Interconnection System Impact Study Report
Request # GI-2014-7

42 MW Increase to Hydro Pumping Generating Facility
Cabin Creek 230 kV Station, Colorado

Public Service Company of Colorado
Transmission Planning
June 5, 2015

Executive Summary

Public Service Company of Colorado (PSCo) received an interconnection request on July 31, 2014 for a 42 MW capacity increase of the existing Cabin Creek pumping hydro generating facility that was assigned GI-2014-7 as the queue number. GI-2014-7 will result in the Gross Maximum Capacity (GMC) of Cabin Creek generating facility to increase from 324 MW to 366 MW. Since GI-2014-7 is a generating capacity uprate request, the point of interconnection (POI) will remain unchanged at the 230 kV bus in PSCo's Cabin Creek 230/115 kV transmission substation. The existing customer-owned 230 kV transmission lines will also interconnect GI-2014-7 to the POI. The in-service date (ISD) requested for GI-2014-7 generating facility is February 11, 2019 for Unit A (183 MW GMC) and February 17, 2020 for Unit B (183 MW GMC).

This request was studied as a Network Resource Interconnection Service and as a stand-alone generator interconnection that excluded any other new generation requests existing in the PSCo Generator Interconnection Request queue. However, the generators in PSCo's electric resource plan that are planned to be in service by the summer of 2020 were included in the study. The purpose of this System Impact Study (SIS) was to evaluate the potential transient stability impact on the interconnected transmission system of PSCo and its neighboring utilities (the affected parties) due to an additional 42 MW of generation injected into the Cabin Creek 230 kV bus. The Interconnection Customer is responsible for ensuring that the 230 kV tie lines to the POI are adequately rated for delivery of the proposed 366 MW generation to the POI.

The Feasibility Study was conducted prior to this study and included power flow and short circuit analyses. PSCo evaluated the reliability of the bulk transmission system to serve the additional 42 MW of Cabin Creek generation beyond the POI. It was noted in the Feasibility Study that the Interconnection Customer is responsible to ensure that the Cabin Creek 195 MVA 230-13.8kV Transformer Bank A and the Cabin Creek 195 MVA 230-13.8kv Transformer Bank B and associated circuit breakers, switches, and other interconnection facilities that connect the Cabin Creek generation facilities to the POI are adequately rated for the proposed 366 MW generation. Power flow studies demonstrated that the existing bulk transmission system can reliably serve the 42 MW

increase to the Cabin Creek generation facility. No network facilities would be needed to ensure that the 42 MW increase of Cabin Creek generation can be reliably served Short circuit studies determined that the existing facilities (circuit breakers, switches, etc.) at Cabin Creek Substation have sufficient rating for the increased fault current levels due to the increase in the Cabin Creek generation capacity. The results of power flow and short circuit analyses were provided to the Customer in the Feasibility Study Report dated November 4, 2014.

The System Impact Study was conducted and the analysis identified transient stability issues associated with the studies that were conducted to simulate the 42 MW increase in the Cabin Creek generation capacity. The preliminary transient stability analysis displayed system instability following a double circuit tower (Category C) outage and these results were shared with the Customer in the report titled *Interconnection System Impact Study Update* dated March 31, 2015.

PSCO Transmission Planning requested that the Customer reexamine the Cabin Creek generation dynamic models (that they supplied to PSCO Transmission Planning) for accuracy. The Customer provided new dynamic models reflecting the Customer's planned upgrades to the excitation controls – including automatic voltage regulator (AVR) and power system stabilizer (PSS) – and planned upgrades to governor/turbine controls for the Cabin Creek generating units. The Interconnection Customer has assured PSCo that these upgrades to the generating unit's control systems will be included in the design specifications for GI-2014-7. The transient stability analyses was rerun using the new models and the 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 system criteria violations and to produce no adverse impacts related to the transient behavior of the Cabin Creek generation increase on the WECC bulk transmission system.

Network Resource Interconnection Service (NRIS)

The GI-2014-7 steady-state (power flow) and transient stability analyses found no system performance criteria violations for any of the studied contingency events (disturbances). Therefore, GI-2014-7 may be granted NRIS without any Network Upgrade, as follows:

NRIS = 42 MW (at Cabin Creek 230 kV POI)

Cost Estimates

Network Upgrades are not required to increase Cabin Creek generating facility's output by 42 MW (resulting in 366 MW GMC). The existing Interconnection Facilities at Cabin Creek are adequate to accommodate 460 Amps from each of the (uprated) 183 MW units. Therefore, the total estimated cost to interconnect GI-2014-7 is **$0**.

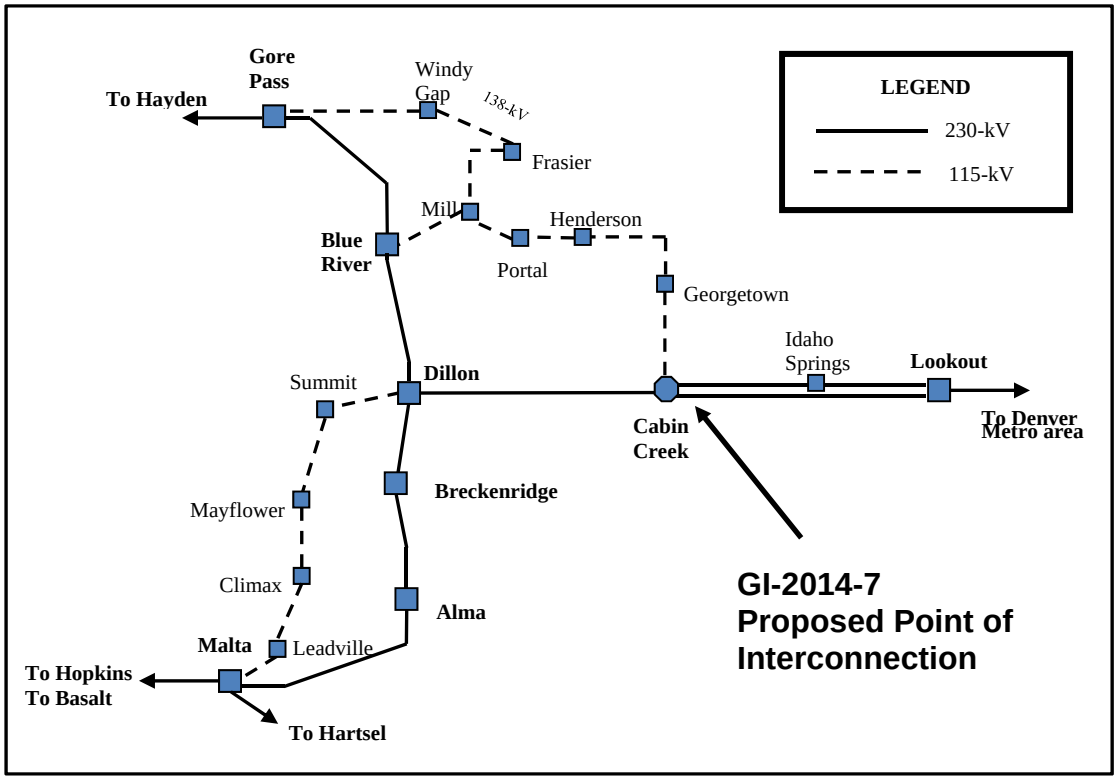


Figure 1 Cabin Creek Station and Surrounding Transmission System

Introduction

Public Service Company of Colorado (PSCo) received an interconnection request for a 42 MW capacity increase of the existing Cabin Creek pumping hydro generating facility on July 31, 2014 that was assigned GI-2014-7 as the queue number. GI-2014-7 will result in the Gross Maximum Capacity (GMC) of Cabin Creek generating facility to increase from 324 MW to 366 MW. Since GI-2014-7 is a generating capacity uprate request, the point of interconnection (POI) will remain unchanged at the 230 kV bus in PSCo's Cabin Creek 230/115 kV transmission substation. The existing customer-owned 230 kV transmission lines will also interconnect GI-2014-7 to the POI. The in-service date (ISD) requested for GI-2014-7 generating facility is February 11, 2019 for Unit A (183 MW GMC) and February 17, 2020 for Unit B (183 MW GMC), and the request is studied as a Network Resource Interconnection Service.

PSCo performed preliminary analysis that was presented to the customer in the report titled *Interconnection System Impact Study Update* dated March 31, 2015. The preliminary analysis demonstrated angular instability of Cabin Creek units following a

double circuit tower outage disturbance. To address these results the Interconnection Customer provided PSCo with an updated dynamic model for each of the uprated 183 MW Cabin Creek generating units. The updated dynamic model reflects the Interconnection Customer's planned upgrades to the excitation controls – including automatic voltage regulator (AVR) and power system stabilizer (PSS) – and planned upgrades to governor/turbine controls for the Cabin Creek generating units. The Interconnection Customer has assured PSCo that these upgrades to the generating unit's control systems will be included in the design specifications for GI-2014-7. Therefore, by using the updated dynamic model in this study, these upgrades to the generating unit's control systems were inherently assumed to have been implemented and in-service.

Study Scope and Analysis

The System Impact Study evaluated the transmission impacts associated with the proposed generation facility expansion. The study consists of transient stability analyses only. Power flow and short circuit analyses were conducted as a part of the Feasibility Study and published in the report dated November 4, 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 (Category A), transmission system bus voltages must remain between 0.95 and 1.05 per unit of nominal, and steady-state power flows must remain below the thermal ratings of all transmission 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 (Category B) disturbance, PSCO transmission system steady state bus voltages must remain between 0.90 per unit to 1.10 per unit for transmission facilities rated 300 kV and below and between 0.95 to 1.10 per unit for PSCO transmission facilities rated above 300 kV, and power flows must remain below 100% of the facilities' continuous thermal ratings. Also, the maximum voltage deviation caused by switching of any shunt device (motor load, capacitor or inductor) under system intact conditions should not exceed 3% at any load serving bus. The maximum voltage deviation caused by switching of any shunt device (motor load, capacitor or inductor) during prior outage of the largest fault current contributing element should not exceed more than 5% at any load serving bus

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 singe 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 man 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.

The project was studied as a Network Resource. 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 generation facilities to serve native load customers; or (2) in an TRO 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.

There are no facilities belonging to other entities in the immediate vicinity of the interconnection and the studies indicated that there were no adverse impacts to other systems.

Power Flow Study Models

The GI-2014-7 System Study was performed using a WECC approved 2020 heavy summer (2020HS2) power flow base case with associated dynamic modeling data in GE PSLF format for the stability analyses. The 2020 case sufficiently models the system after the in-service date for Unit B of GI-2014-7. The case was updated to output Cabin Creek hydro at its full present capacity of 324 MW. Two power flow cases were created for evaluating the impact of the proposed generator – the reference case and the study case. The study case includes the 42 MW increased generation dispatch at Cabin Creek 230 kV bus due to the proposed generator interconnection. The study case also included an update to the Cabin Creek dynamic model of the exciters and power system stabilizers (PSS) which were provided by the customer. The TOT5 transfer path flow is 430 MW in the study case.

Transient Stability 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 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.

Transient Stability Disturbances Simulated

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

A. NERC/WECC Category B & C Disturbances
(Three-phase, close-in faults at Cabin Creek with normal clearing of 6 cycles)

1. Cabin Creek - Lookout 230 kV Line (Circuit #5003)
2. Cabin Creek - Idaho Springs - Lookout 230 kV Line (Circuit #5005)
3. Cabin Creek - Dillon 230 kV Line (Circuit #5007)
4. Cabin Creek - Georgetown - Henderson 115 kV Line (Circuit #9665)
5. Cabin Creek - Lookout Nos. 1 & 2 230 kV Lines (Double Circuit)

B. NERC/WECC Category C Disturbances
(Single-line-to-ground, close-in faults at Cabin Creek with delayed clearing of 21 cycles)

6. Cabin Creek - Lookout 230 kV Line (Circuit #5003)
7. Cabin Creek - Idaho Springs - Lookout 230 kV Line (Circuit #5005)
8. Cabin Creek - Dillon 230 kV Line (Circuit #5007)

Transient Stability Study Results

The transient stability analysis for the GI-2014-7 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-2014-7 transient stability analysis found no WECC disturbance performance criteria violations in the pre-project and post-project cases for any of the studied contingency events (disturbances). Therefore, it is determined that GI-2014-7 produced no adverse system impact. The following results were obtained for every case and disturbance analyzed:

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

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

Network Resource Interconnection Service (NRIS)

The GI-2014-7 steady-state (power flow) and transient stability analyses found no system performance criteria violations for any of the studied contingency events (disturbances). Therefore, GI-2014-7 may be granted NRIS without any Network Upgrade, as follows:

NRIS = 42 MW (at Cabin Creek 230 kV POI)

Costs Estimates

GI-2014-7 (System Impact Study Report)

Network Upgrades are not required to increase Cabin Creek generating facility's output by 42 MW (resulting in 366 MW GMC). The existing Interconnection Facilities at Cabin Creek are adequate to accommodate 460 Amps from each of the (uprated) 183 MW units. Therefore, total estimated cost to interconnect GI-2014-7 is **$0**.

Table 1: PSCo Owned; Customer Funded Transmission Provider Interconnection Facilities

Element	Description	Cost Est. (Millions)
	N/A	

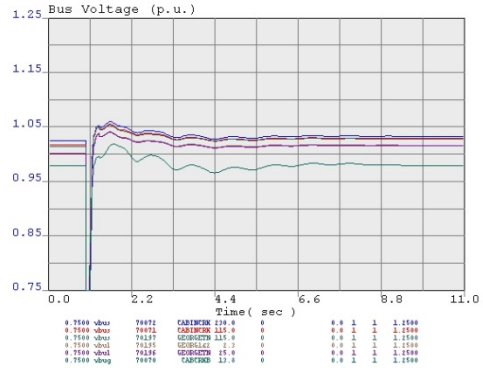
Table 2: PSCo Owned; PSCo Funded Interconnection Network Facilities

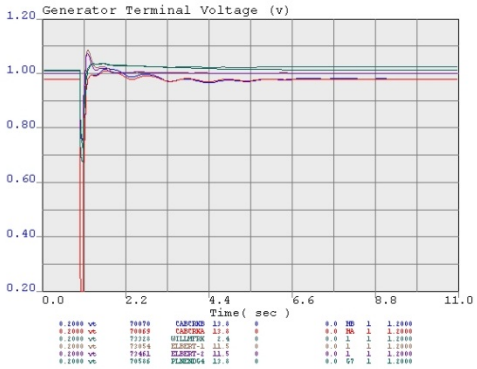
Element	Description	Cost Est. (Millions)
	N/A	

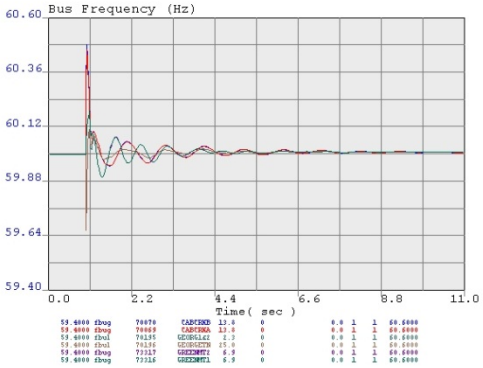
Table 3: PSCo Network Upgrades for Delivery

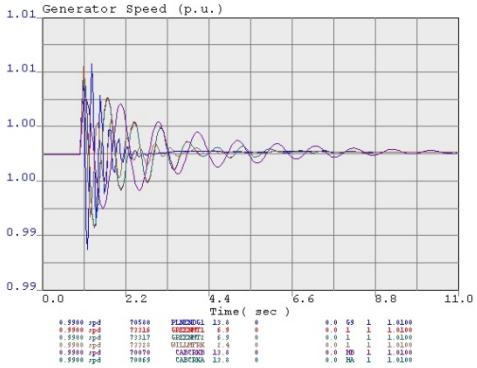
Element	Description	Cost Est. (Millions)
	N/A	

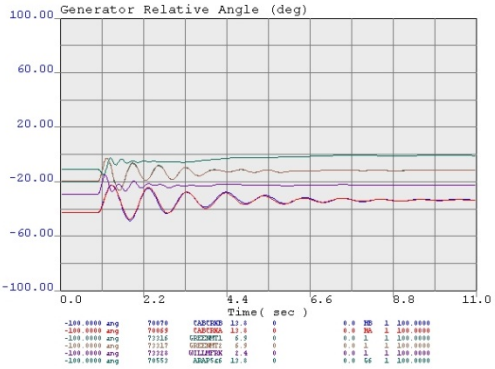
Appendix A
Transient Stability Plots

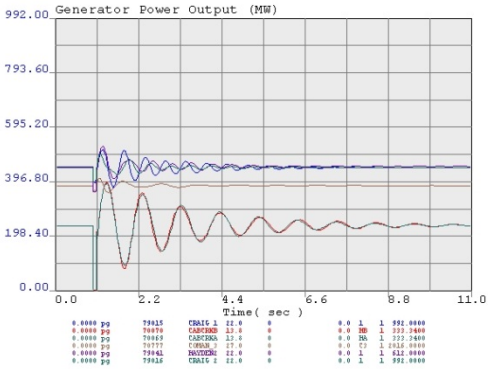












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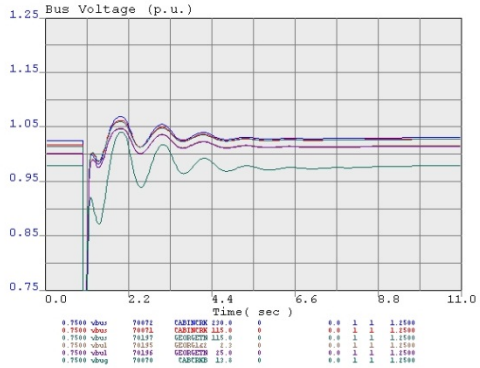

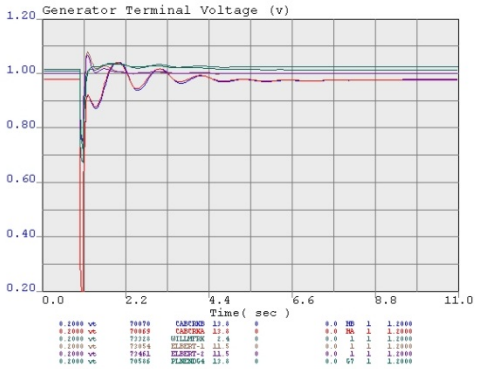

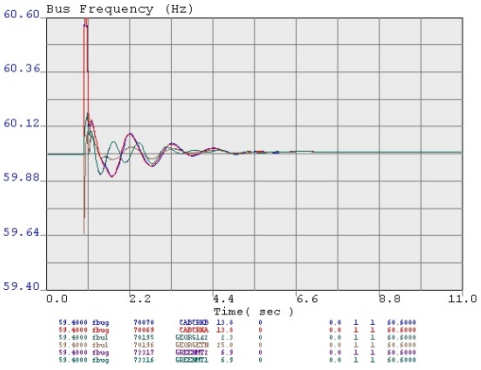

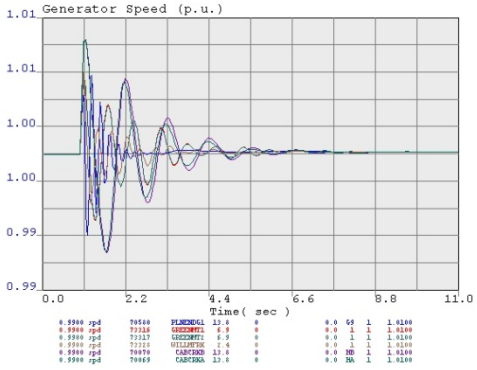

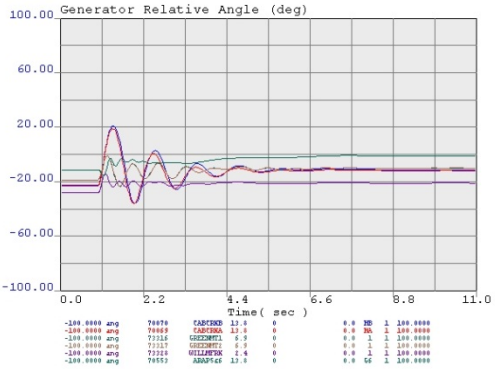

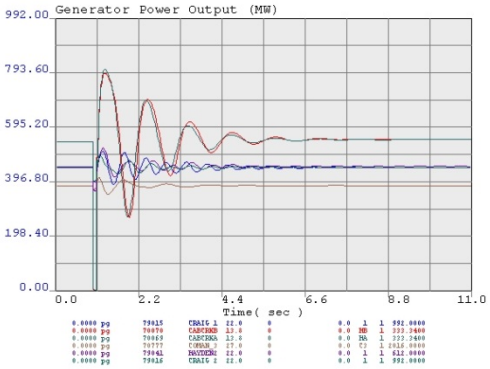

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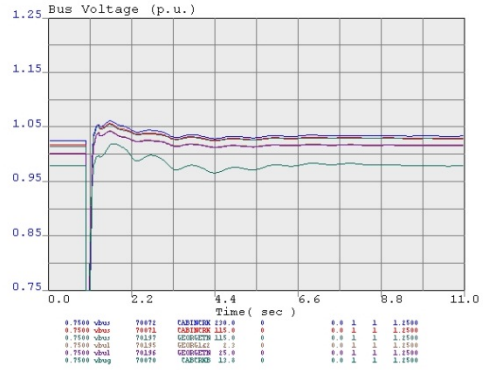

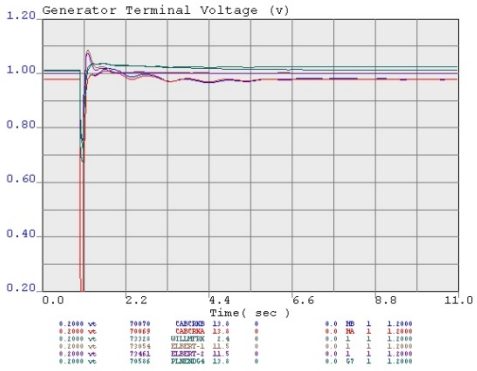

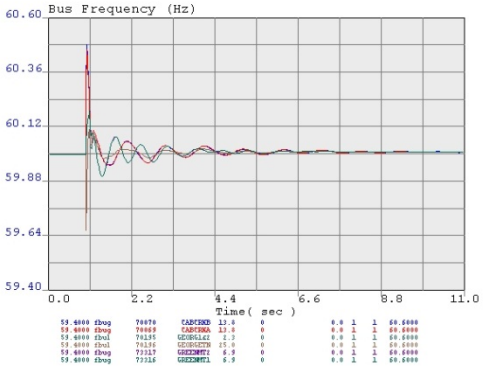

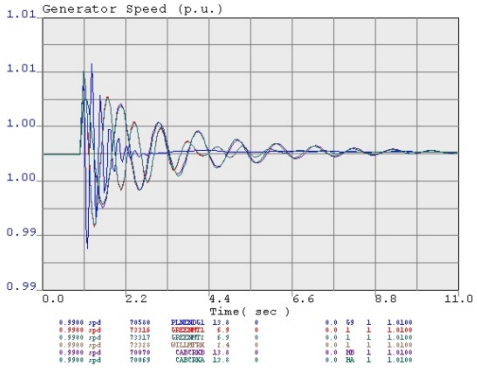

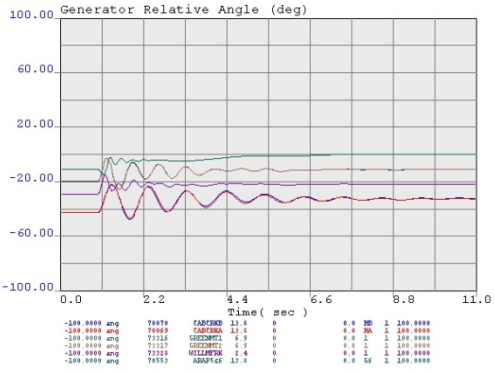

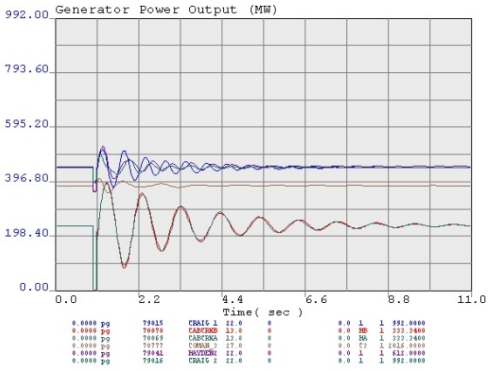

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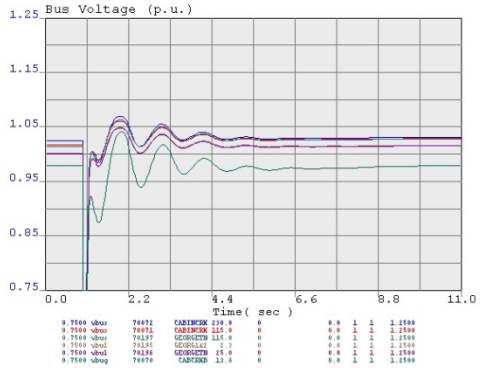

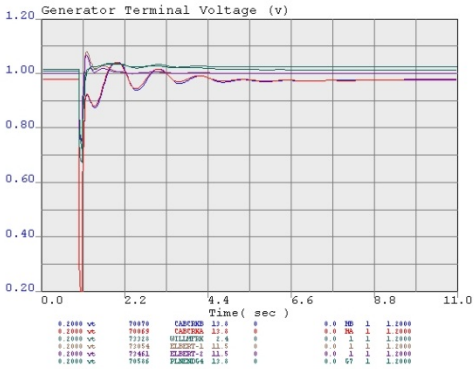

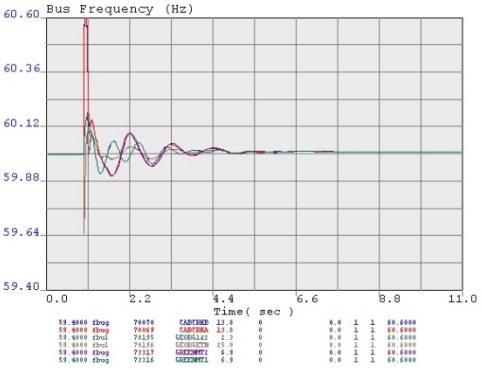

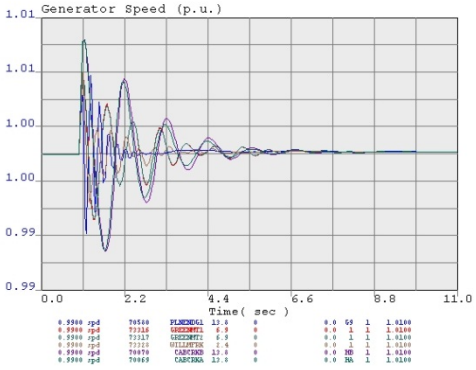

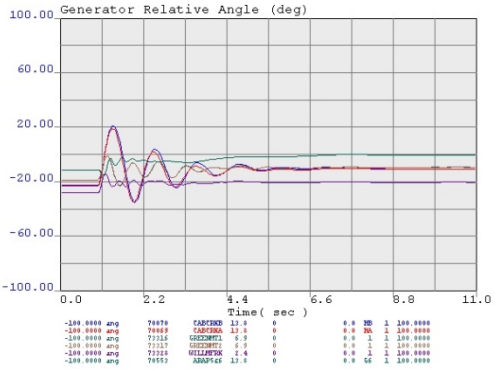

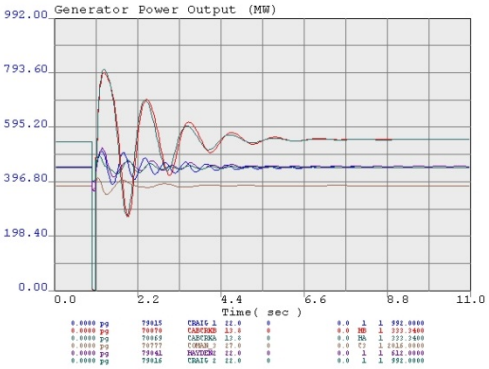

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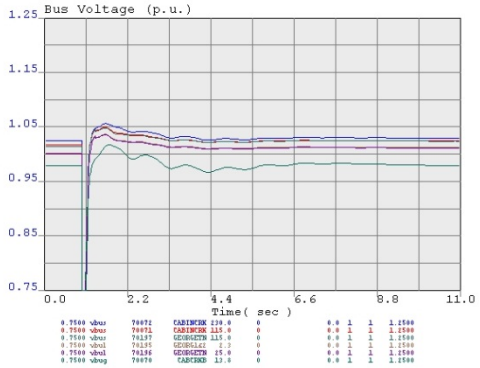

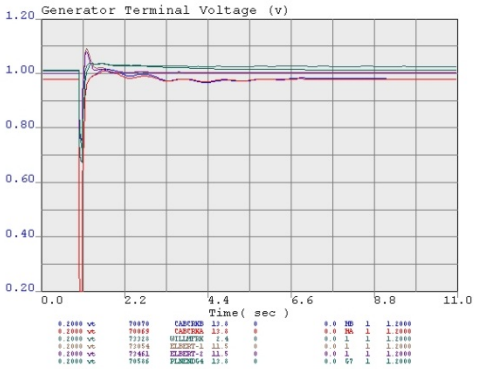

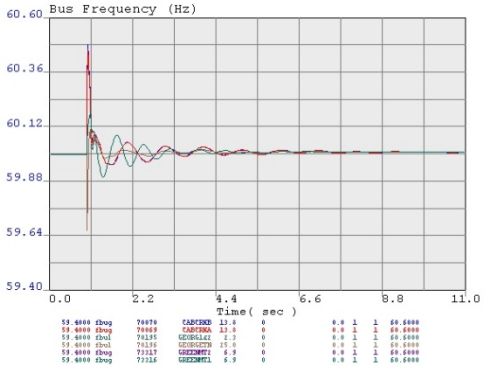

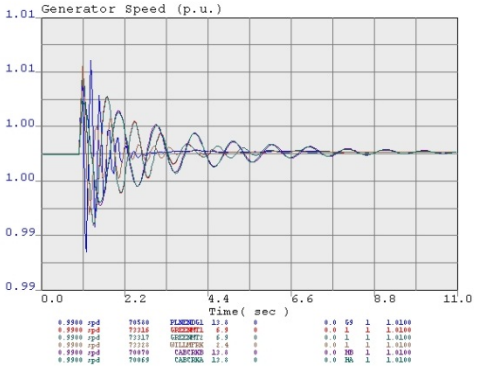

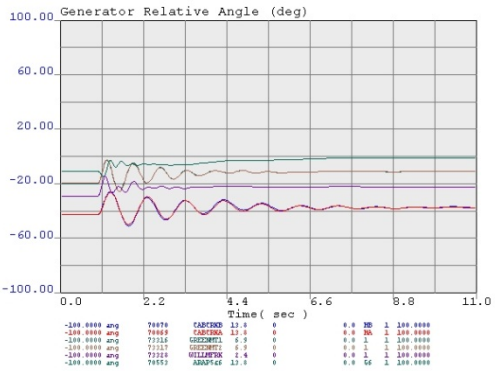

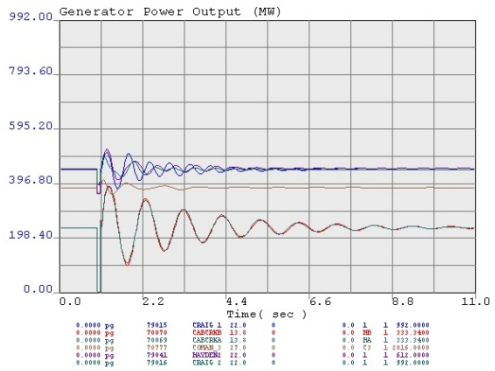

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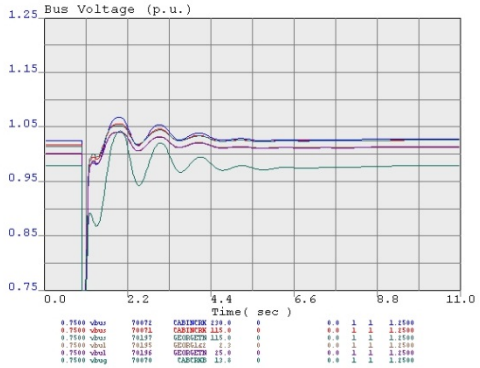
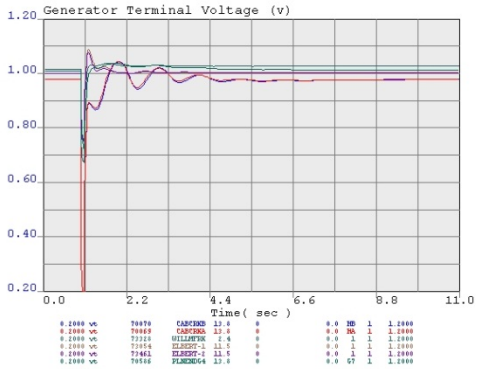
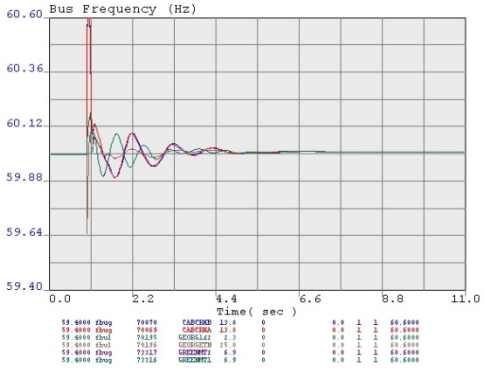
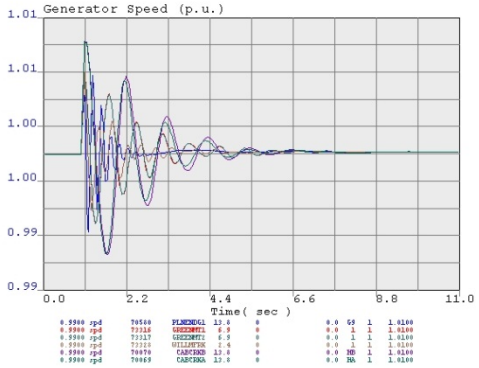
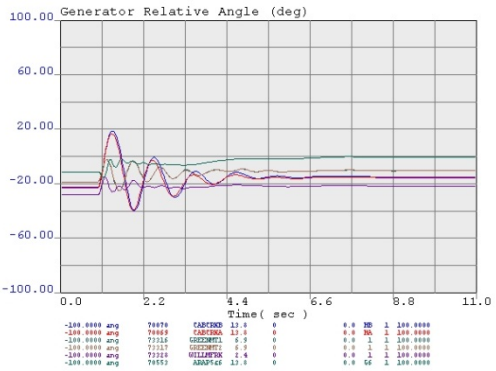
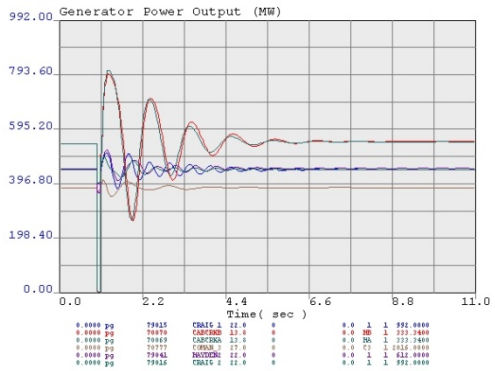








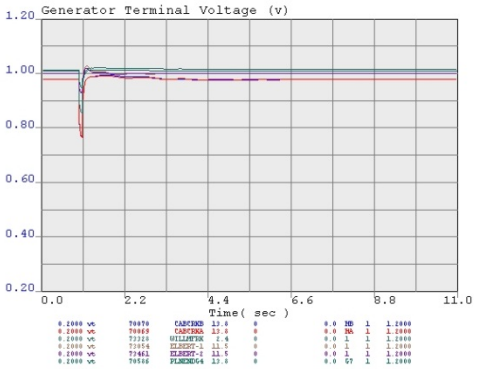


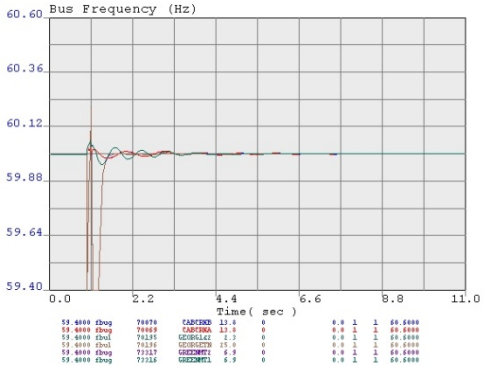


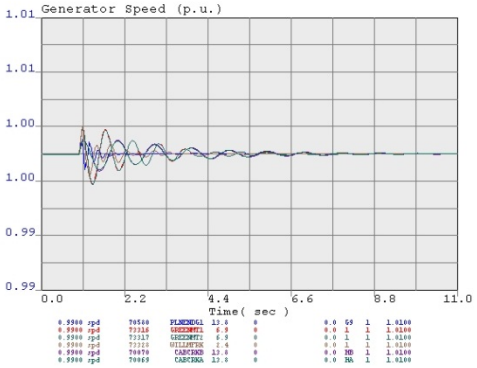
20hs2 BASE CASE
Study case
GI-2014-7 stability analysis
Fault on Cabin Creek 230 kV bus - clear in 6 cycles
Element removed: Cabin Creek - Dillon 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

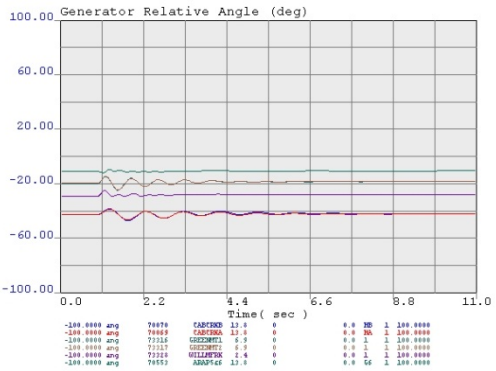
Page 1

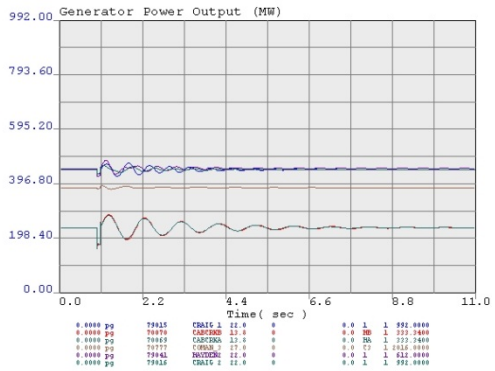
	3xCC-Dill230.chf	C:\1-GE\GI-2014-7\plots Mon May 11 10:57:25 2015











20hs2 BASE CASE
Benchmark case
GI-2014-7 stability analysis
Fault on Cabin Creek 115 kV bus - clear in 6 cycles
Element removed: Cabin Creek - Georgetown - Henderson 115 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

Page 1

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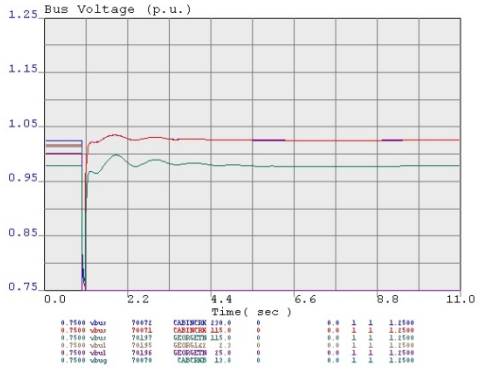

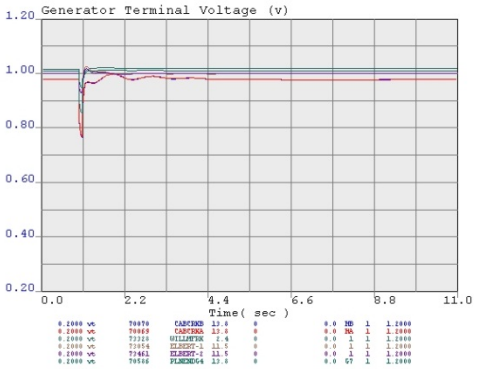

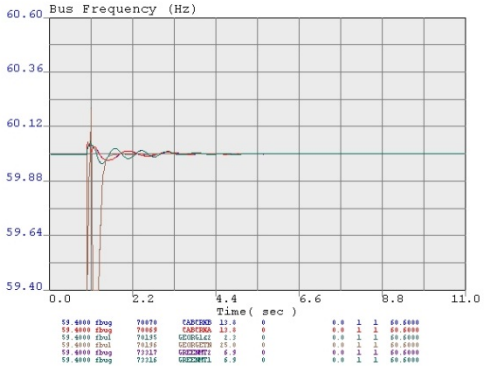

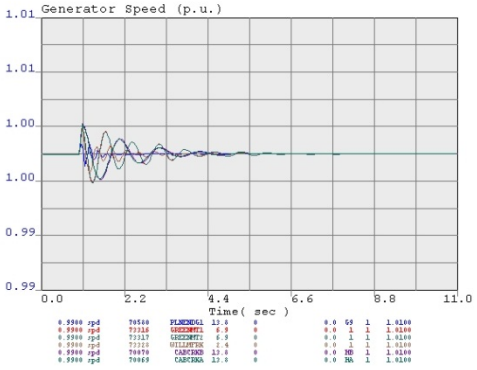

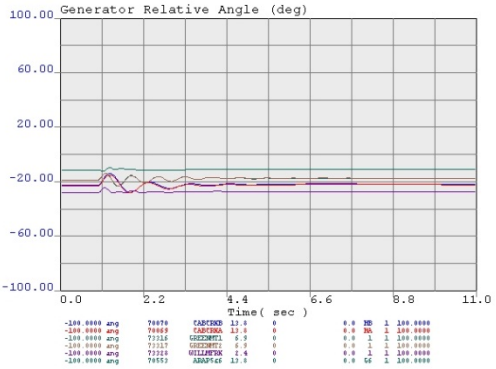

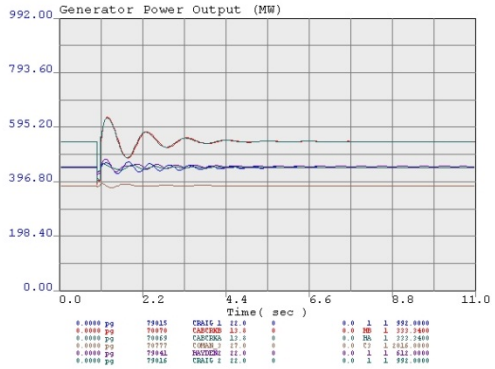

20hs2 BASE CASE
Study case
GI-2014-7 stability analysis
Fault on Cabin Creek 115 kV bus - clear in 6 cycles
Element removed: Cabin Creek - Georgetown - Henderson 115 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

Page 1

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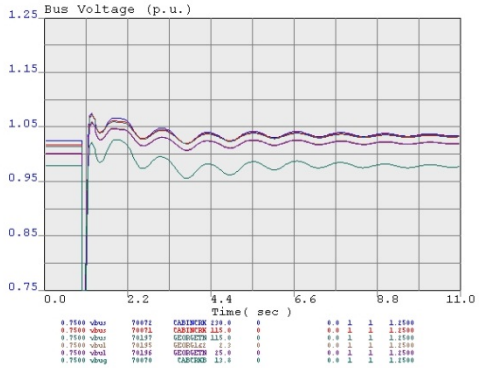

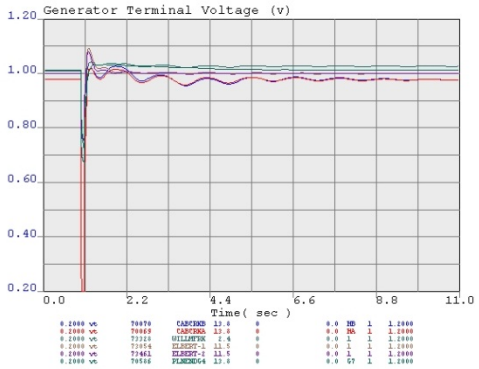

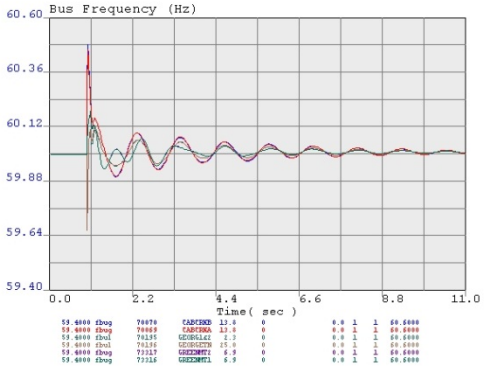

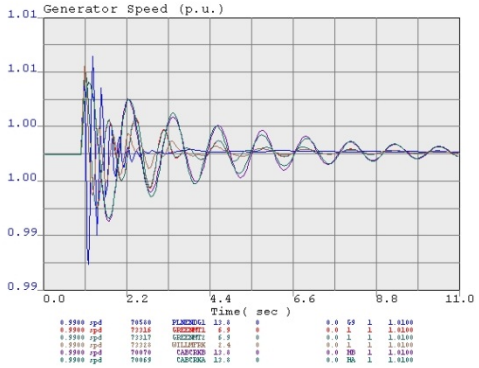

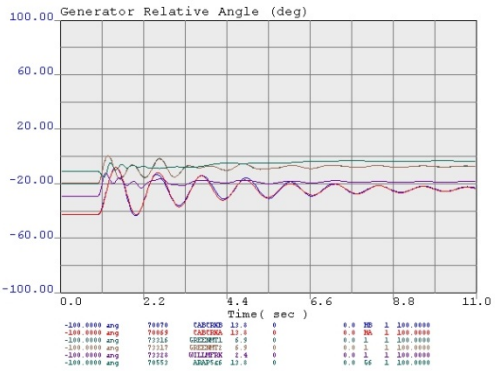

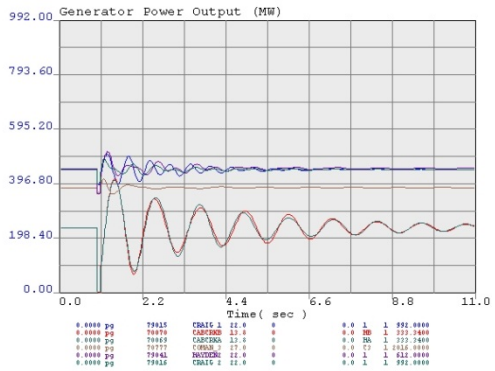

20hs2 BASE CASE
Benchmark case
GI-2014-7 stability analysis
Fault on Cabin Creek 230 kV bus - clear in 6 cycles
Element removed: Cabin Creek - Lookout #1 & #2 DCTL 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

Page 1

5CC-DCTL230.chf

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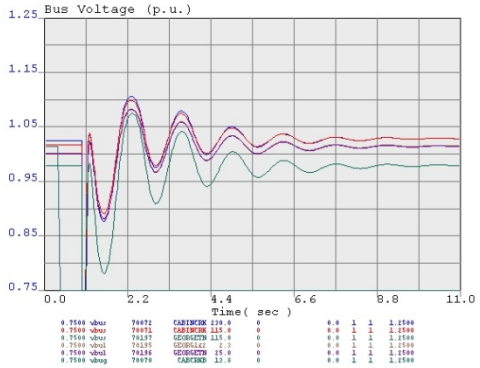
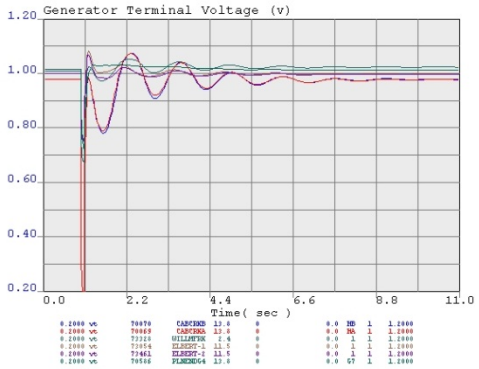
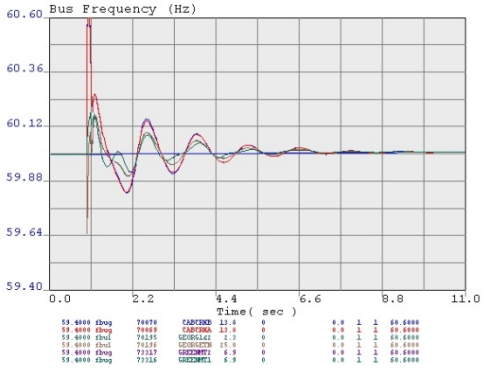
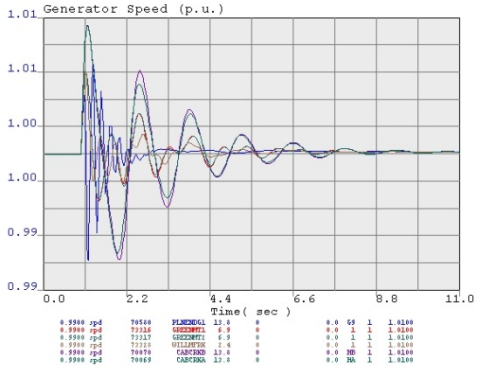
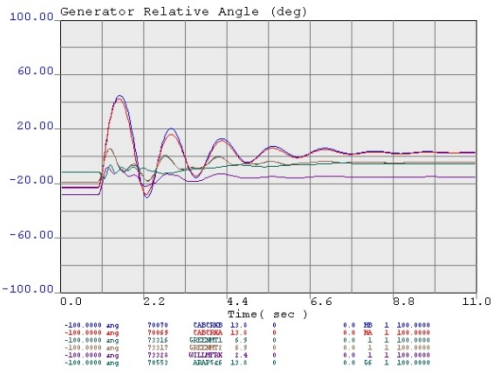
Thu Mar 12 10:43:06 2015

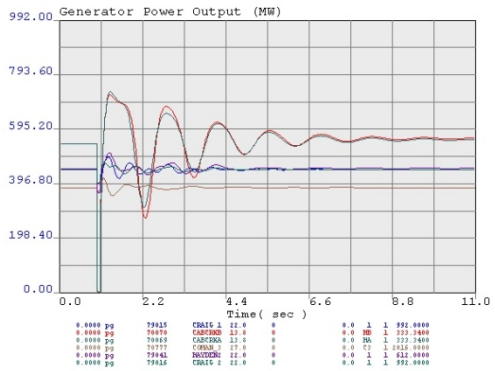








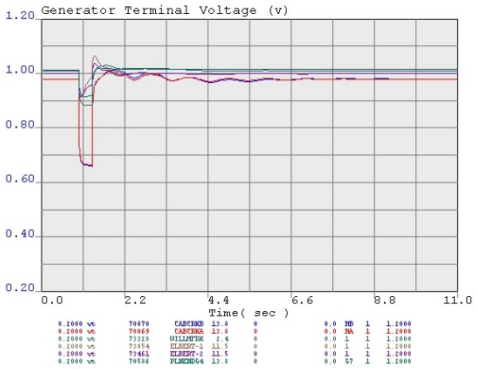


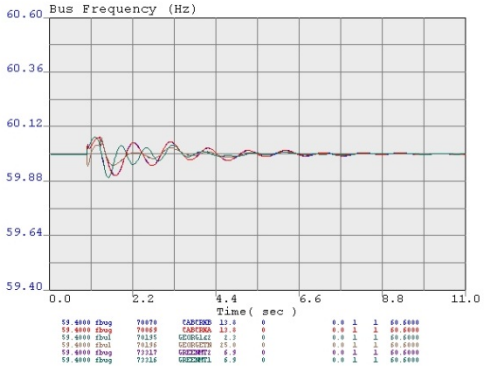


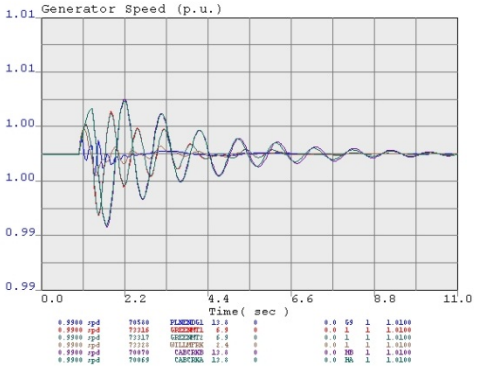
20hs2 BASE CASE
Study case
GI-2014-7 stability analysis
Fault on Cabin Creek 230 kV bus - clear in 6 cycles
Element removed: Cabin Creek - Lookout #1 & #2 DCTL 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

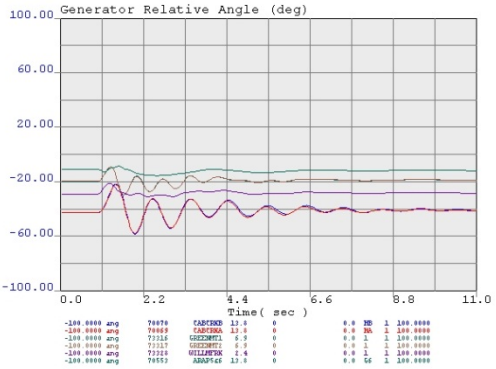
Page 1

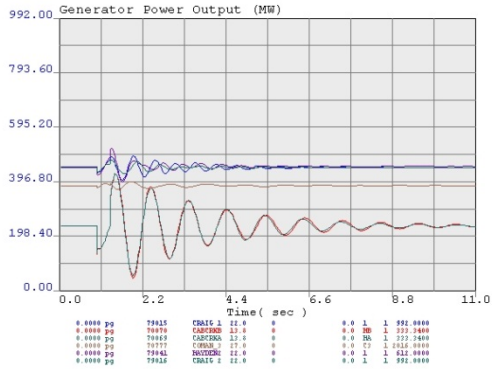
5xCC-DCTL230.chf | C:\1-GE\GI-2014-7\plots | Mon May 11 10:58:42 2015







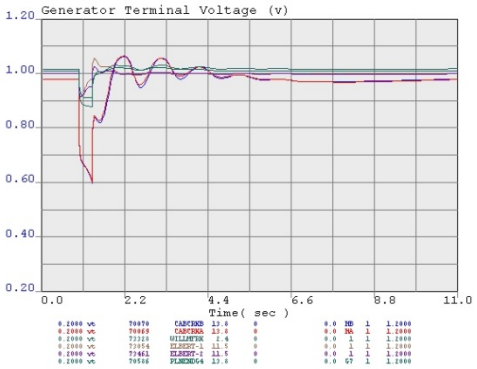


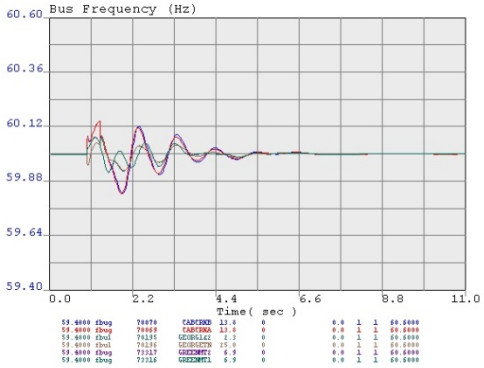


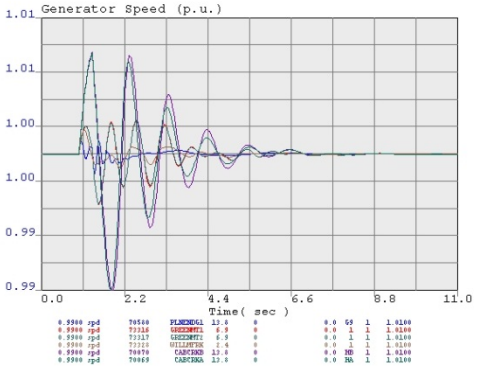
20hs2 BASE CASE
Benchmark case
GI-2014-7 stability analysis
SLG Fault on Cabin Creek 230 kV bus - clear in 21 cycles (delayed)
Element removed: Cabin Creek - Lookout 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

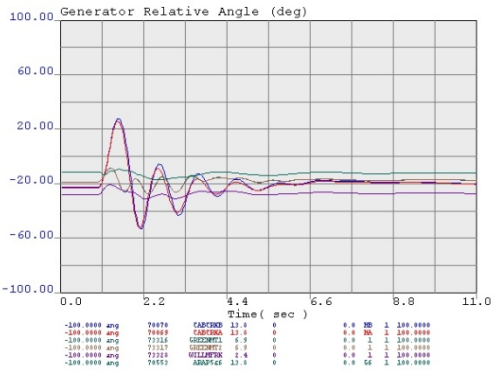
Page 1

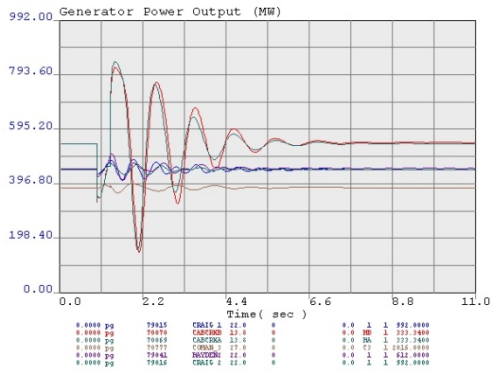
	6CC-Look230.chf	C:\1-GE\GI-2014-7\output Thu Mar 12 10:45:17 2015











20hs2 BASE CASE
Study case
GI-2014-7 stability analysis
SLG Fault on Cabin Creek 230 kV bus - clear in 21 cycles (delayed)
Element removed: Cabin Creek - Lookout 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

Page 1

6xCC-Look230.chf

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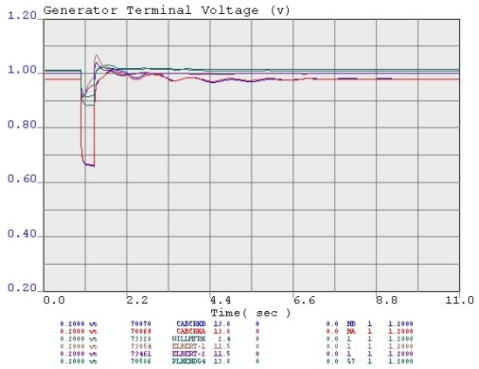
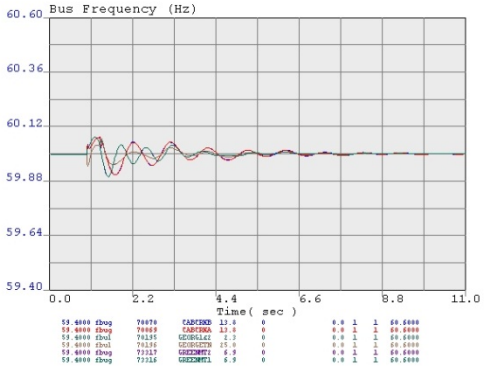
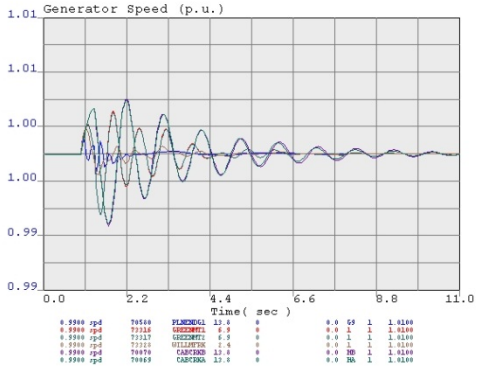
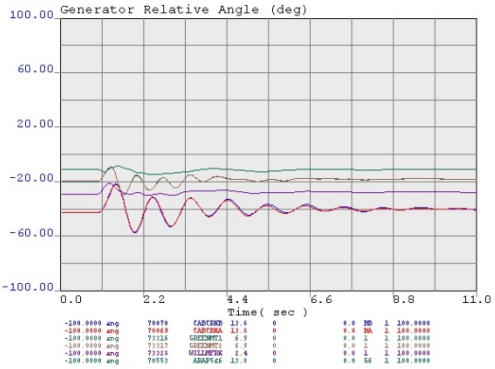
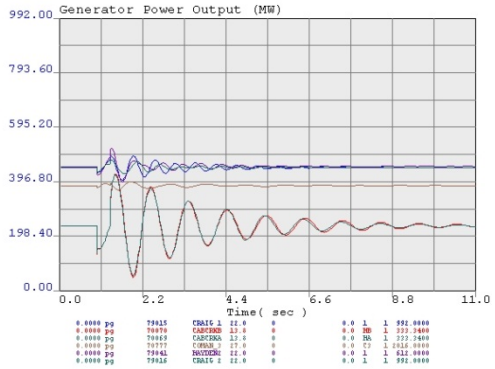
Mon May 11 10:59:35 2015







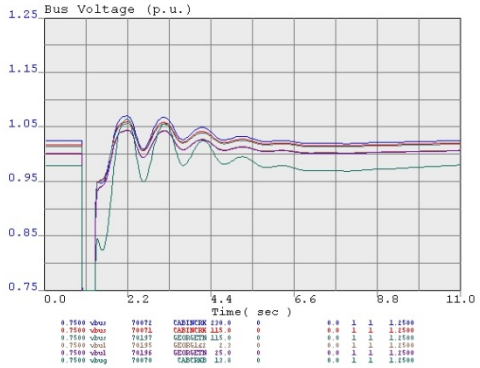


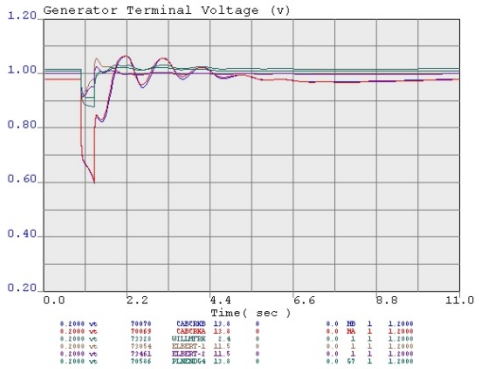


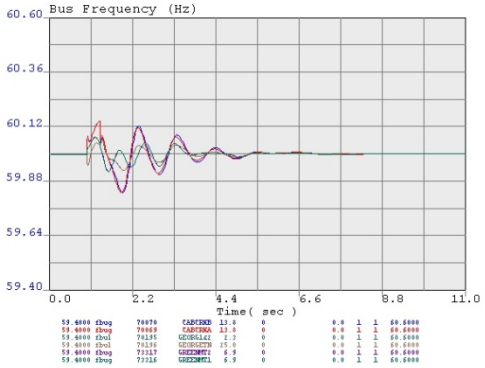
20hs2 BASE CASE
Benchmark case
GI-2014-7 stability analysis
SLG Fault on Cabin Creek 230 kV bus - clear in 21 cycles (delayed)
Element removed: Cabin Creek - Idaho Springs - Lookout 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

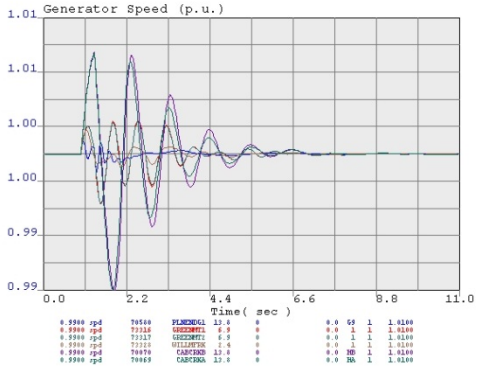
Page 1

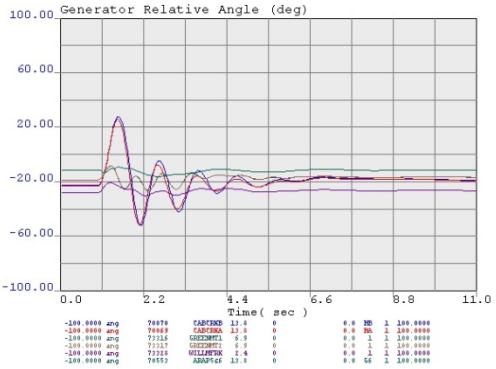
	7CC-Idaho230.chf	C:\1-GE\GI-2014-7\output Thu Mar 12 10:48:17 2015

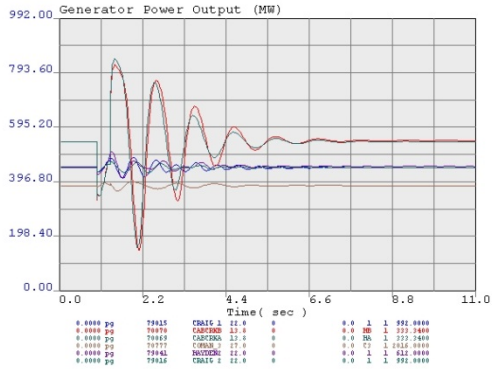








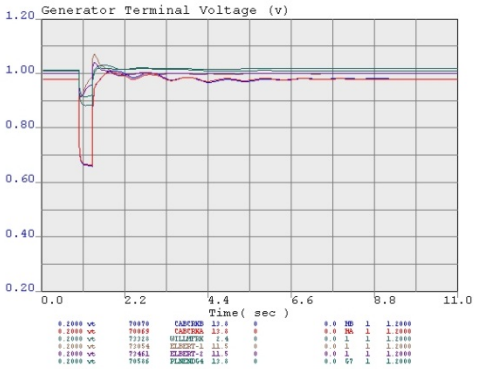


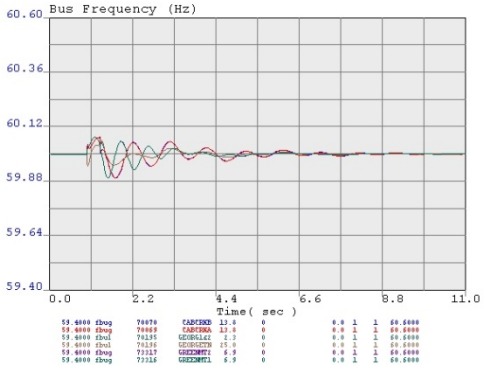


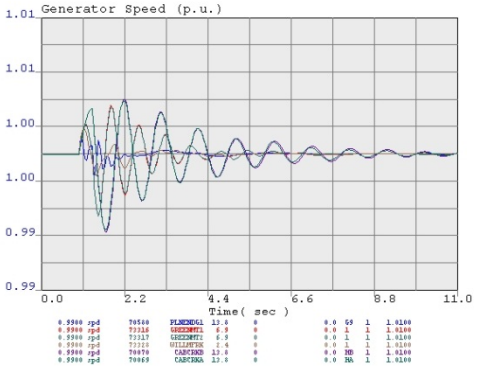
20hs2 BASE CASE
Study case
GI-2014-7 stability analysis
SLG Fault on Cabin Creek 230 kV bus - clear in 21 cycles (delayed)
Element removed: Cabin Creek - Idaho Springs - Lookout 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

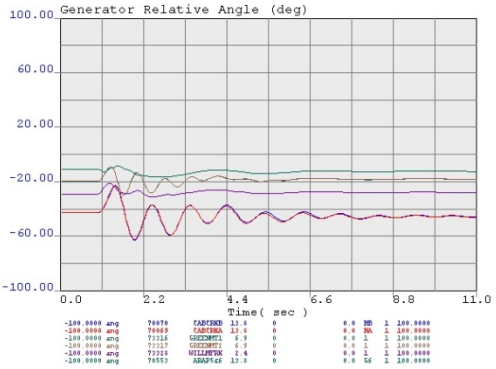
Page 1

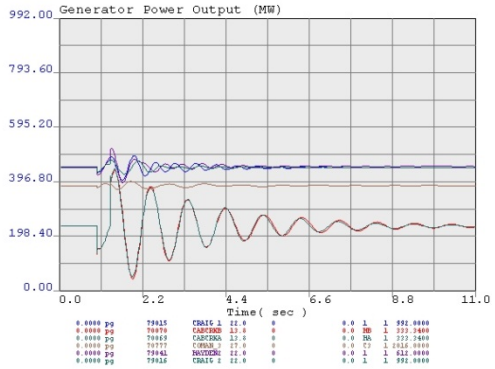
	7xCC-Idaho230.chf	C:\1-GE\GI-2014-7\plots Mon May 11 11:00:24 2015











20hs2 BASE CASE
Benchmark case
GI-2014-7 stability analysis
SLG Fault on Cabin Creek 230 kV bus - clear in 21 cycles (delayed)
Element removed: Cabin Creek - Dillon 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

Page 1

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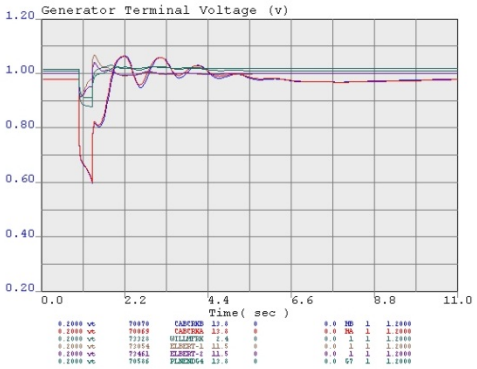

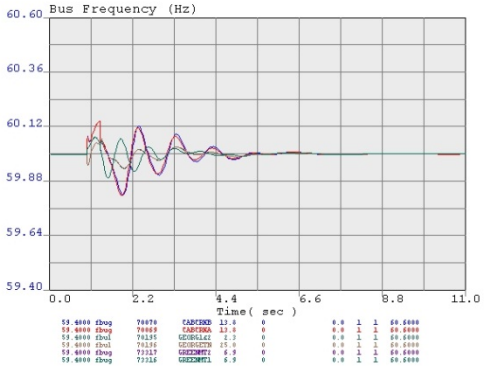

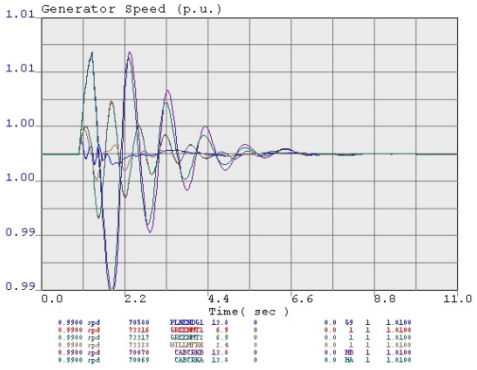

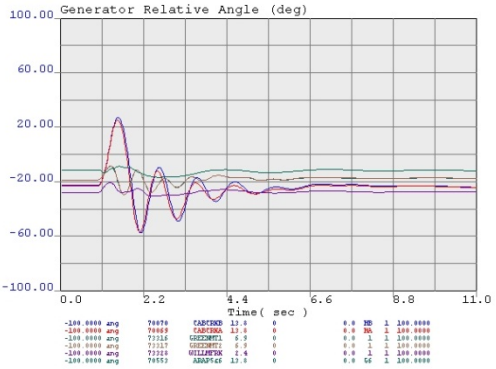

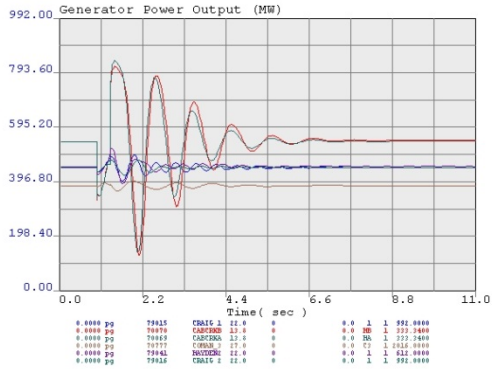

20hs2 BASE CASE
Study case
GI-2014-7 stability analysis
SLG Fault on Cabin Creek 230 kV bus - clear in 21 cycles (delayed)
Element removed: Cabin Creek - Dillon 230 kV
COMMENTS DUE TO AREA COORDINATORS BY JULY 31, 2014
COMMENTS FROM AREA COORDINATORS TO STAFF BY AUGUST 7, 2014

Page 1

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