Interconnection System Impact Study Report
Request # GI-2016-25

500.25 MW Wind Generating Facility
Missile Site 345 kV Substation, Colorado

Public Service Company of Colorado
Transmission Planning
February 20, 2018

Executive Summary

Public Service Company of Colorado (PSCo) received an Interconnection Request (IR) on October 5, 2016 which was assigned GI-2016-25 queue position. GI-2016-25 is a wind generating facility rated at 500.25 MW gross electrical output that will be located in Kit Carson and Cheyenne County Colorado. The GI-2016-25 generating facility will physically interconnect near the Rush Creek II collector station site located at the end of the 83 mile, 345 kV Missile Site – Rush Creek radial transmission line (aka "Rush Creek Gen-Tie") under construction for the planned Rush Creek wind generation project. However, the point of interconnection (POI) for GI-2016-25 is the 345 kV bus within the Missile Site Substation, which is the point at which power from the wind generating facility is delivered to the PSCo transmission system.

The proposed 500.25 MW generating facility is expected to consist of approximately 145 wind turbine generators, where each turbine is rated 3.45 MW and is equipped with a 0.69/34.5 kV step-up transformer. Preliminary information on the wind generating facility's layout suggests that the 145 wind turbine generators will be grouped together into a 34.5 kV collector system, and the 34.5 kV collector system will connect to a 34.5/345 kV main step-up transformer (MST). The MST will connect to the Rush Creek II site via an approximately 25 mile 345 kV transmission line (the "GI-2016-25 Gen-Tie"). The proposed 500.25 MW generating facility will ultimately connect to the Missile Site POI through the Rush Creek Gen-Tie, which is expected to be in-service by October 2018.

The Commercial Operation Date (COD) requested for the generating facility is October 31, 2020. Based on the requested COD, the assumed back-feed date for the facility is April 31, 2020 (approximately six months before the COD).

Figure 1 below is a conceptual one-line diagram of the proposed physical connection location for GI-2016-25 the POI and the surrounding transmission system.

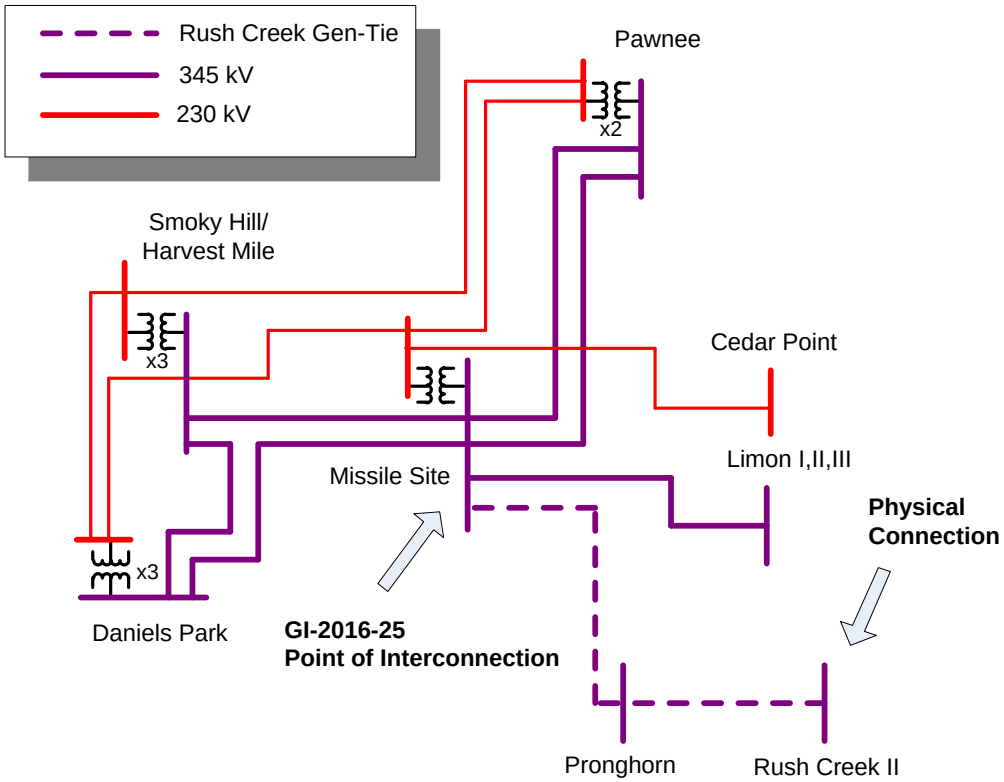


Figure 1: Conceptual one-line of proposed physical connection, the POI and surrounding Transmission System

As per the IR, GI-2016-25 is studied for both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS). The 500.25 MW electrical output of GI-2016-25 is studied as a stand-alone project. That is, the study did not include any prior-queued IR's existing in PSCo's or any affected party's Generation Interconnection queue except those IR's which are:

a) considered to be PSCo planned resources in recognition of their signed Power Purchase Agreements, or
b) assumed in-service as per the agreed-upon study assumptions with the Interconnection Customer.

Accordingly, this System Impact Study determined the steady state and dynamic system impacts of the aggregate injection at the Missile Site 345 kV POI resulting from the proposed 500.25 MW output of GI-2016-25 in addition to the 600 MW output of the planned Rush Creek wind generation project (GI-2016-3) and the concurrent outputs of the existing Limon and Cedar Point wind generation facilities. Further, this study also identifies the transmission improvements (i.e. Network Upgrades) needed to enable delivery of the proposed 500.25 MW electrical output of GI-2016-25 to PSCo network loads – that is, for GI-2016-25 to qualify for NRIS.

The System Impact Study consisted of steady state (power flow), short-circuit and transient stability analyses. The power flow analyses were performed using 2021 heavy

summer (2021HS) base case. Two power flow models were created from the 2021HS case – a Benchmark Case which models the planned transmission system topology before the proposed GI-2016-25 interconnection (i.e. Before GI-2016-25 case) and a Study Case that includes the 500.25 MW generation under study (i.e. After GI-2016-25 case). Since the Pawnee – Daniels Park (P-DP) 345 kV project[1] was identified as the Network Upgrade needed to deliver the 600 MW output of the planned Rush Creek wind generation project (GI-2016-3), and its October 31, 2019 target in-service date is before the COD of GI-2016-25, the P-DP project was included in the Benchmark Case for GI-2016-25.

Power flow analysis performed for this study shows that the additional 500.25 MW generation injection into Missile Site Substation may cause a thermal overload of the Greenwood – Monaco 230 kV line (L5281) following the loss of Smoky Hill – Leetsdale 230 kV line (L5285). The Network Upgrade required for mitigation consists of replacing limiting equipment at Monaco substation to increase the thermal rating of the Greenwood – Monaco 230 kV line.

The short circuit analysis results based on the 2020 transmission topology did not identify the need for any network upgrades for the proposed GI-2016-25 interconnection.

The transient stability analysis was performed using a 2021 heavy summer (2021HS) case and did not identify any unacceptable/degraded stability performance due to the proposed GI-2016-25 interconnection. Both angular stability as well as LVRT (Low Voltage Ride-Through) performance was acceptable for all normally cleared three-phase fault disturbances at the Missile Site 345 kV bus. Also, stability performance was acceptable following the loss of over 500 MW of conventional (synchronous) generation at Pawnee substation. Therefore, no additional network upgrades are required based on the transient stability analysis.

Network Upgrades identified by the power flow analysis are required for the proposed GI-2016-25 interconnection to achieve 500.25 MW NRIS[2].

Therefore, for GI-2016-25 interconnection:

NRIS (after network upgrades & Pawnee-Daniels Park) = 500.25 MW

ERIS (before network upgrades) = 0 to 500.25 MW on “as-available” basis

[1] A PSCo planned transmission project for which the Colorado Public Utility Commission (CPUC) has approved a Certificate of Public Convenience and Necessity (CPCN) and has a target in-service date of October 31, 2019. More information at: http://www.transmission.xcelenergy.com/Projects/Colorado

[2] Network Resource Interconnection Service allows Interconnection Customer 's Large Generating Facility to be designated as a Network Resource, up to the Large Generating Facility's full output, on the same basis as existing Network Resources interconnected to Transmission Provider's Transmission System, and to be studied as a Network Resource on the assumption that such a designation will occur. (*section 3.2.2 of Attachment N in Xcel Energy OATT*)

As shown in **Tables 1–2**, (see pages 13-14) the cost for the Interconnection Facilities and the Network Upgrades for Delivery is **$11.635 million** and includes:

- $11.585 million for PSCo Interconnection Customer Owned; Non-affiliated, third-party Interconnection Customer Funded Interconnection Facilities
- $0.050 million for PSCo Transmission Provider Owned; PSCo Transmission Provider Funded Network Upgrades for Delivery.

It is estimated that this work can be completed in approximately 36 months following receipt of authorization to proceed. The schedule assumes a Certificate of Public Convenience and Necessity (CPCN) would be required for the new 345 kV switching station located at the Rush Creek II end of the Rush Creek Gen-Tie. The 36 months duration assumes approximately 18 months to obtain a CPCN and 18 months for land acquisition, permitting, substation design, procurement, construction, testing, and commissioning.

No adverse impacts on the transmission systems of other entities are identified in the System Impact Study. However, Tri-State Generation and Transmission (Tri-State) has requested to be identified as an Affected System for all IR's with physical interconnections at the Rush Creek Gen Tie, and therefore is an affected party for GI-2016-25.

Power Flow N-1 Contingency Analysis

The 2021HS base case was updated to dispatch the existing and planned generation within the Pawnee and Missile Site "generation pockets" (i.e. aggregate of generation in the local area) at their respective highest coincident output deemed appropriate for the planning of adequate transmission capacity. This was done in accordance with the generation dispatch assumptions practiced by PSCo Transmission Planning function to study the feasibility and system impact of generator interconnection requests as a Transmission Provider. Accordingly, the existing, planned and proposed generating plants at Pawnee and Missile Site stations were dispatched as noted below.

Pawnee local "generation pocket"

- ✓ Pawnee Fossil Fuel generation = 100% of rated capacity = 536 MW
- ✓ Manchief Gas generation = 90% of rated capacity = 252 MW
- ✓ Peetz Logan Wind generation = 40% of rated capacity = 230 MW

Aggregate Generation Dispatched at Pawnee in all Cases = 1018 MW

Missile Site local "generation pocket"

- ✓ Cedar Point (Missile Site 230kV) = 80% of rated capacity = 200 MW
- ✓ Limon I, II, III (Missile Site 345kV) = 80% of rated capacity = 480 MW
- ✓ Rush Creek (Missile Site 345kV) = 100% of rated capacity = 600 MW
- ✓ GI-2016-25 (Missile Site 345kV) = 100% of rated capacity = 500.25 MW

Aggregate Generation Dispatched at Missile Site in Benchmark Case = 1280 MW

Aggregate Generation Dispatched at Missile Site in Study Case(s) = 1780.25 MW

The GI-2016-25 *Benchmark Case* was derived from the 2021HS base case by changing the generation dispatch at Pawnee and Missile Site as noted above. The planned Rush Creek wind generating plant (GI-2016-3) was added at the Missile Site 345kV bus and dispatched at 600 MW rated output. Transmission facilities comprising the Pawnee – Daniels Park project modeled in the 2021HS case were retained in the Benchmark Case since they comprise the network upgrades identified for GI-2016-3.

The GI-2016-25 *Study Case* was created by adding the proposed GI-2016-25 generating plant in the Benchmark Case and dispatching it at 500.25 MW rated output. With Rush Creek generation dispatched at its 600 MW rated output, this results in 1100.25 MW aggregate injection from the Rush Creek Gen Tie at the Missile Site 345kV bus.

PSCo adheres to applicable NERC Reliability Standards & WECC Reliability Criteria for Bulk Electric System (BES) acceptable performance, as well as its internal performance criteria for planning studies. For steady state analysis, the performance criteria are as follows:

P0 - System Intact conditions:
Thermal Loading: <=100% Normal facility rating
Voltage range: 0.95 to 1.05 per unit

P1-P2 – Single Contingencies:
Thermal Loading: <=100% Normal facility rating[3]
Voltage range: 0.90 to 1.10 per unit
Voltage deviation: <=5% of pre-contingency voltage

P3-P7– Multiple Contingencies:
Thermal Loading: <=100% Emergency facility rating
Voltage range: 0.90 to 1.10 per unit
Voltage deviation: <=5% of pre-contingency voltage

As is evident from the power flow analysis results provided in Table A.1 in the Appendix, the additional 500.25 MW generation injection into Missile Site Substation may cause a thermal overload of the Greenwood – Monaco 230 kV line (L5281) following the loss of the Smoky Hill – Leetsdale 230 kV line (L5285). The Network Upgrade required for mitigation consists of replacing limiting substation equipment to increase the thermal rating of the Greenwood – Monaco 230 kV line. Therefore, Network Upgrades are required for the proposed GI-2016-25 interconnection to achieve 500.25 MW NRIS[4].

[3] PSCo allows use of eight-hour facility rating for transformers for which it is available.
[4] Network Resource Interconnection Service allows Interconnection Customer 's Large Generating Facility to be designated as a Network Resource, up to the Large Generating Facility's full output, on the same basis as existing Network Resources interconnected to Transmission Provider's Transmission System, and to be studied as a Network Resource on the assumption that such a designation will occur. (*section 3.2.2 of Attachment N in Xcel Energy OATT*)

Voltage Regulation and Reactive Power Capability

Interconnection Customers are required to interconnect its Large Generating Facility with Public Service of Colorado's (PSCo) Transmission System in accordance with the *Xcel Energy Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW.* The guidelines are available at:

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

Accordingly, the following requirements for POI voltage range and Generating Facility's dynamic reactive power capability 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 Northeast Colorado - Region 7 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 Generator Interconnection (GI) 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. Accordingly, for GI-2016-25, the 0.95 lead – 0.95 lag dynamic reactive power capability is measured at the metered interface between the Generating Facility and the Interconnection Facilities of the GI Customer – that is, at the metering location shown in the conceptual one-line in Figure 2. The GI Customer has the responsibility to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (MVAR), and the locations (34.5 kV or 230 kV bus) of any additional static reactive power compensation needed to ensure adequate reactive power capability exists within the Generating Facility to meet the 0.95 lead – 0.95 lag dynamic power factor standard at the high side of the generator substation (i.e. metering location shown in Figure 2). Further, the GI Customer must also ensure that approximately zero reactive power flows at the metering location under no load conditions (i.e. when all or most generators are off-line).
- Every Generating Facility interconnected to the PSCo Transmission System is expected to have dynamic voltage control capability to assist in maintaining the POI voltage schedule specified by PSCo Transmission Operations as long as the Generating Facility does not have to operate outside its 0.95 lead– 0.95 lag dynamic power factor range capability.
- The GI Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the Generating Facility that it can safely and reliably operate within the required power factor and voltage ranges (noted above).
- The GI Customer has the responsibility to ensure that its generating facility is capable of meeting the voltage ride-through and frequency ride-through (VRT and FRT) performance specified in NERC Reliability Standard PRC-024-2.

Transient Stability Analysis

The transient stability analysis was performed using a benchmark and study case derived from the WECC 2021 Heavy Summer (2021HS) dynamics case created for use with the General Electric PSLF software program. The benchmark case was updated to match the generation dispatch in the Pawnee and Missile Site area similar to the power flow cases discussed previously. The study case was developed by adding the GI-2016-3 and GI-2016-25 generating facilities and the transmission facilities comprising the Pawnee – Daniels Park project. The model for the generation facility was included from the wind farm model supplied by the Interconnection Customer.

The transient stability analysis conducted three-phase faults in the immediate study area as well as in northern Colorado. Eight transient stability disturbances were simulated for the benchmark and/or project cases, including the following:

A. NERC/WECC Category P1 (single contingency) Disturbances
(Three-phase, close-in faults at * with normal clearing of 6 cycles)

1. Missile Site* – Pronghorn 345 kV Line
2. Pawnee – Missile Site* #1 345 kV Line
3. Missile Site* – Smoky Hill 345 kV Line
4. Missile Site* – Daniels Park 345 kV Line
5. Missile Site 345*/230 kV transformer
6. Craig – Ault* 345 kV Line
7. Pawnee 22*/345 kV step-up transformer w/ tripping of Pawnee gen

B. NERC/WECC Category P7 (common structure) Disturbances
(Three-phase, close-in faults at * with normal clearing of 6 cycles)

8. Pawnee – Missile Site* #1 & #2 345 kV double circuit tower line
9. Missile Site* – Smoky Hill and Missile Site* – Daniels Park 345 kV double circuit tower line

The results noted in Appendix B demonstrate that no unacceptable/degraded stability performance occurs due to the proposed GI-2016-25 interconnection. Since none of the normally cleared three-phase fault disturbances at Missile Site resulted in tripping of the wind turbine generators proposed for the GI-2016-25 generating facility, it is concluded that angular stability as well as LVRT (Low Voltage Ride-Through) performance of GI-2016-25 is acceptable. Further, loss of a major transmission path from Craig as well as loss of a significant conventional (synchronous) generator at Pawnee did not demonstrate any angular or voltage stability issues on the transmission system. Select stability plots are provided in Appendix C. A complete set of stability plots are available on request.

Short Circuit Analysis

The short circuit study results show that no circuit breakers in the Missile Site Substation (or in other stations in PSCo's transmission system in proximity of the POI) will be over-dutied by interconnecting the proposed GI-2016-25 wind generation facility. The base case scenario before GI-2016-25 included preliminary models for all planned transmission system improvements and planned generating plants projected to be in-service through the end of 2020. Therefore, the base scenario includes the Pawnee – Daniels Park 345 kV Project and the Rush Creek wind generation project. The GI-2016-25 Gen-Tie impedance was estimated based on a length of 25 miles.

GI-2016-25 Impact on Short Circuit Levels and Breaker Duty Margins at Missile Site 345 kV POI

System Condition	Three-Phase (3-Ph) Fault Level (Amps)	Single-Line-to-Ground (SLG) Fault Level (Amps)	Thevenin System Equivalent Impedance (R + jX) (Ohms)
Before GI-2016-25 Y2020	18,600	16,507	Z1(pos)= 0.825 +j 10.677 Z2(neg)= 0.866 +j 10.673 Z0(zero)= 2.210 +j 14.640
After GI-2016-25 Y2020	19,025	16,797	Z1(pos)= 0.813 +j 10.438 Z2(neg)= 0.852 +j 10.434 Z0(zero)= 2.233 +j 14.488

Costs Estimates and Assumptions

Scoping level cost estimates (± 30% accuracy) for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery were developed by Public Service Company of Colorado (PSCo) / Xcel Energy (Xcel) Engineering. The cost estimates are in 2017 dollars with escalation and contingency factors included. AFUDC is not included. Cost estimates are developed assuming typical construction costs for previous completed projects. These cost estimates include all applicable labor and overheads associated with the siting support, engineering, design, material/equipment procurement, construction, testing and commissioning of these new substation and transmission line facilities. These cost estimates do not include the cost for any other Customer owned equipment and associated design and engineering.

Figure 2 below shows a conceptual one-line of the transmission facilities needed to electrically interconnect the proposed GI-2016-25 Generating Facility to the Missile Site 345kV POI.

Figure 3 shows the new Rush Creek II Station needed for physical interconnection of GI-2016-25 to the Rush Creek Gen-Tie.

The following tables list the transmission improvements required to accommodate the interconnection and delivery of GI-2016-25 output. The cost responsibilities associated with these transmission facilities shall be handled as per current FERC guidelines. Cost estimates and transmission improvements are subject to change upon a more detailed and refined design, which will occur in the facility studies.

The estimated total cost for the Interconnection Facilities and Network Upgrades is $11.635 million.

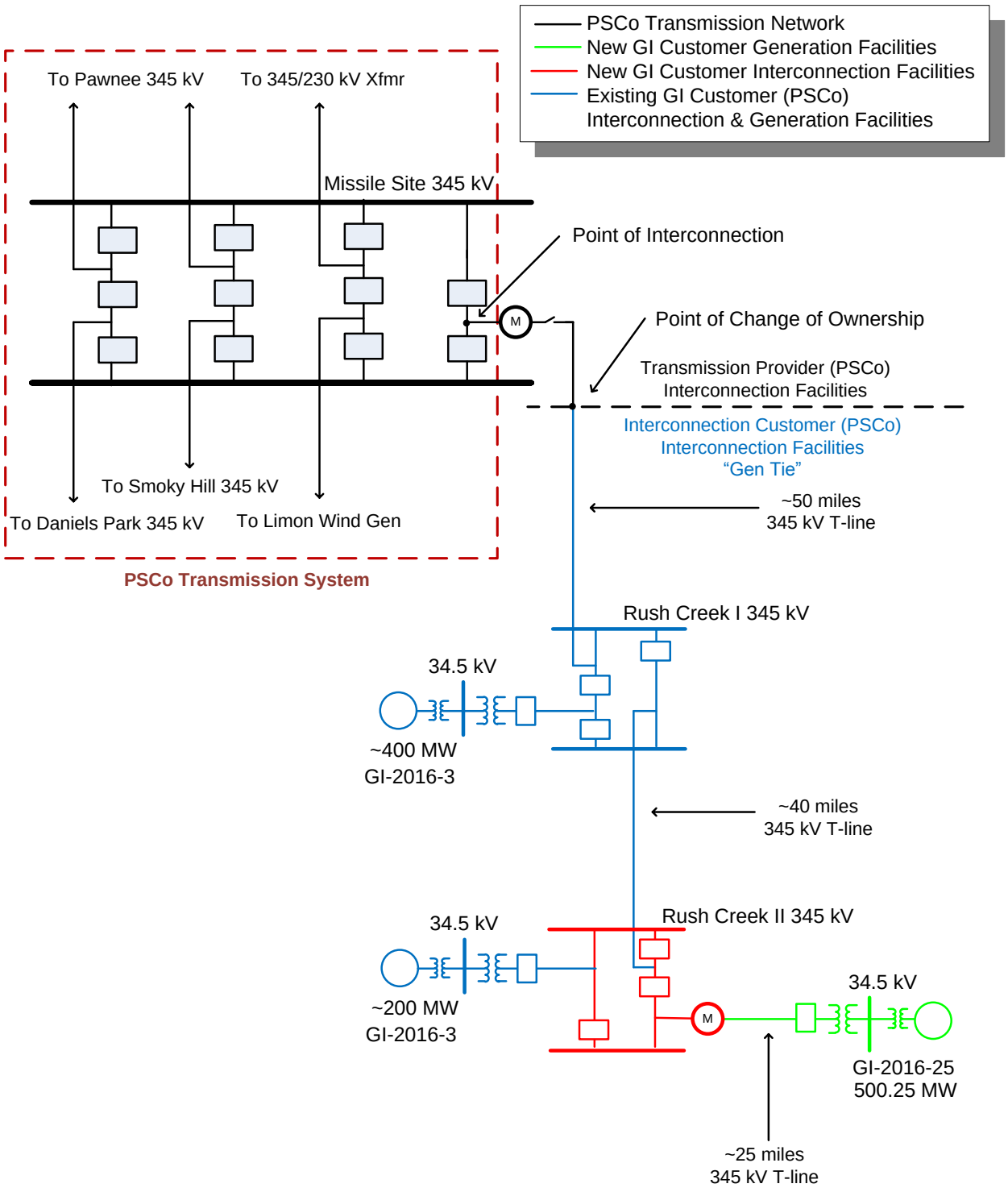


Figure 2: GI-2016-25 Interconnection to the Missile Site 345kV Bus POI via Existing Rush Creek Gen-Tie and New Rush Creek II 345kV Station Interconnection Facilities

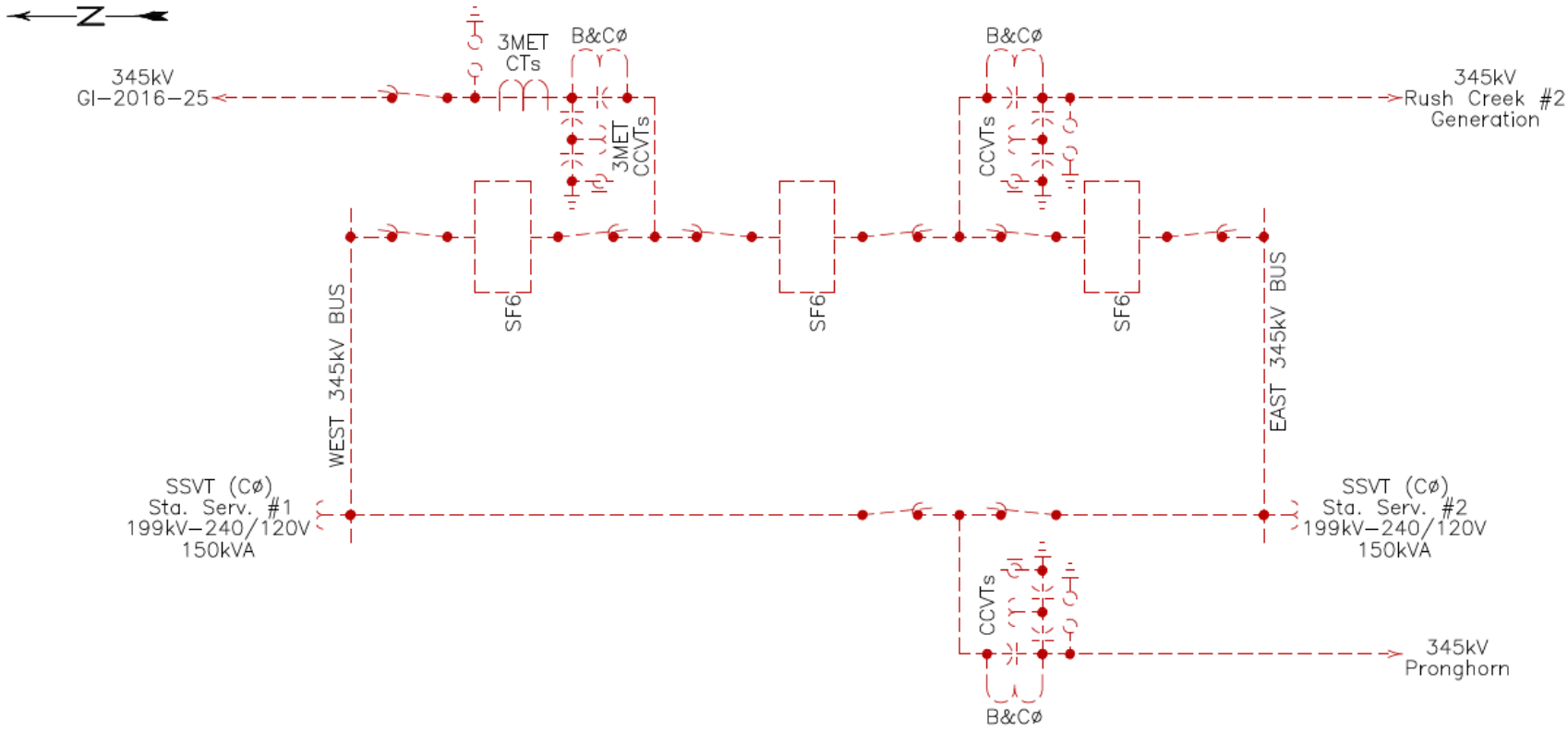


Figure 3: New Rush Creek II Station needed for Physical Interconnection of GI-2016-25 to Rush Creek Gen-Tie

Table 1: PSCo Owned; Interconnection Customer Funded Interconnection Facilities

Element	Description	Cost Estimate (Millions)
PSCo's New Rush Creek II 345kV Station	Three-position ring-bus 345kV station needed to interconnect the new Generating Facility to the planned Rush Creek-Missile Site (L7132) 345kV Transmission Line. The new equipment includes: • Three 345kV circuit breakers • Six 345kV disconnect switches • Six 345kV CCVT's • Four 345kV line traps/tuner equipment • 345kV arresters • New Electric Equipment Enclosure (Control Bldg.) • New station battery system • Station controls • Associated communications, supervisory and SCADA equipment • Associated line relaying and testing • Associated bus, miscellaneous electrical equipment, cabling and wiring • Associated foundations and structures • Associated road and site development, fencing and grounding	**$9.174**
Interconnection of Generating Facility's 345kV T-Line to New Rush Creek II Station	Interconnect the last span of Transmission Line from new Generating Facility into the new 345 kV station. The new equipment includes: • Two 345kV disconnect switches • 345kV arresters • One set (of 3) 345kV CT/PT metering units • Two 345kV line traps/tuner equipment • Station controls • Instrument transformers • Associated bus, wiring and equipment • Associated site development, grounding, foundations and structures • Associated transmission line communications, relaying and testing • Last span to substation	**$2.056**
	Siting and Land Rights support for siting studies, land and ROW acquisition and construction.	**$0.355**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$11.585**
Time Frame	**Regulatory (CPCN), site, design, procure and construct**	**36 Months**

Table 2: PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
PSCo's Monaco 230kV Transmission Substation	Upgrade/replace limiting substation equipment to achieve required MVA ratings on circuit 5281 Monaco-Greenwood OH/UG Line: • Six 1272 dual jumpers	**$0.050**
	Total Cost Estimate for PSCo Network Upgrades for Delivery Facilities	**$0.050**
Time Frame	**Design, procure and construct**	**18 months**

Cost Estimate Assumptions

- Scoping level project cost estimates for Interconnection Facilities and Infrastructure Upgrades for Delivery have an assumed +/- 30% accuracy.
- Estimates are in 2017 dollars (appropriate contingency and escalation applied).
- Allowance for Funds Used During Construction (AFUDC) has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The Customer Generation Facility is not in PSCo's retail service territory. Therefore, no costs for retail load (distribution) facilities and metering required for station service are included in these estimates. .
- PSCo (or our Contractor) crews will perform all construction, wiring, testing and commissioning for PSCo owned and maintained facilities.
- A CPCN will be required. The estimated time frame for regulatory activities (CPCN) and to site, design, procure and construct the interconnection and network delivery facilities (entire Project) is approximately 36 months after authorization to proceed has been obtained.
- The Customer will be required to design, procure, install, own, operate and maintain a Load Frequency/Automated Generation Control (LF/AGC) RTU at their Customer Substation. PSCo / Xcel will need indications, readings and data from the LFAGC RTU.
- Customer will string OPGW fiber into substation (Rush Creek II) as part of the transmission line construction scope.
- Breaker duty study determined that no breaker replacements are needed in neighboring substations.

Conclusion

The power flow, transient stability, and short circuit analysis performed for this System Impact Study shows that the additional 500.25 MW generation injection into Missile Site Substation may cause a thermal overload of the Greenwood – Monaco 230 kV line (L5281) following the loss of Smoky Hill – Leetsdale 230 kV line (L5281).

Therefore, for GI-2016-25 interconnection:

NRIS (after network upgrades & Pawnee-Daniels Park) = 500.25 MW

ERIS (before network upgrades) = 0 to 500.25 MW on “as-available” basis

The estimated total cost for the required upgrades for the interconnection is $11.635 million. It is estimated that this work can be completed in approximately 36 months, following receipt of authorization to proceed. The schedule assumes a Certificate of Public Convenience and Necessity (CPCN) for the Rush Creek II 345 kV station would be required.

Appendix A – Power Flow N-1 Contingency Analysis Results

High Coincidence Generation Dispatch at Pawnee & Missile Site:

Pawnee 230kV (100% Coal + 90% Gas + 40% Wind) = 1018 MW;

Missile Site 345kV Wind = 480 MW (80%); Missile Site 230kV Wind = 200 MW (80%)

600 MW output from Rush Creek is dispatched to sink at Blue Spruce, Rocky Mountain Energy Center, & Comanche

500.25 MW output from GI-2016-25 is dispatched to sink at Spindle, Rocky Mountain Energy Center & Comanche

Table A.1 – Differential Impact[5] of GI-2016-25 on Facility Loadings
With Pawnee – Daniels Park 345kV Project In-Service

				Branch N-1 Loading Before 500.25 MW GI (600 MW Total Injection)		Branch N-1 Loading After 500.25 MW GI (1100 MW Total Injection)			
Monitored Facility (Line or Transformer)	Type	Owner	Summer Normal (Continuous) Facility Rating in MVA	Flow in MVA	Flow in % of Summer Normal Rating	Flow in MVA	Flow in % of Summer Normal Rating	Differential Impact of GI-2016-25	N-1 Contingency Outage
Greenwood – Monaco 230 kV	Line	PSCo	404	404	100%	**464.6**	**115%**	15%	Smoky Hill -- Leetsdale 230 kV

[5] **Due to proposed 500.25 MW generation increase at Missile Site 345 kV Substation**

Appendix B – Transient Stability Analysis Results

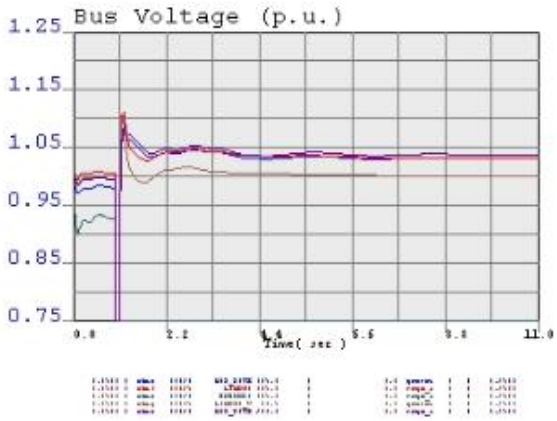
Stability Disturbances							
#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Stability Performance	Post-Fault Voltage Recovery	Angular Stability
1	Missile Site 345 kV	3ph	Missile Site – Pronghorn 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
2	Missile Site 345 kV	3ph	Missile Site – Pawnee 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
3	Missile Site 345 kV	3ph	Missile Site – Smoky Hill 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
4	Missile Site 345 kV	3ph	Missile Site – Daniels Park 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
5	Missile Site 345 kV	3ph	Missile Site 345/230 kV Auto-Transformer	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
6	Craig 345 kV	3ph	Craig – Ault 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
7	Pawnee 22 kV	3ph	Pawnee Generator	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
8	Missile Site 345 kV	3ph	Pawnee – Missile Site #1 and #2 345 kV double circuit tower line (DCTL)	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
9	Missile Site 345 kV	3ph	Missile Site – Smoky Hill and Missile Site – Daniels Park 345 kV double circuit tower line (DCTL)	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping

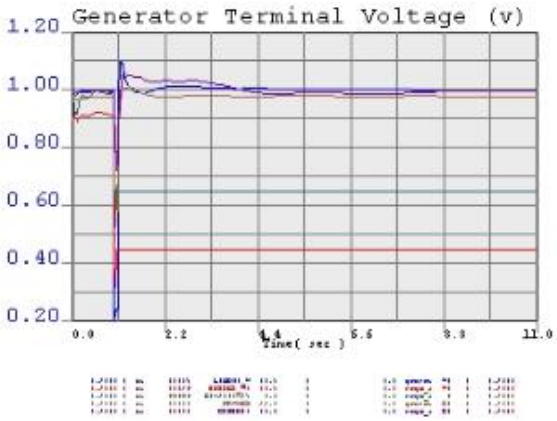
Appendix C – Transient Stability Analysis Plots

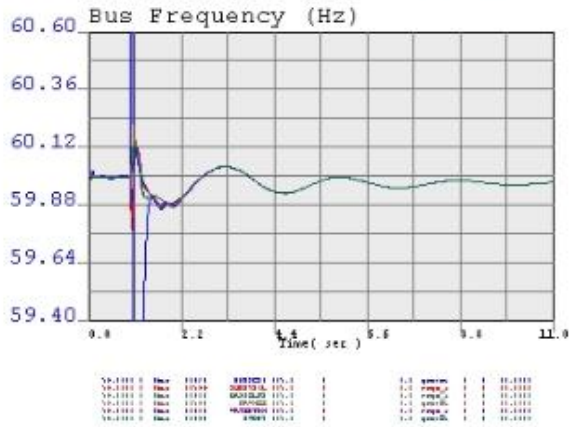
Plots shown below various recordings of bus voltage, bus frequency, generator angle, generator terminal voltage, generator speed, and generator power output for the following outages performed on the study case:

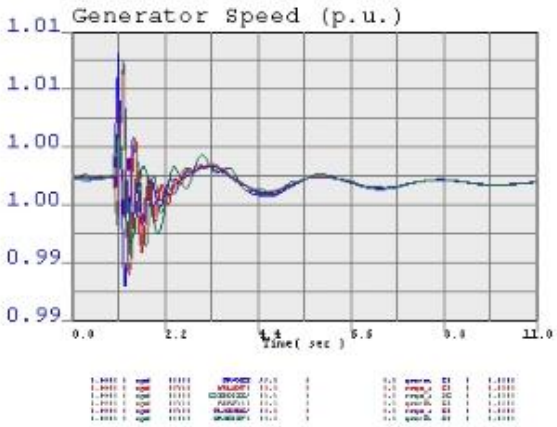
#1 – Missile Site – Pronghorn 345 kV line
#8 – Pawnee – Missile Site 345 kV double circuit tower line
#9 – Missile Site-Smoky Hill & Daniels Park 345 kV Double Circuit Tower line

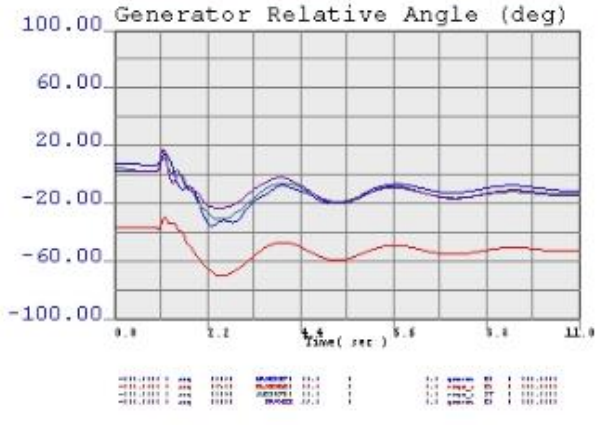
Other plots are available upon request.

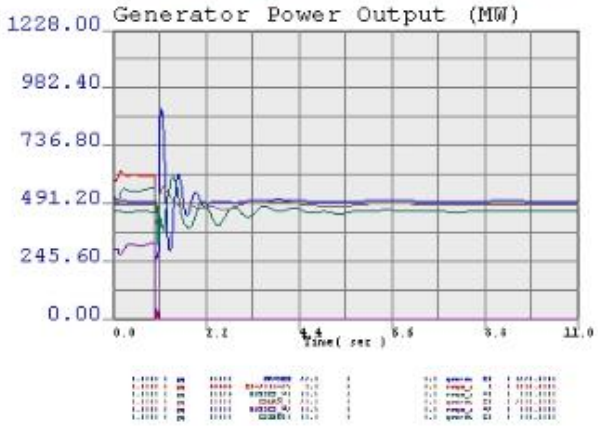




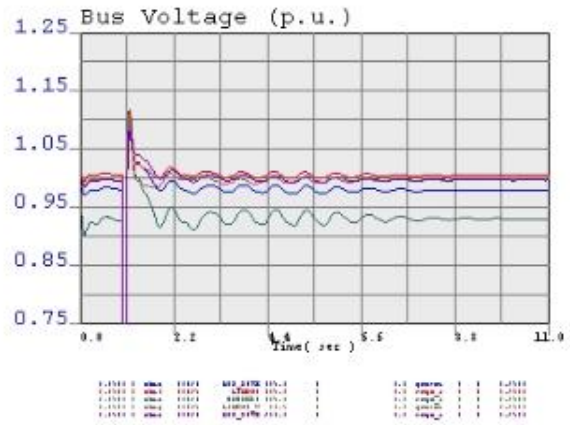


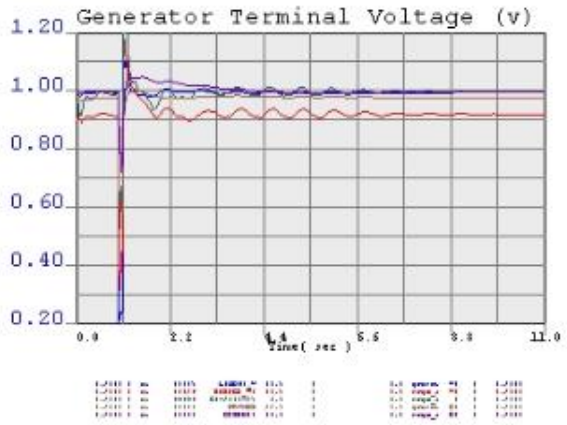


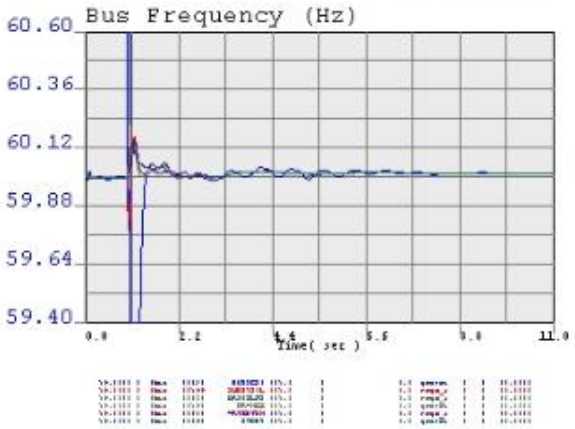


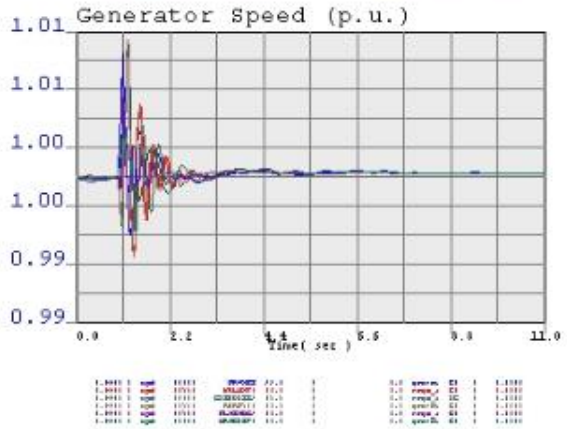


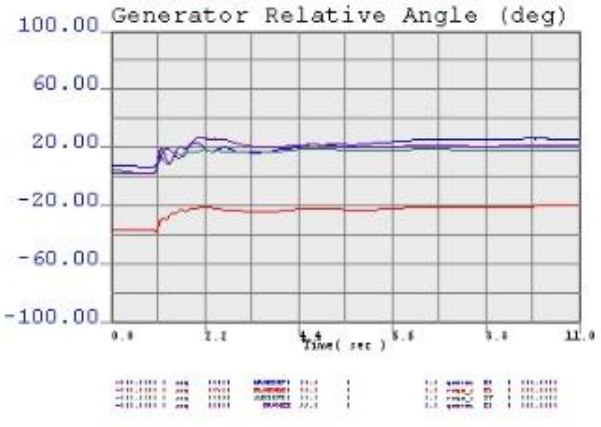
1
Missile fault, lose Missile-Rush Creek

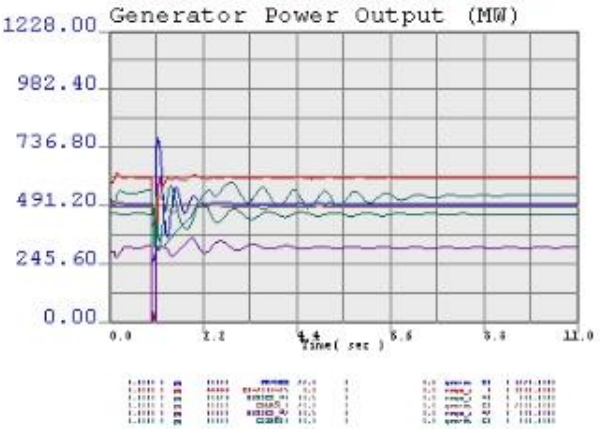




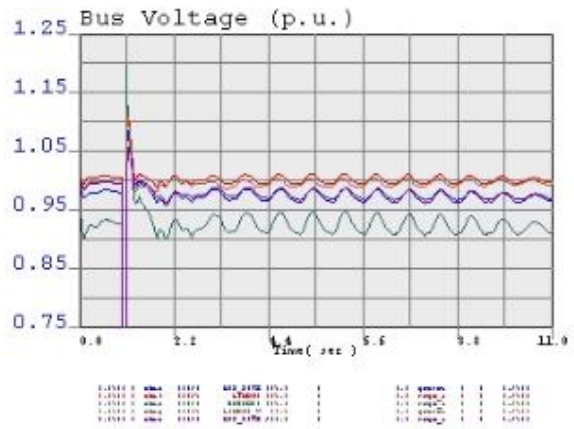


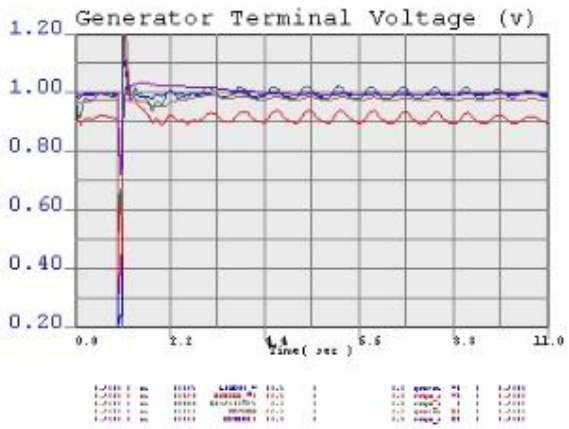


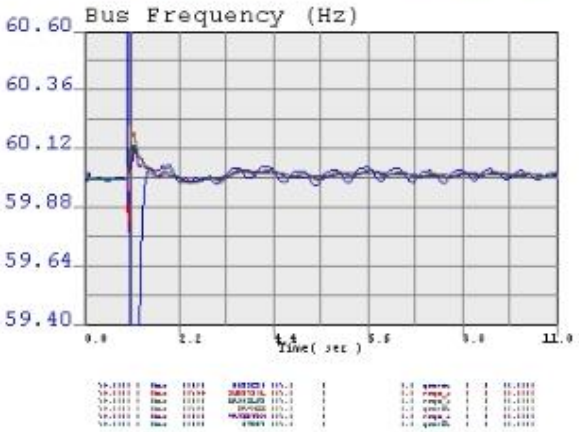


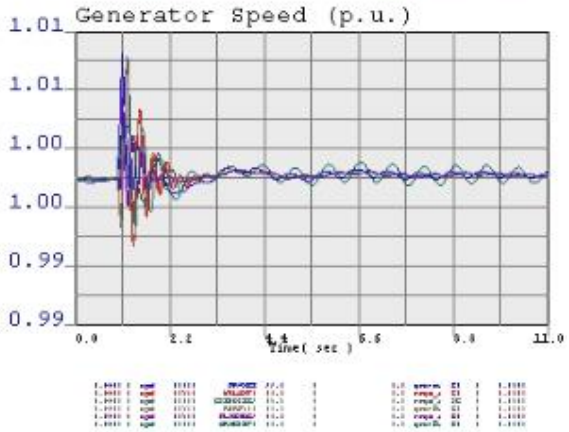


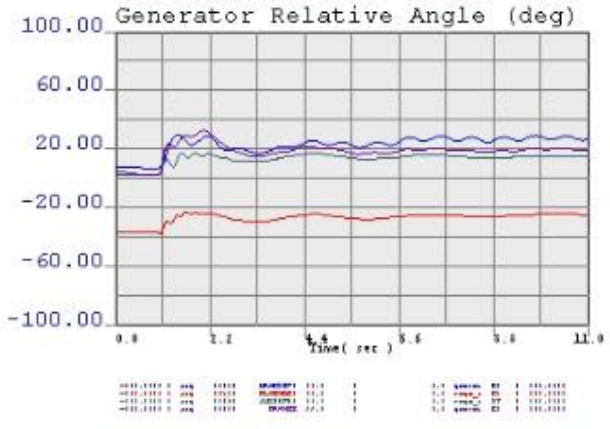
6
Missile fault, lose Pawnee-Missile DCTL

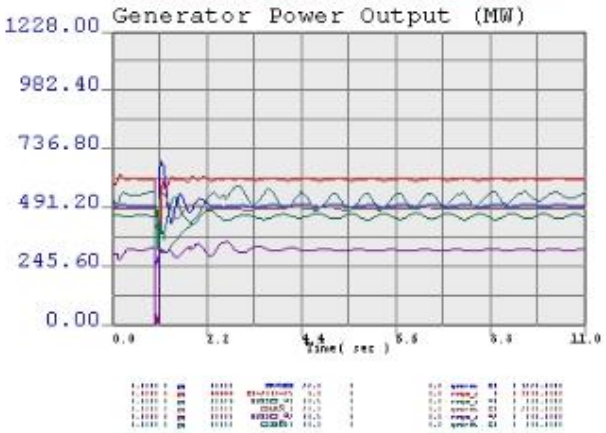












9
Missile fault, lose Missile-S/D DCTL