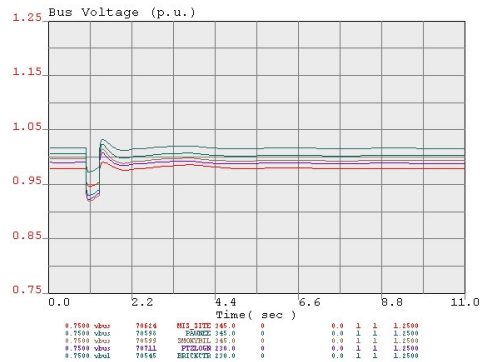


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19hs21 BASE CASE
 Benchmark case
 GI-2012-6 stability analysis
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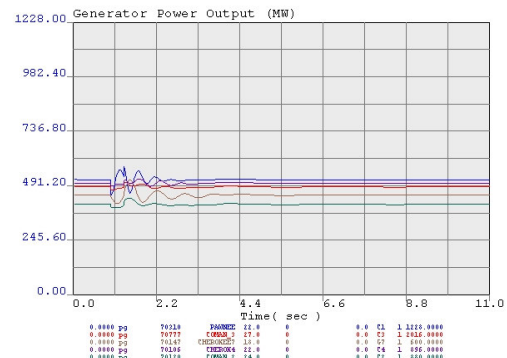
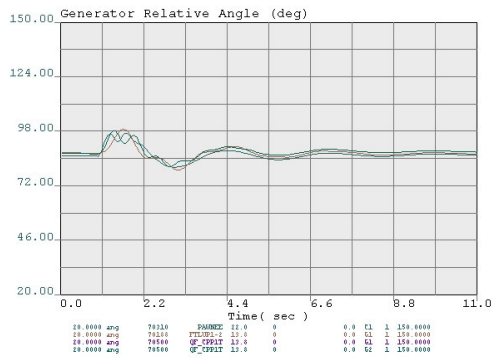
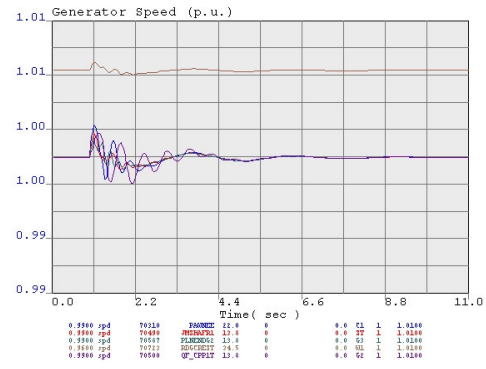
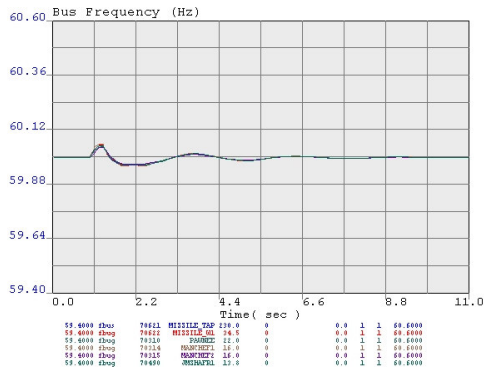
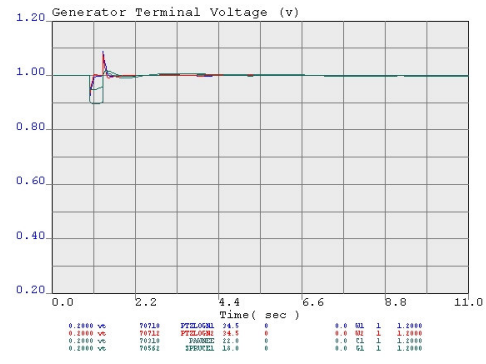
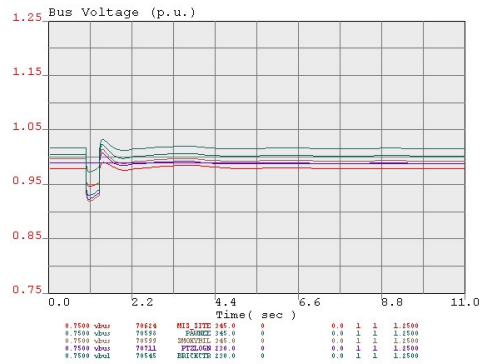


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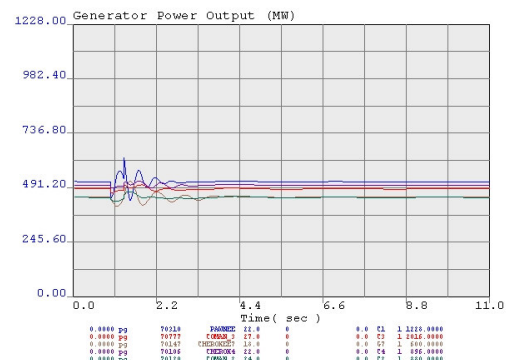
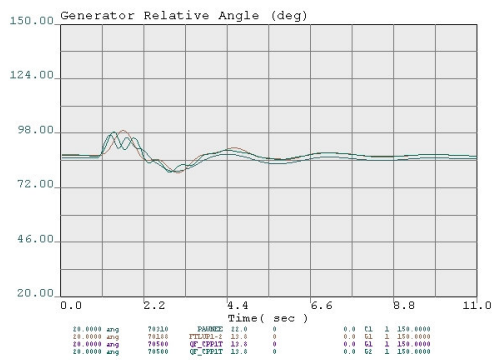
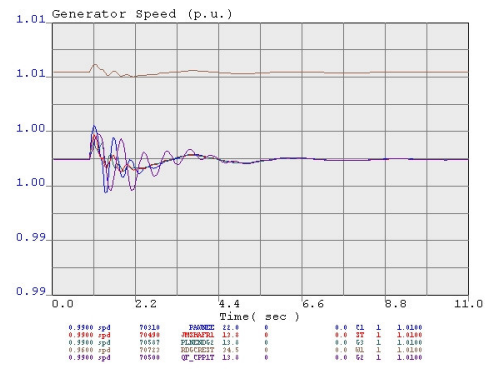
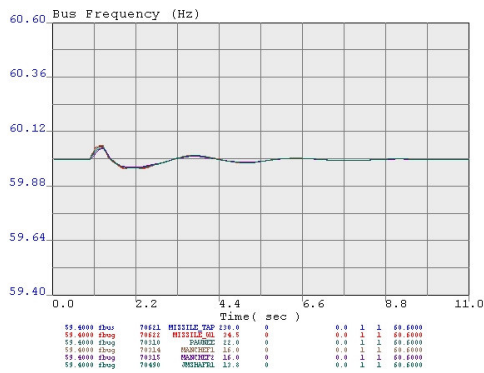
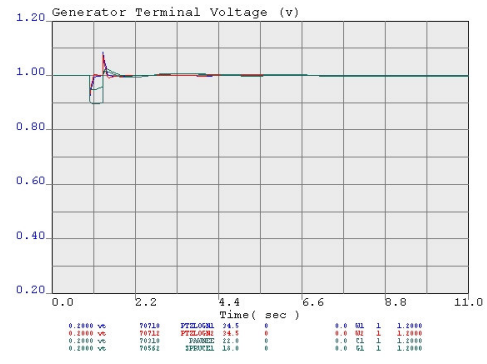
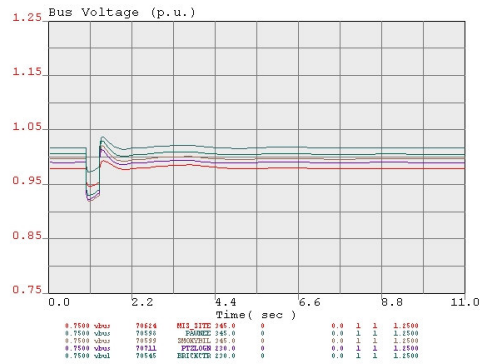
19hs21_GI-2012-6 BASE CASE
 30MW solar PV generation at Missile Site 230 kV bus
 GI-2012-6 stability analysis
 Fault on Missile 230 kV bus, breaker failure - clear in 21 cycles
 Element removed: Missile Site - Daniels Park 230 kV
 ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.



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19hs21 BASE CASE
 Benchmark case
 GI-2012-6 stability analysis
 Fault on Missile 230 kV bus, breaker failure - clear in 21 cycles
 Element removed: Missile Site - Pawnee 230 kV
 ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.

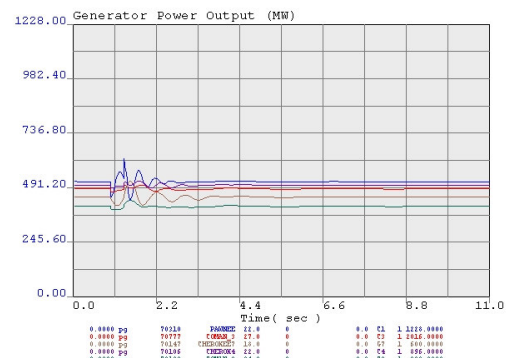
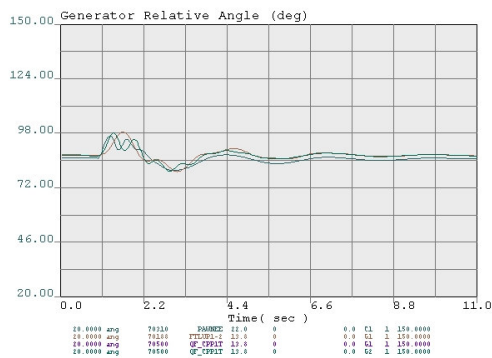
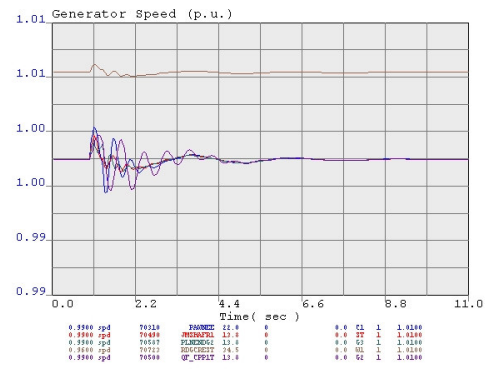
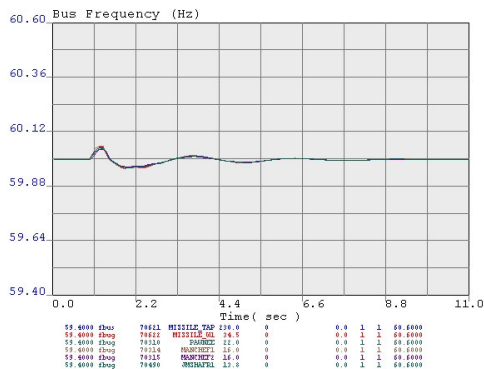
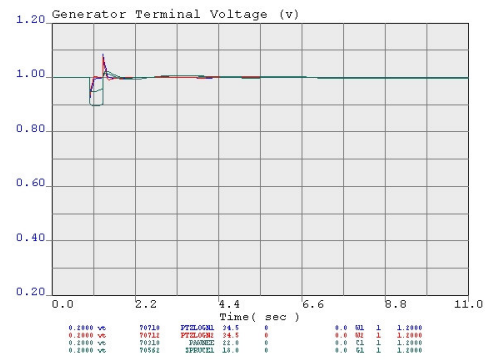
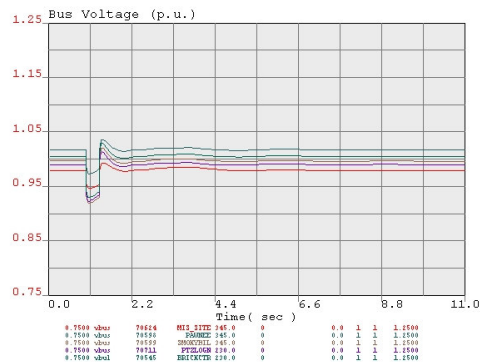


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19hs21_GI-2012-6 BASE CASE
 30MW solar PV generation at Missile Site 230 kV bus
 GI-2012-6 stability analysis
 Fault on Missile 230 kV bus, breaker failure - clear in 21 cycles
 Element removed: Missile Site - Pawnee 230 kV
 ALL COMMENTS FROM TSS AND OC REVIEW ARE INCLUDED.



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