



Interconnection System Impact Study Report Request # GI-2011-04

587 MW (summer), 643 MW (winter) 2x1 Combined Cycle Generators
Cherokee Station, Denver, Colorado

Public Service Company of Colorado
Transmission Asset Management
August 30, 2013

A. Executive Summary

Public Service Company of Colorado (PSCo) received an interconnection request (GI-2011-04) on April 7, 2011 for a 2x1 Combined Cycle generation facility that is proposed to be interconnected to the PSCo transmission system at Cherokee 115 kV substation in Denver, Colorado.

GI-2011-4 is a Network Resource Interconnection Service (NRIS) request for the following aggregate MW output from the 2x1 Combined Cycle (CC) generation facility, based on the gross output capability of the three generating units comprising the proposed generation facility.

Summer (95° F) = 587 MW based on each CT = 168.6 MW and ST = 249.5 MW
Winter (6° F) = 643 MW based on each CT = 194.2 MW and ST = 254.7 MW

The proposed generation facility will consist of two (2) gas-fired 218 MVA combustion turbine generators and a 300 MVA steam turbine generator connected in a combined cycle configuration. This facility is proposed to interconnect with the PSCo Cherokee 115 kV substation (the Point Of Interconnection) via three (3) separate generator step-up transformers – see Figure 1 below. The requested in-service date was June 30, 2015. However, in a plan filed by the Customer with the Colorado Public Utilities Commission, the 2x1 CC generation facility is required to be placed in service by December 31, 2015.

This generation interconnection request was studied as a stand-alone request – that is, without including any other prior-queued generation interconnection requests existing in the Large Generator Interconnection Request (LGIR) queue, but including the generation interconnection projects that are already planned to be in service by December 31, 2015.

The main purpose of this System Impact Study (SIS) was to identify and mitigate the potential adverse impacts on the PSCo transmission infrastructure as well as that of neighboring utilities when injecting the additional generation of 587 MW (summer) and 643 MW (winter) at the existing Cherokee 115 kV substation, and delivering this additional generation to native PSCo loads. Therefore, the SIS evaluated the steady-state performance (thermal impacts) for 2016 summer peak and 2016-17 winter peak projected system load conditions, and evaluated the stability performance for maximum (winter) generation output of 643 MW during 2016-17 light-load conditions. The power flow and stability analyses address NERC Category B and NERC Category C contingencies. The SIS also includes short circuit analysis during system intact conditions to evaluate the fault duty impact of the interconnecting generator.

The short circuit analysis found that interconnection of the three generating units (Cherokee #5, #6, #7) comprising the 2x1 CC generating plant results in the short circuit level at the POI (Cherokee 115

kV bus) to exceed the 63 kA interrupting duty rating of all 29 circuit breakers in the 115 kV switchyard. The circuit breakers remain over-dutied even after the mitigating effect due to the planned retirement of Cherokee #3 unit after the 2x1 CC generators achieve commercial operation. The mitigation strategy developed to reduce the short-circuit level below 63 kA consists of the following system topology modifications implemented within the Cherokee 115 kV Station —

- (a) splitting the Cherokee 115 kV Station into separate Cherokee North and Cherokee South 115 kV Stations by removing the existing 115kV bus-ties between switchyards,
- (b) re-terminating the Cherokee 230/115 kV #T2 transformer from South to North switchyard, and
- (c) re-terminating the Cherokee-Semper 115 kV transmission line from South to North switchyard.

The power flow analysis results for 587 MW summer output are provided in Tables 7 & 8 in Appendix A and for 643 MW winter output are provided in Table 9 in Appendix B.

Table 7 shows four (4) new thermal overloads above their respective summer normal facility ratings due to Category B contingencies and Table 8 shows three (3) new thermal overloads at or above their respective summer emergency facility ratings due to Category C contingencies. Transmission improvements needed to mitigate the thermal constraints consist of re-conductoring the Cherokee–Conoco 115kV transmission line and upgrading substation terminal equipment at three stations. Table 9 shows only one thermal constraint for 643 MW output due to two (2) Cat-B contingencies – the use of facility emergency rating and/or generation curtailment are mitigation options for it.

The stability analysis demonstrated acceptable transient stability performance for the proposed GI-2011-4 generating units and all existing generators – therefore no transmission improvement was identified from stability considerations.

The total estimated cost of the transmission improvements identified to interconnect the proposed GI-2011-4 generation is approximately **\$10.01 million (in 2013 dollars)** and includes:

- \$ 4.614 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- \$ 1.62 million for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection
- \$ 3.865 million for PSCo Network Upgrades for Energy Delivery to PSCo Loads

Details for the above cost estimates are provided in Tables 4 – 6 in the Cost Estimates section of this report. The site, design, procure and construct time for each of the above transmission improvements is estimated at 15 months – therefore all required transmission improvements will be complete by the June 30, 2015 in-service date requested by GI-2011-4.

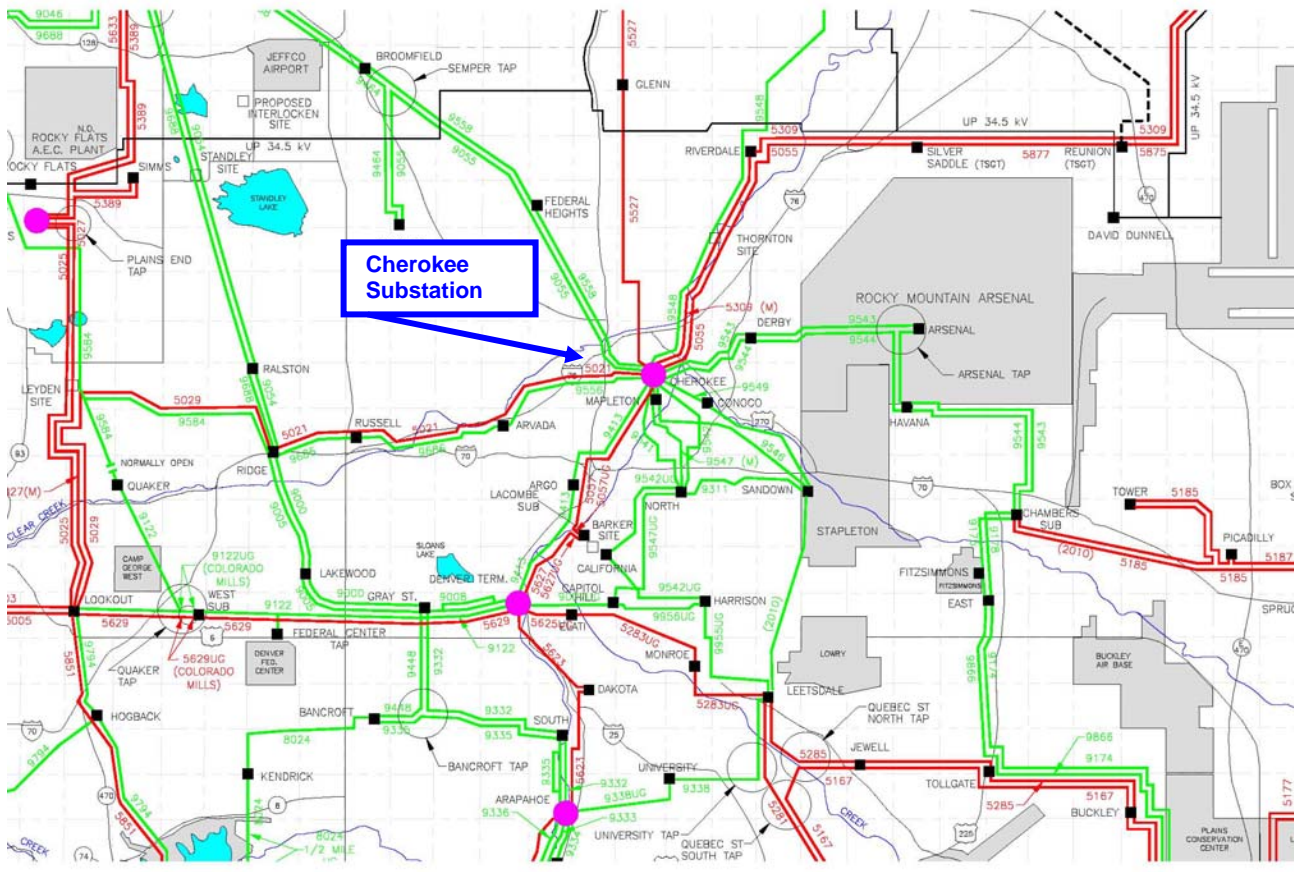
After implementation of the network upgrades, the proposed generation will be able to provide the full 587 MW (summer) output without any restriction. Although there are no stability related limits on providing the full 643 MW (winter) output, some generation curtailment may be required to mitigate the N-1 post-contingency thermal overload on the underground section of the Cherokee – California 115kV line L9542. Since this thermal overload is sensitive to the winter load levels at specific load-serving 115kV stations such as California, Capitol Hill, Harrison and Leetsdale, the use of generation curtailment as operating procedure will be determined during real-time operations.

Therefore, Network Resource Integration Service (NRIS) for GI-2011-4

= 587 MW (summer) without restriction

= 643 MW (winter) without restriction (system intact); with potential curtailment (N-1 outage)

Figure 1 Cherokee Substation and Surrounding Transmission System



B. Introduction

Public Service Company of Colorado (PSCo) received an interconnection request (GI-2011-04) for a 587 MW 2 x 1 Combined Cycle generation facility to be connected to the PSCo transmission system in Denver, Colorado. The interconnection request was received April 7, 2011.

The proposed generation facility will consist of two (2) gas-fired 218 MVA combustion turbine generators and a 300 MVA steam turbine generator connected in a combined cycle configuration. This facility is proposed to interconnect with the PSCo Cherokee 115 kV substation (the Point Of Interconnection) via three (3) separate generator step-up transformers (see Figure 1 above). The requested in-service date was June 30, 2015. However, in a plan filed by the Customer with the Colorado Public Utilities Commission, the plant is required to be placed in service by December 31, 2015. Therefore, the studies examined system performance for 2016 peak summer conditions.

C. Study Scope and Analysis

The Feasibility Study evaluated the transmission impacts associated with the proposed 587 MW Combined Cycle (CC) plant. It consisted of power flow and short circuit analyses.

The power flow analysis was performed to identify any steady-state thermal or voltage limit violations resulting from the installation of the proposed generation and an identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified short circuit levels and determined short circuit impacts on area circuit breakers due to the installation of the proposed 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 tries to maintain a transmission system voltage profile ranging from 1.02 per unit or higher at regulating (generation) buses to 1.00 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 1.05 per unit, and power flows within 100% of the facilities' continuous thermal ratings.

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

D. Power Flow Study Models

In this Feasibility study, two main power flow generation dispatch scenarios were evaluated. One was created as a reference benchmark scenario and the other was created with the proposed generation. The power flow studies were based on the WECC approved 17HS1AP case. The Colorado Coordinated Planning Group (CCPG) portion of the case was adjusted to 2016 peak summer conditions using load, topology and generation dispatch updates from the PSCo, IREA, CSU, TSG&T, WAPA, PRPA, BHE, and BEPC systems. PSCo loads in the case were adjusted to reflect the September 2011 PSCo load forecast. IREA loads were also adjusted to reflect IREA's latest load forecast.

Some of the PSCo upgrades that were included in the transmission system models were system upgrades that were developed as a result of studies PSCo performed in compliance with the Colorado Clean Air Clean Jobs Act (CACJA). These upgrades and their associated cost estimates are described in CPUC Decision No. C10-1328, Docket No. 10M-245 concerning PSCo's CACJA compliance filing.

The following system modifications/upgrades required by the CPUC CACJA Order were implemented in all models (benchmark and study cases):

1. Cherokee Unit 2 conversion to a synchronous condenser (currently in service)
2. Arapahoe Unit 3 Retirement (planned for 2013)
3. Arapahoe Unit 4 Conversion to Natural Gas (planned for 2014)
4. Cherokee Unit 3 Retirement (planned for 2015)
5. 90 Mvar Capacitor bank installation at the Cherokee 115 kV South Station (planned for 2013)
6. 90 Mvar Capacitor bank installation at the Arapahoe 115 kV Station (planned for 2013)

The following planned transmission project was also implemented in all models (benchmark and study cases):

- Voltage conversion of the Cherokee-Arvada-Russell-Ridge line from 115 kV to 230 kV operation – this requires line re-termination at Cherokee and Ridge 230 kV stations.

The following system topology modifications needed to address the short circuit level exceedance above 63 kA at the Cherokee 115 kV bus due to the proposed Cherokee 2x1 CC generation were included in the study cases only:

1. Split the Cherokee 115 kV North and South station by opening the existing 115 kV bus ties between them (*to alleviate short circuit level exceedance above 63 kA*)
2. Re-terminate the Cherokee 230/115 kV #T2 auto-transformer from the Cherokee South 115 kV station to the Cherokee North 115 kV station (*to alleviate short circuit level exceedance above 63 kA*)
3. Re-terminate the Cherokee-Semper 115 kV line from the Cherokee South 115 kV station to the Cherokee North 115 kV station (*to offset the adverse power flow impacts caused by the Cherokee 115kV bus split*).

As part of the power flow model preparation, the existing and planned PSCo-connected wind turbine generation levels were increased to a level (21% of max) that represents the approximate average output of these wind plants during historical summer peak periods. These wind plants include Peetz Logan, Cedar Creek, Cedar Point and Limon.

The PSCo thermal units were dispatched according to their relative average maximum MW generation costs. Also, the Area 70 (Area PSCOLORADO) swing machine in the WECC load flow case was moved to Comanche Unit 1. The resulting PSCo generation dispatch in the Benchmark Case is provided in Appendices A and B. The generation dispatch adjustments needed in the Study Cases to sink the proposed 2x1 CC generation output (summer/winter MW as noted below) is provided for 2016HS case in Appendix A and 2016HW case in Appendix B.

Based on information received from the Customer, the summer/winter generating capacities for the units comprising the 2x1 CC plant are tabulated below: In the study cases, 587 MW (summer) and 643 MW (winter) injection was modeled at the Cherokee South 115 kV bus.

	MW (Summer)	MW (Winter)	Mvar Limits	GSU Tap Setting
Combustion Turbine Gen #1	168.6	194.2	+133.0 to -69.0	115.0/17.7 kV
Combustion Turbine Gen #2	168.6	194.2	+133.0 to -69.0	115.0/17.7 kV
Steam Turbine Gen	249.5	254.7	+155.0 to -100.0	115.0/18.0 kV
2x1 CC Plant	~587	~643		

Also, 8.8 MW of auxiliary load was modeled connected to each of the combustion turbine generator buses for a total of 17.6 MW of auxiliary load. The three generator step-up transformers for each of the three units were modeled set to the nominal/center tap (115/xx.x kV). However, the actual GSU transformer fixed tap settings to optimize the reactive capability of these units may be different than those modeled in this study. Additional studies will be required after the transformers and their test reports are received to determine the recommended fixed tap settings.

E. Power Flow Study Process

Contingency power flow studies were completed on the benchmark model and the model with the proposed new generation using PTI's PSSE Ver. 32.1.0 and MUST Ver. 10.2.1 programs. Results from the two cases were compared and new overloads in the new generation case were noted. Voltage criteria violations were also recorded. MUST's contingency analysis activities were used to perform the load flow contingency analysis. The PSCo Category B & C analysis was performed using contingency definitions that reflect breaker to breaker outages. Single branch switching was also performed for branches in and around the Denver Metro Area. Single unit outages were also modeled for generators in PSCo's control area. Single unit outages were also modeled in the CSU and Foothills area. The transmission facilities in and around the Denver Metro Area were monitored for overloads and voltage problems.

F. Power Flow Thermal Results (587 MW Summer Output) using 2016HS case

The results of the Category B and Category C contingency analyses are provided in Table 7 and Table 8 respectively in Appendix A. Of the four (4) Cat-B facility overloads, two are due to exceeding the substation terminal equipment rating. The remaining two Cat-B facility overloads involve exceeding the line conductor rating, as discussed below: All Cat-C overloads are with respect to the facility's emergency rating and get resolved by the network upgrades for Cat-B.

Cherokee – Conoco 115 kV Line (L9549) - This facility is limited by the 159 MVA rating of the 1.95 miles of 1-477 26/7 ACSR conductor. This line section will be re-conducted with 1-477 26/7 ACSS to achieve ~190 MVA rating. Also, some terminal equipment at Cherokee will need to be upgraded.

California – Cherokee 115 kV Line (L9542) – This facility is limited by the 137 MVA continuous rating of the 2.69 miles of 1-1250 kcmil 91 strand copper underground cable (the overhead portion of the line is rated 199 MVA normal). Transmission Line Engineering reviewed the emergency rating for the underground portion of this circuit and found that it could be loaded to 1040 A (207 MVA) for up to 8 hours assuming a pre-contingency loading of 524 A (104 MVA). This is 151.2% of the 137 MVA continuous rating. The pre-contingency loading in the study case with the new generation was 112 MVA. Therefore, the indicated 8 hour 207 MVA emergency rating should be adequate and cable replacement is not being recommended as required network upgrade at this time.

Besides overloading the underground cable, the contingency also causes the loading on the substation jumpers at California to exceed their normal rating. The jumper conductor is 795 kcmil AL and has normal and 30 minute emergency ratings of 763 A / 901 A (152 MVA / 180 MVA). The cost to upgrade these jumpers is small compared to the cost of replacing the underground cable. Therefore, we recommend that these jumpers be upgraded with 1-1272 kcmil AL.

G. Power Flow Thermal Results (643 MW Winter Output) using 2016HW case

The power flow analysis for 643 MW winter output was conducted by using the 2016-17 heavy winter model (2016HW) derived from the 2016 heavy summer (2016HS) model. The winter peak load in Denver metro area (i.e. zones 700 and 703 in the model) was scaled to 80% of summer peak load, which translated to ~1100 MW load reduction. The corresponding generation dispatch adjustments for the 2016HW study case are provided in Appendix B. The facility ratings resulting from the transmission improvements identified for 587 MW output were included in the 2016HW model. Consequently, the facility overloads provided in Table 9 in Appendix B are indicative of new thermal constraints due to the increase in GI-2011-4 output from 587 MW to 643 MW.

It may be observed from Table 9 that only one facility – the California–Cherokee 115kV line (L9542) – is a thermal constraint to 643 MW output for two Cat-B contingencies. The previous discussion regarding the 8-hour emergency rating of the underground portion of this line is still applicable. However, since this facility overload is sensitive to the winter load levels at specific load-serving 115kV stations such as California, Capitol Hill, Harrison and Leetsdale, the use of generation curtailment as operating procedure may become necessary for N-1 contingencies during real-time operations.

H. Transient Stability Study Model & Results (643 MW Output) using 2016LL case

The transient stability analysis was performed by developing a 2016 light load model derived from the 2016 heavy winter power flow model by scaling the load and adjusting the generation dispatch. The transient stability analysis results are provided in Tables 10 – 13 in Appendix C. The results indicate that with the proposed addition of the GI-2011-04 generation, the system is stable with satisfactory damping for all studied disturbances. Also the voltage and frequency responses of all monitored buses are within WECC criteria for all studied disturbances.

No stability constraints were identified and therefore no transmission upgrades are required to mitigate for stability impacts.

I. Voltage Regulation and Reactive Power Capability

Interconnection Customers are required to interconnect their Large Generating Facilities with Public Service of Colorado's (PSCo) Transmission System in conformance to the *Xcel Energy Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW* (available at <http://www.xcelenergy.com/staticfiles/xcel/Regulatory/Transmission-Interconnection-Guidelines-Great-20MW.pdf>). Accordingly, the following voltage regulation and reactive power capability requirements (at the POI) are applicable to this interconnection request:

- To ensure reliable operation, all Generating Facilities interconnected to the PSCo transmission system should adhere to the Rocky Mountain Area Voltage Coordination Guidelines. Accordingly, since the POI for this interconnection request is located within Metro-Denver-Boulder-Ft Lupton Region 8; 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 for the 115kV and 230 kV systems.
- Xcel Energy's OATT requires all Interconnection Customers to have the reactive capability to achieve +/- 0.95 power factor at the POI, with the maximum "full output" reactive capability available at all output levels. Furthermore, Xcel Energy requires all Interconnection Customers to have dynamic voltage control and maintain the voltage specified by the Transmission Operator within the limitation of +/- 0.95 power factor at the POI, as long as the generating plant is on-line and producing power.
- The Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and voltage ranges (noted above).

This study examined the impact of the proposed Cherokee 2x1 CC plant on area transmission system voltages. No problems were found that could be attributed to the proposed generation.

J. Short Circuit Study Results

A circuit breaker short circuit duty study was performed to assess the impact of the proposed generation on the ability of the area circuit breakers to safely and successfully interrupt fault current. The single line to ground fault levels were found to be most limiting. The study determined that 29 115 kV circuit breakers at the Cherokee 115 kV station are expected to exceed their capabilities following installation of the new generation. Therefore, additional studies were performed to develop a station reconfiguration plan that would mitigate the circuit breaker short circuit over-duty problem. The configurations are identified on each line in the Tables 1 & 2 below.

Scenario #1 represents the benchmark station configuration without the proposed 2x1 generation and the existing Cherokee Station configuration. Scenario #2 includes the proposed 2x1 generation and the existing Station configuration but excludes Cherokee Unit 3. This unit is scheduled for retirement in 2015. The breakers at the Cherokee 115 kV Station all have a symmetrical rating of 63 kA. Therefore, without any other station adjustments, 29 of the breakers at Cherokee 115 kV Station could experience a short circuit over-duty event presenting a serious safety risk.

Scenarios 3 – 8 represent different alternative Cherokee Station configurations that were tested to evaluate and improve the Station short circuit performance with the proposed generation. Please note that based on previous studies related to the Colorado Clean Air Clean Jobs Act that were separate from this study, PSCo decided to move the terminations of the Cherokee 230/115 kV T2 transformer and the Cherokee-Semper 115 kV from the Cherokee South 115 kV station to the North Station for thermal overload reasons. The short circuit performance with the facility re-terminations was found to improve.

The configuration specified for Scenario #5 was found to satisfactorily mitigate the breaker over-duty problem while allowing an adequate safety margin. The calculated short circuit levels for the Cherokee 115 kV & 230 kV stations are shown in Tables 1 & 2 below. Besides the facility re-terminations, Scenario #5 includes a separation of the Cherokee North and South 115 kV Stations.

Please note that Scenarios 6 – 8 include Cherokee Unit 3 modeled in-service. This information was included for information only since Unit 3 is planned for retirement in 2015.

Table 3 below shows the Thevenin System Impedances for the original and recommended Cherokee Station configurations.

Table 1 – Single Line to Ground Short Circuit Parameters at the Cherokee 115 kV & 230 kV Substations

Scenario #	GI-2011-04 Project Status	North-South 115kV Bus-Tie Status	Cherokee Unit 3 Status	Cherokee 230/115 kV T2 Low-Side Termination	Cherokee – Semper 115 kV Line 9055 Termination	North 115kV Bus Fault (SLG-Amps)	South 115kV Bus Fault (SLG-Amps)	230kV Bus Fault (SLG-Amps)	Num. BKR's needing to be replaced 230kV/115kV
1	Off-Line	Closed	On	115kV South Bus	115kV South Bus	62.2	62.2	33.6	0/0
2	On-Line	Closed	Off	115kV South Bus	115kV South Bus	73.9	73.9	34.7	0/29
3	On-Line	Open	Off	115kV South Bus	115kV South Bus	31.2	61.2	34.2	0/0
4	On-Line	Open	Off	115kV North Bus	115kV South Bus	37.9	57.3	34.7	0/0
5	On-Line	Open	Off	115kV North Bus	115kV North Bus	37.7	55.4	34.7	0/0
6	On-Line	Open	On	115kV South Bus	115kV South Bus	31.4	65.9	34.6	0/19
7	On-Line	Open	On	115kV North Bus	115kV South Bus	38.2	62.0	35.0	0/0
8	On-Line	Open	On	115kV North Bus	115kV North Bus	37.8	60.0	35.0	0/0

Table 2 – Three Phase Short Circuit Parameters at the Cherokee 115 kV & 230 kV Substations

Scenario #	GI-2011-04 Project Status	North-South 115kV Bus-Tie Status	Cherokee Unit 3 Status	Cherokee 230/115 kV T2 Low-Side Termination	Cherokee – Semper 115 kV Line 9055 Termination	North 115kV Bus Fault (3PH-kA)	South 115kV Bus Fault (3PH-kA)	230kV Bus Fault (3PH-kA)
1	Off-Line	Closed	On	115kV South Bus	115kV South Bus	59.9	59.9	31.9
2	On-Line	Closed	Off	115kV South Bus	115kV South Bus	68.7	68.7	33.4
3	On-Line	Open	Off	115kV South Bus	115kV South Bus	31.0	58.2	32.6
4	On-Line	Open	Off	115kV North Bus	115kV South Bus	39.4	54.2	33.4
5	On-Line	Open	Off	115kV North Bus	115kV North Bus	40.0	52.4	33.4
6	On-Line	Open	On	115kV South Bus	115kV South Bus	31.1	61.3	33.2
7	On-Line	Open	On	115kV North Bus	115kV South Bus	39.7	57.3	33.8
8	On-Line	Open	On	115kV North Bus	115kV North Bus	40.3	55.5	33.8

The yellow highlighted lines show the short circuit levels with GI-2011-04 connected and Cherokee Unit 3 retired. These levels exceed the interrupting ratings of the breakers. The blue highlighted lines show the short circuit levels with the new generation and Unit 3 retired, as well as the station split and the Semper line & T2 autotransformer re-terminated. These short circuit levels are satisfactory.

Table 3 – Thevenin System Impedances at the Cherokee 115 kV & 230 kV Substations for Studies 1 & 5

Scenario #	GI-2011-04 Project Status	North-South 115kV Bus-Tie Status	Cherokee Unit 3 Status	Cherokee 230/115 kV T2 Low-Side Termination	Cherokee – Semper 115 kV Line 9055 Termination	North 115kV Bus R +j X (Ohms)	South 115kV Bus R +j X (Ohms)	230kV Bus R +j X (Ohms)
1	Off-Line	Closed	On	115kV South Bus	115kV South Bus	+ 0.09362 +j 1.10404	+ 0.09362 +j 1.10404	+ 0.34583 +j 4.14888
						- 0.09641 +j 1.09738	- 0.09641 +j 1.09738	- 0.36128 +j 4.13399
						0 0.09536 +j 0.98928	0 0.09536 +j 0.98928	0 0.36529 +j 3.53929
5	On-Line	Open	Off	115kV North Bus	115kV North Bus	+ 0.17814 +j 1.64745	+ 0.11160 +j 1.26253	+ 0.31736 +j 3.96792
						- 0.18276 +j 1.64524	- 0.12182 +j 1.25398	- 0.33772 +j 3.95515
						0 0.17600 +j 1.96952	0 0.10272 +j 1.06473	0 0.36768 +j 3.52716

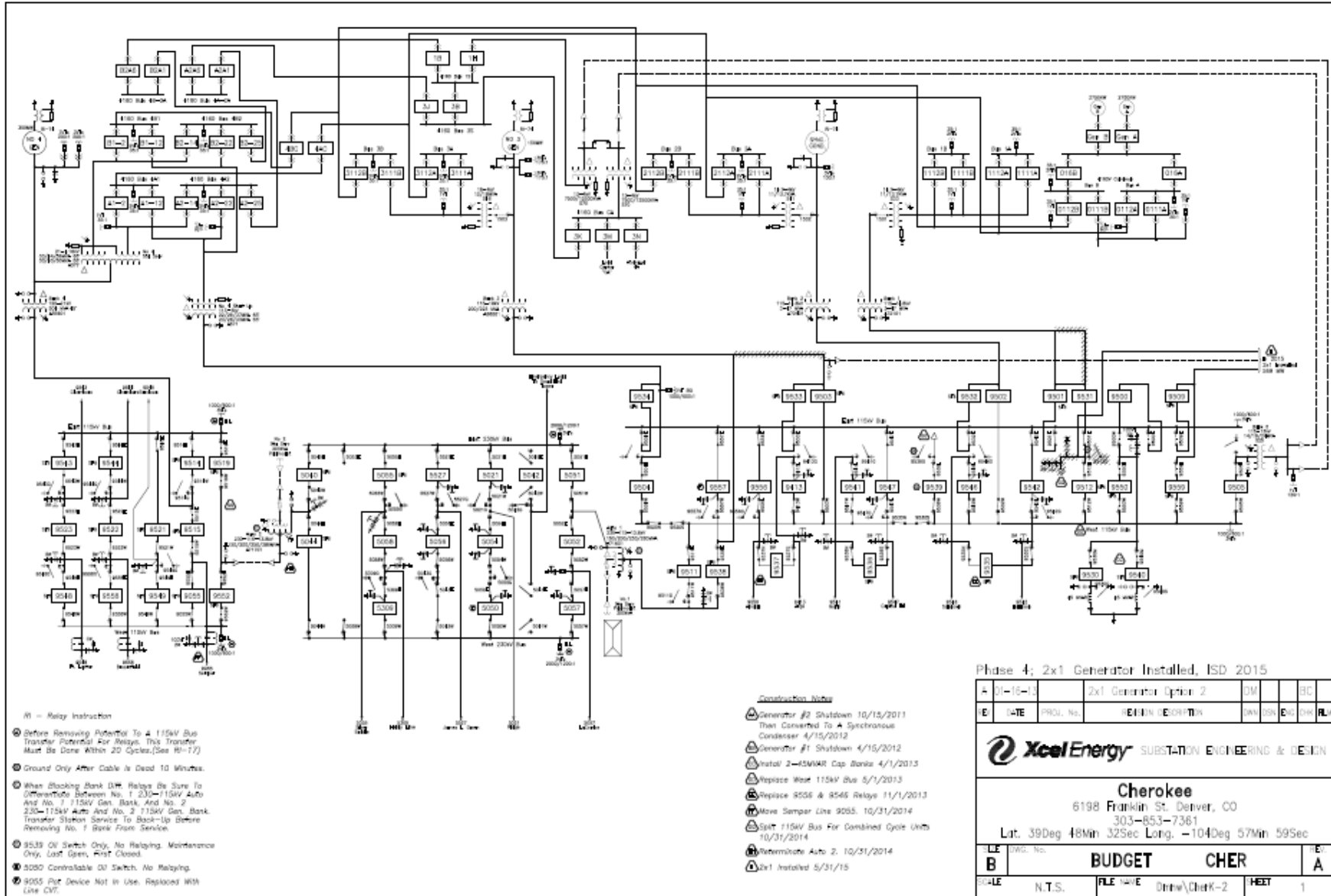
Costs Estimates and Assumptions

(excerpted from Facilities Study)

Appropriation level cost estimates for Interconnection Facilities and Network/Infrastructure Upgrades for Delivery (+/- 20% accuracy) were developed by Xcel Energy/PSCo Engineering. The cost estimates are in 2013 dollars with escalation and contingencies applied (AFUDC is not included) and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, material/equipment procurement and construction of these new PSCo facilities. This estimate does not include the cost for any other Customer owned equipment and associated design and engineering.

The estimated total cost for the required upgrades for is **\$10.250M**. Figure 2 below represents a conceptual one-line of the proposed expansion/interconnection at the Cherokee Switchyard. These estimates do not include costs for any other Customer owned equipment and associated design and engineering. The following tables list the improvements required to accommodate the interconnection and the delivery of the Project generation output. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to change upon a more detailed and refined design.

Figure 2 Cherokee Station One-Line with GI-2011-04 and Station Upgrades



- R - Relay Instruction
- ⊗ Before Removing Potential To 4 115kV Bus Transfer Potential For Relays, This Transfer Must Be Done Within 20 Cycles.(See R5-17)
- ⊗ Ground Only After Cable Is Dead 10 Minutes.
- ⊗ When Backing Bank Off, Relays Be Sure To Differentiate Between No. 1 230-115kV Auto And No. 2 115kV Gen. Bank And No. 2 230-115kV Auto And No. 2 115kV Gen. Bank Transfer Station Service To Back-Up Before Removing No. 1 Bank From Service.
- ⊗ R553 OI Switch Only, No Relaying, Maintenance Only, Last Open, First Closed.
- ⊗ R550 Controllable OI Switch, No Relaying.
- ⊗ R555 Pct Device Not In Use, Replaced With Line CVT.

- Construction Notes**
- ⊗ Generator #2 Shutdown 10/15/2011 Then Converted To A Synchronous Condenser 4/15/2012
 - ⊗ Generator #1 Shutdown 4/15/2012
 - ⊗ Install 2-45MVAR Cap Banks 4/1/2013
 - ⊗ Replace West 115kV Bus 5/1/2013
 - ⊗ Replace R555 & R546 Relays 11/1/2013
 - ⊗ Move Sempur Line 9055, 10/31/2014
 - ⊗ Split 115kV Bus For Combined Cycle Units 10/31/2014
 - ⊗ Reenergize Auto 2, 10/21/2014
 - ⊗ 2x1 Installed 5/31/15

Phase 4: 2x1 Generator Installed, ISD 2015

A	01-15-13	2x1 Generator Option 2	DM	BC
E	DATE	PROJ. NO.	REVISION	DATE
SUBSTATION ENGINEERING & DESIGN				
Cherokee 6198 Franklin St. Denver, CO 303-853-7361 Lat. 39Deg 48Min 32Sec Long. -104Deg 57Min 59Sec				
FILE	DWG. No.	BUDGET	CHER	REV. A
FILE	N.T.S.	FILE NAME	D:\na\CherK-2	HEET 1

Table 4 – PSCo Owned; Customer Funded Transmission Provider Interconnection Facilities

Element	Description	Cost Est. (Millions)
PSCo's Cherokee Transmission Substation	Interconnect Customer to the 115kV bus at Cherokee Substation. The new equipment includes: <ul style="list-style-type: none"> • Two 115kV, 3000 amp gang switches • Six 115kV lightning arresters • Primary metering for Load Frequency/Automated Generation Control • Power Quality Metering • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing 	\$1.348
PSCo's Cherokee Transmission Substation	Overhead 115kV Transmission line tap from Customer's last line structure outside of PSCo's yard for units 5 and 6 into new bay position (assumed 1000 span, conductor, hardware and labor).	\$0.676
PSCo's Cherokee Transmission Substation	Underground 115kV transmission line tap from Customer's last line structure outside of PSCo's yard for unit 7 into new bay position (assumed 1400' span, conductor, hardware and labor).	\$2.590
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	\$4.614
Time Frame	Site, design, procure and construct	15 Months

Table 5: PSCo Owned; PSCo Funded Interconnection Network Facilities

Element	Description	Cost Estimate (Millions)
PSCo's Cherokee Transmission Substation	Interconnect Customer to the bus at the Cherokee Substation. The new equipment includes: <ul style="list-style-type: none"> • Two 115kV 3000 amp gas circuit breakers • Four 115kV, 3000 amp gang switches • Associated station controls, communications, supervisory and SCADA equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated equipment and system testing • Associated yard surfacing, landscaping, fencing 	\$1.620

	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	\$1.620
Time Frame	Site, design, procure and construct	15 months

Table 6 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. (Millions)
PSCo's Cherokee Transmission Substation	Major equipment for removing 115kV bus ties, re-terminating autotransformer #2 to the north 115kV yard, relocating the Semper 9055 line terminal to the north 115 yard, and replacing the SE strain bus with 6" AL tube. <ul style="list-style-type: none"> • Three 115kV 3000 amp gas circuit breakers • Five 115kV, 3000 amp gang switches • Associated station controls, communications, supervisory and SCADA equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated equipment and system testing • Associated yard surfacing, landscaping, fencing 	\$3.256
PSCo's Line 9549 Cherokee to Conoco Transmission Line	Re-conductor 1.985 miles of existing 1-477 ACSR Hawk transmission line with 477 ACSS Hawk conductor	\$0.409
PSCo's Capital Hill Terminal 115kV Transmission Substation	Replace existing 1-795 Al termination jumpers with new bundled 795 ACSR conductor.	\$0.100
PSCo's California Terminal 115kV Transmission Substation	Replace existing 1-795 Al termination jumpers with new 1-1272 AL conductor.	\$0.100
	Total Cost Estimate for PSCo Network Upgrades for Delivery	\$3.865
Time Frame	Site, design, procure and construct	15 Months
	Total Project Estimate	\$10.010

Appendix A

I. Power Flow Results (2016HS) – GI-2011-04 at 587 MW (summer) rated output

Table 7 – Summary Listing of Differentially Overloaded Facilities (Category B Contingencies)¹

					Benchmark Case Without GI-2011-04 (Existing Cherokee 115 Station Topology)		Study Case With GI-2011-04 (Includes Planned Modifications to Cherokee 115 Station Topology)		
					Post-Contingency Facility Loading		Post-Contingency Facility Loading		
Overloaded Monitored Facility (Line or Transformer)	Type	Line Owner	Facility Rating – Summer Normal MVA	Line Cond Rating Summer Normal MVA	MVA Flow	% of Facility Rating	MVA Flow	% of Facility Rating	Worst NERC Category B Contingency Outage
Cherokee – Conoco 115 kV #9549	LN	PSCo	159	159	-	<75%	173.0	108.8%	Cherokee Unit 5 or 6 Trip + 1/2 Unit 7 ST MW
Cherokee – Conoco 115 kV #9549	LN	PSCo	159	159	-	<75%	161.9	101.8%	Broomfield – Cherokee 115 kV #9558
California – Cherokee 115 kV #9542	LN	PSCo	137	137 (UG) 199 (OH)	-	< 75.0%	149.2	108.0%	Cherokee – Capitol Hill 115 kV #9547
California – Cherokee 115 kV #9542	LN	PSCo	137	137 (UG) 199 (OH)	-	< 75.0%	145.1	105.2%	Cherokee – Argo (DenverTerm) 115 kV #9413
Capitol Hill – Mapleton 115kV #9547	LN	PSCo	152	182	-	< 75.0%	173.6	113.5%	Cherokee – Argo (DenverTerm) 115 kV #9413
Cherokee – Federal Heights 115 kV #9558	LN	PSCo	139	187	120.3	86.6%	142.9	101.6% *	Valmont – Spindle 230 kV #5385
Cherokee – Federal Heights 115 kV #9558	LN	PSCo	139	187	120.3	86.6%	180.1	129.2% *	Valmont – Spindle 230 kV #5385 (after Valmont #5 is retired)

* Mitigated by planned project at Federal Heights (ISD 2014) that will increase L9558 Facility Rating to 187 MVA

¹ Newly overloaded elements due to proposed 587 MW generation increase at POI.

Table 8 – Summary Listing of Differentially Overloaded Facilities (Category C Contingencies)²

					Benchmark Case Without GI-2011-04 (Existing Cherokee 115 Station Topology)		Study Case With GI-2011-04 (Includes Planned Modifications to Cherokee 115 Station Topology)		
					Post-Contingency Facility Loading		Post-Contingency Facility Loading		
Overloaded Monitored Facility (Line or Transformer)	Type	Line Owner	Normal Summer Facility Rating MVA	Emergency Summer Facility Rating MVA	MVA Flow	% of Emergency Facility Rating	MVA Flow	% of Emergency Facility Rating	Worst NERC Category C Contingency Outage BF = Breaker Failure DCT = Double Circuit Tower
California – Cherokee 115 kV #9542	LN	PSCo	137	151	-	< 75.0%	177.0	127.5%	DCT Cherokee – Sandown 115 kV Cherokee – Capitol Hill 115 kV #9546 & 9547
Cherokee – Conoco 115 kV #9549	LN	PSCo	159	175	-	< 75.0%	175.2	100.1%	DCT Cherokee – Semper 115 kV Cherokee – Broomfield 115 kV #9055 & 9558
Cherokee – Federal Heights 115 kV #9558	LN	PSCo	139	153	173.2	113.2%	172.3	112.6% *	BF Valmont 115 kV Station

* Mitigated by planned project at Federal Heights (ISD 2014) that will increase L9558 Facility Rating to 187 MVA

² Newly overloaded elements due to proposed 587 MW generation increase at POI & facilities also overloaded for Category B.

II. Generation Dispatch in 2016HS Benchmark & Study Cases

Case 2016 HS; based on WECC 17HS1AP including updates from CCPG companies.

Benchmark Case

Arapahoe Unit 4	118 MW
Cabin Creek Units	210 MW
Cherokee Unit 2 SC	0 MW
Cherokee Unit 4	383 MW
Comanche Unit 1	359.9 MW
Comanche Unit 2	365 MW
Ft Lupton Units 1 & 2	13.4 MW
Pawnee Unit 1	536 MW
Manchief Units 1 & 2	259.5 MW
Ft St Vrain Units 1-4	700 MW
Valmont Unit 5	196 MW
Valmont Unit 6	0 MW
QF Thermo	256 MW
Brush Unit 2	66 MW
Brush Units 1, 3, & 4	104 MW
QF UNC	0 MW
Arapahoe Units 5,6,7	0 MW
Valmont Units 7 & 8	0 MW
Lamar DC Tie	101 MW Import from SPS
Spruce Units 1 & 2	268 MW
Brighton Units 1 & 2	86.6 MW
Fountain Valley Units	0 MW
Plains End Units	227.6 MW
RMEC Units 1-3	586 MW
Spindle Units 1 & 2	278 MW
Missile Site 230 kV	52.5 MW
Missile Site 345 kV	84.0 MW
Peetz Logan 230 kV	120.9 MW
Cedar Creek Wind	116.0 MW
Comanche Unit 3	804.0 MW
Ft St Vrain Unit 5 & 6	295.0 MW
Ft St Vrain Unit 7	0 MW
Rawhide Plant	535.5 MW (PRPA)
Baculite Mesa Plant	478.0 MW (BHE)

GI-2011-04 Study Case Adjustments

GI-2011-04 CT #1	168.6 MW
GI-2011-04 CT #2	168.6 MW
GI-2011-04 ST	249.5 MW
Arapahoe Unit 4	0 MW
Ft Lupton Units 1 & 2	0 MW
Manchief Unit 2	0 MW
Brush Unit 4	0 MW
Plains End Units	137.3 MW
Arapahoe Units 5,6,7	119 MW
Valmont Unit 5	0 MW (planned retirement)
Manchief Unit 1	140 MW
Comanche Unit 1 (slack)	300.3 MW

Appendix B

I. Power Flow Results (2016HW) – GI-2011-04 at 643 MW (winter) rated output

Table 9 – Summary Listing of Differentially Overloaded Facilities (Category B and Category C Contingencies)³

					Benchmark Case Without GI-2011-04 (Existing Cherokee 115 Station Topology)		Study Case With GI-2011-04 (Includes Planned Modifications to Cherokee 115 Station Topology)		
					Post-Contingency Facility Loading		Post-Contingency Facility Loading		
Overloaded Monitored Facility (Line or Transformer)	Type	Line Owner	Facility Rating – Winter Normal MVA	Line Cond Rating Winter Normal MVA	MVA Flow	% of Winter Normal Facility Rating	MVA Flow	% of Winter Normal Facility Rating	Worst NERC Category B / C Contingency Outage
California – Cherokee 115 kV #9542	LN	PSCo	137	137 (UG) 199 (OH)	-	< 75.0%	151.5	110.6%	Cherokee – Capitol Hill 115 kV #9547
California – Cherokee 115 kV #9542	LN	PSCo	137	137 (UG) 199 (OH)	-	< 75.0%	145.3	106.0%	Cherokee – Argo (DenverTerm) 115 kV #9413
California – Cherokee 115 kV #9542	LN	PSCo	137	137 (UG) 199 (OH)	-	<75%	178.3	130.1%	Double Ckt Tower Cherokee – Sandown 115 kV Cherokee – Capitol Hill 115 kV #9546 & 9547

³ Newly overloaded elements due to proposed 643 MW (winter) generation at POI.
Network Upgrades needed for 587 MW (summer) generation at POI are assumed in-service.

II. Generation Dispatch in 2016HW Benchmark & Study Cases

Case 2016 HW; based on Denver metro area (zones 700, 703) load scaling to 80% of 2016HS load.

Benchmark Case

Arapahoe Unit 4	118 MW
Cabin Creek Units	210 MW
Cherokee Unit 2 SC	0 MW
Cherokee Unit 4	383 MW
Comanche Unit 1	359.9 MW
Comanche Unit 2	365 MW
Ft Lupton Units 1 & 2	13.4 MW
Pawnee Unit 1	536 MW
Manchief Units 1 & 2	259.5 MW
Ft St Vrain Units 1-4	700 MW
Valmont Unit 5	196 MW
Valmont Unit 6	0 MW
QF Thermo	256 MW
Brush Unit 2	66 MW
Brush Units 1, 3, & 4	104 MW
QF UNC	0 MW
Arapahoe Units 5-7	0 MW
Valmont Units 7 & 8	0 MW
Lamar DC Tie	101 MW Import from SPS
Spruce Units 1 & 2	268 MW
Brighton Units 1 & 2	86.6 MW
Fountain Valley Units	0 MW
Plains End Units	227.6 MW
RMEC Units 1-3	586 MW
Spindle Units 1 & 2	278 MW
Missile Site 230 kV	52.5 MW
Missile Site 345 kV	84.0 MW
Peetz Logan 230 kV	120.9 MW
Cedar Creek Wind	116.0 MW
Comanche Unit 3	804.0 MW
Ft St Vrain Unit 5 & 6	295.0 MW
Ft St Vrain Unit 7	0 MW
Rawhide Plant	535.5 MW (PRPA)
Baculite Mesa Plant	478.0 MW (BHE)

GI-2011-04 Case Adjustments

GI-2011-04 CT #1	194.2 MW
GI-2011-04 CT #2	194.2 MW
GI-2011-04 ST	254.7 MW
Arapahoe Unit 4	0 MW
Ft Lupton Units 1 & 2	0 MW
Manchief Units 1 & 2	0 MW
Brush Unit 4	0 MW
Plains End Units	137.3 MW
Arapahoe Units 5,6,7	119 MW
Valmont Unit 5	0 MW (planned retirement)

For 1100 MW Load Reduction in Denver metro-area (i.e. zones 700, 703) corresponding to HW load = 80% of HS load

Brighton Units 1 & 2	0 MW
RMEC Units 2-3	0 MW
Spindle Units 1 & 2	0 MW
Ft St Vrain Unit 5 & 6	0 MW
Comanche Unit 1 (slack)	247.9 MW

Appendix C

Transient Stability Analysis (2016 LW case) – GI-2011-04 at 643 MW rated output

Table 10 GI-2011-4 Disturbance Definitions

Disturbance Scenario #	Fault Type	Faulted Bus	Clearing Time (Cycle)	Initial Clearing Description	Failed Breaker	Delayed Clearing Time (cycles)	Delayed Clearing Description
Category B Disturbances							
N1B	3ph	Cherokee-N 115 kV	6 Cycles	Tripping the Cherokee 230 kV - Cherokee-N 115 kV Tx #2.			
N2B	3ph	Cherokee-N 115 kV	6 Cycles	Tripping the Cherokee-N - Sandown 115 kV line.			
S1B	3ph	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee 230 kV - Cherokee-S 115 kV Tx #2.			
S2B	3ph	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee-S - Denver Term 115 kV line.			
S3B	3ph	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee-S - North 115 kV line.			
S4B	3ph	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee-S - Harrison 115 kV line.			
S5B	3ph	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee-S - Sandown 115 kV line.			
S6B	3ph	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee-S - Capitol Hill 115 kV line.			
Category C Disturbances							
N3C8	SLG with Delayed-BF	Cherokee-N 115 kV	6 Cycles	Tripping the Cherokee-N - Chambers 115 kV line.	breaker #9523	19	Trip the Cherokee-N to Ft Lupton 115 kV line
N4C8	SLG with Delayed-BF	Cherokee-N 115 kV	6 Cycles	Tripping the Cherokee-N - Chambers 115 kV line.	breaker #9522	19	Trip the Cherokee-N to Broomfield 115 kV line
N5C8	SLG with Delayed-BF	Cherokee-N 115 kV	6 Cycles	Tripping the Cherokee-N - Semper 115 kV line.	breaker #9515	19	Trip the Cherokee Unit #4
S3C8	SLG with Delayed-BF	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee-S - North 115 kV line.	breaker #9536	19	Trip the Cherokee-N to Ft Lupton 115 kV line
S4C8	SLG with Delayed-BF	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee-S - Harrison 115 kV line.	breaker #9535	19	Trip the Cherokee-N to Broomfield 115 kV line
S5C5	3ph-Double CKT	Cherokee-S 115 kV	6 Cycles	Tripping the Cherokee-S - Sandown & Capitol Hill 115 kV			

Table 11 GI-2011-4 Transient Stability Analysis Results

Disturbance Scenario #	Fault Type	Faulted Bus	Simulation Results
Category B Disturbances			
GI-2011-4_16LW_n1b	3ph	Cherokee-N 115 kV	Passed Stability Criteria
GI-2011-4_16LW_n2b	3ph	Cherokee-N 115 kV	Passed Stability Criteria
GI-2011-4_16LW_s1b	3ph	Cherokee-S 115 kV	Passed Stability Criteria
GI-2011-4_16LW_s2b	3ph	Cherokee-S 115 kV	Passed Stability Criteria
GI-2011-4_16LW_s3b	3ph	Cherokee-S 115 kV	Passed Stability Criteria
GI-2011-4_16LW_s4b	3ph	Cherokee-S 115 kV	Passed Stability Criteria
GI-2011-4_16LW_s5b	3ph	Cherokee-S 115 kV	Passed Stability Criteria
GI-2011-4_16LW_s6b	3ph	Cherokee-S 115 kV	Passed Stability Criteria
Category C Disturbances			
GI-2011-4_16LW_N3C8	SLG with Delayed-BF	Cherokee-N 115 kV	System Stable
GI-2011-4_16LW_N4C8	SLG with Delayed-BF	Cherokee-N 115 kV	System Stable
GI-2011-4_16LW_N5C8	SLG with Delayed-BF	Cherokee-N 115 kV	System Stable
GI-2011-4_16LW_S3C8	SLG with Delayed-BF	Cherokee-S 115 kV	System Stable
GI-2011-4_16LW_S4C8	SLG with Delayed-BF	Cherokee-S 115 kV	System Stable
GI-2011-4_16LW_S5C5	3ph – Double Ckt	Cherokee-S 115 kV	System Stable

**Table 12 GI-2011-4 Transient Stability Study Results
Minimum Voltage and Frequency for each Studied Disturbance**

Disturbance name	Bus Name	Minimum Transient Voltage	Bus Name	Minimum Transient Frequency
Category B Faults				
GI-2011-4_16LW_n1b	SEMPER	0.85	CHEROK4 22.0	59.66
GI-2011-4_16LW_n2b	SEMPER	0.85	CHEROK4 22.0	59.67
GI-2011-4_16LW_s1b	CHEROKEE_S	0.83	CHEROKEE5 18.0	59.78
GI-2011-4_16LW_s2b	CHEROKEE_S	0.84	CHEROKEE5 18.0	59.80
GI-2011-4_16LW_s3b	CHEROKEE_S	0.84	CHEROKEE5 18.0	59.79
GI-2011-4_16LW_s4b	CHEROKEE_S	0.84	CHEROKEE5 18.0	59.80
GI-2011-4_16LW_s5b	CHEROKEE_S	0.84	CHEROKEE5 18.0	59.80
GI-2011-4_16LW_s6b	CHEROKEE_S	0.84	CHEROKEE5 18.0	59.79
Category C Faults				
GI-2011-4_16LW_n3c8	SEMPER	0.94	CHEROK4 22.0	59.73
GI-2011-4_16LW_n4c8	SEMPER	0.95	CHEROK4 22.0	59.73
GI-2011-4_16LW_n5c8	SEMPER	0.97	CHEROKEE7 18.0	59.88
GI-2011-4_16LW_s3c8	CHEROKEE_S	0.90	CHEROKEE5 18.0	59.74
GI-2011-4_16LW_s4c8	CHEROKEE_S	0.91	CHEROKEE5 18.0	59.74
GI-2011-4_16LW_s5c5	CHEROKEE_S	0.84	CHEROKEE5 18.0	59.79

**Table 13 GI-2011-4 Transient Stability Study Results
Critical Clearing Times for Cherokee 115 kV Bus 3-ph Fault Disturbances**

Disturbance name	Critical Clearing Time (Cycles)
Prior Outage: None	
GI-2011-4_16LW_n1b	9.5
GI-2011-4_16LW_n2b	10
GI-2011-4_16LW_s1b	13
GI-2011-4_16LW_s2b	13
GI-2011-4_16LW_s3b	13
GI-2011-4_16LW_s4b	13
GI-2011-4_16LW_s5b	13
GI-2011-4_16LW_s6b	13
Prior Outage: Cherokee 230 - Cherokee-N 115 Transformer	
GI-2011-4_16LW_n2b	10
Prior Outage: Cherokee-N - Broomfield 115 kV line	
GI-2011-4_16LW_n1b	10
GI-2011-4_16LW_n2b	10
Prior Outage: Cherokee 230 - Cherokee-S 115 Transformer	
GI-2011-4_16LW_s2b	13
GI-2011-4_16LW_s3b	13
GI-2011-4_16LW_s4b	13
GI-2011-4_16LW_s5b	13
GI-2011-4_16LW_s6b	13
Prior Outage: Cherokee-S - Denver Term 115 kV line	
GI-2011-4_16LW_s1b	13
GI-2011-4_16LW_s3b	13.5
GI-2011-4_16LW_s4b	13.5
GI-2011-4_16LW_s5b	13.5
GI-2011-4_16LW_s6b	13
Prior Outage: Cherokee-S - North 115 kV line	
GI-2011-4_16LW_s1b	13
GI-2011-4_16LW_s2b	13
GI-2011-4_16LW_s4b	13
GI-2011-4_16LW_s5b	13
GI-2011-4_16LW_s6b	13
Prior Outage: Cherokee-S - Harrison 115 kV line	
GI-2011-4_16LW_s1b	13
GI-2011-4_16LW_s2b	13.5
GI-2011-4_16LW_s3b	13.5
GI-2011-4_16LW_s5b	13.5
GI-2011-4_16LW_s6b	13

Disturbance name	Critical Clearing Time (Cycles)
Prior Outage: Cherokee-S - Sandown 115 kV line	
GI-2011-4_16LW_s1b	13
GI-2011-4_16LW_s2b	13
GI-2011-4_16LW_s3b	13
GI-2011-4_16LW_s4b	13
GI-2011-4_16LW_s6b	13
Prior Outage: Cherokee-S - Capitol Hill 115 kV line	
GI-2011-4_16LW_s1b	13
GI-2011-4_16LW_s2b	13
GI-2011-4_16LW_s3b	13.5
GI-2011-4_16LW_s4b	13.5
GI-2011-4_16LW_s5b	13.5



Detailed Dynamic Modeling Data Applied to the New Cherokee Units

PLANT MODELS

REPORT FOR ALL MODELS AT ALL BUSES BUS 70145 [CHEROKEE5 18.000] MODELS

** GENROU ** BUS X-- NAME --X BASEKV MC CONS STATES

70145 CHEROKEE5 18.000 G5 45747-45760 19352-19357

MBASE ZSORCE XTRAN GENTAP

218.0 0.00000+J 0.17500 0.00000+J 0.00000 1.00000

T'D0 T"Q0 T'Q0 T"Q0 H DAMP XD XQ X'D X'Q X"D XL S(1.0) S(1.2)

7.70 0.039 0.55 0.081 5.36 0.00 1.8500 1.7600 0.2300 0.4200 0.1750 0.1300 0.0792 0.7214

** PSS2B ** BUS X-- NAME --X BASEKV MC CONS STATES VARS ICONS

70145 CHEROKEE5 18.000 G5 73841-73863 40959-40975 6325-6328 8386-8391

IC1 REMBUS1 IC2 REMBUS2 M N

1 0 3 0 5 1

TW1 TW2 T6 TW3 TW4 T7 KS2 KS3 T8 T9 KS1 T1

2.000 2.000 0.000 2.000 0.000 2.000 0.187 1.000 0.500 0.100 10.000 0.150

T2 T3 T4 T10 T11 VS1MAX VS1MIN VS2MAX VS2MIN VSTMAX VSTMIN

0.030 0.150 0.030 0.000 0.000 99.000 -99.000 99.000 -99.000 0.100 -0.100

** ESST4B ** BUS X-- NAME --X BASEKV MC CONS STATES

70145 CHEROKEE5 18.000 G5 129432-129448 56278-56281

TR KPR KIR VRMAX VRMIN TA KPM KIM VMMAX VMMIN KG KP KI VBMAX KC XL THETAP

0.000 3.560 3.560 1.000 -0.800 0.010 1.000 0.000 1.000 -0.800 0.000 5.620 0.000 7.030 0.150 0.0000 0.000

** GGOV1 ** BUS X-- NAME --X BASEKV MC CONS STATES VARS ICONS

70145 CHEROKEE5 18.000 G5 190356-190388 73148-73157 33923-33943 12642-12643

R TPELEC MAXERR MINERR KPGOV KIGOV KDGOV TDGOV VMAX VMIN TACT KTURB WFNL TB TC TENG TFLOAD

0.040 1.000 0.050 -0.050 10.000 2.000 0.000 1.000 1.000 0.150 0.150 1.500 0.200 0.100 0.000 0.000 3.000

KPLOAD KILOAD LDREF DM ROPEN RCLOSE KIMW ASET KA TA TRATE DB TSA TSB RUP RDOWN

2.000 0.670 1.000 0.000 0.100 -0.100 0.000 0.010 10.000 0.100 194.200 0.000 4.000 5.000 99.000 -99.000



PLANT MODELS

REPORT FOR ALL MODELS AT ALL BUSES BUS 70146 [CHEROKEE6 18.000] MODELS

** GENROU ** BUS X-- NAME --X BASEKV MC CONS STATES

70146 CHEROKEE6 18.000 G6 45761-45774 19358-19363

MBASE ZSORCE XTRAN GENTAP

218.0 0.00000+J 0.17500 0.00000+J 0.00000 1.00000

T'D0 T'D0 T'Q0 T'Q0 H DAMP XD XQ X'D X'Q X'D XL S(1.0) S(1.2)

7.70 0.039 0.55 0.081 5.36 0.00 1.8500 1.7600 0.2300 0.4200 0.1750 0.1300 0.0792 0.7214

** PSS2B ** BUS X-- NAME --X BASEKV MC CONS STATES VARS ICONS

70146 CHEROKEE6 18.000 G6 73864-73886 40976-40992 6329-6332 8392-8397

IC1 REMBUS1 IC2 REMBUS2 M N

1 0 3 0 5 1

TW1 TW2 T6 TW3 TW4 T7 KS2 KS3 T8 T9 KS1 T1 T2

2.000 2.000 0.000 2.000 0.000 2.000 0.187 1.000 0.500 0.100 10.000 0.150 0.030

T3 T4 T10 T11 VS1MAX VS1MIN VS2MAX VS2MIN VSTMAX VSTMIN

0.150 0.030 0.000 0.000 99.000 -99.000 99.000 -99.000 0.100 -0.100

** ESST4B ** BUS X-- NAME --X BASEKV MC CONS STATES

70146 CHEROKEE6 18.000 G6 129449-129465 56282-56285

TR KPR KIR VRMAX VRMIN TA KPM KIM VMMAX VMMIN KG KP KI VBMAX KC XL THETAP

0.000 3.560 3.560 1.000 -0.800 0.010 1.000 0.000 1.000 -0.800 0.000 5.620 0.000 7.030 0.150 0.0000 0.000

** GGOV1 ** BUS X-- NAME --X BASEKV MC CONS STATES VARS ICONS

70146 CHEROKEE6 18.000 G6 190389-190421 73158-73167 33944-33964 12644-12645

R TPELEC MAXERR MINERR KPGOV KIGOV KDGOV TDGOV VMAX VMIN TACT KTURB WFNL TB TC TENG TFLOAD

0.040 1.000 0.050 -0.050 10.000 2.000 0.000 1.000 1.000 0.150 0.150 1.500 0.200 0.100 0.000 0.000 3.000

KPLOAD KILOAD LDREF DM ROPEN RCLOSE KIMW ASET KA TA TRATE DB TSA TSB RUP RDOWN

2.000 0.670 1.000 0.000 0.100 -0.100 0.000 0.010 10.000 0.100 194.200 0.000 4.000 5.000 99.000 -99.000



PLANT MODELS

REPORT FOR ALL MODELS AT ALL BUSES BUS 70147 [CHEROKEE7 18.000] MODELS

** GENROU ** BUS X-- NAME --X BASEKV MC CONS STATES

70147 CHEROKEE7 18.000 G7 45775-45788 19364-19369

MBASE ZSORCE XTRAN GENTAP

300.0 0.00151+J 0.19500 0.00000+J 0.00000 1.00000

T'D0 T"D0 T'Q0 T"Q0 H DAMP XD XQ X'D X'Q X"D XL S(1.0) S(1.2)

5.50 0.038 0.46 0.073 5.85 0.00 1.5800 1.5200 0.2550 0.4450 0.1950 0.1450 0.0490 0.4207

** PSS2B ** BUS X-- NAME --X BASEKV MC CONS STATES VARS ICONS

70147 CHEROKEE7 18.000 G7 73887-73909 40993-41009 6333-6336 8398-8403

IC1 REMBUS1 IC2 REMBUS2 M N

1 0 3 0 5 1

TW1 TW2 T6 TW3 TW4 T7 KS2 KS3 T8 T9 KS1 T1

2.000 2.000 0.000 2.000 0.000 2.000 0.187 1.000 0.500 0.100 10.000 0.150

T2 T3 T4 T10 T11 VS1MAX VS1MIN VS2MAX VS2MIN VSTMAX VSTMIN

0.030 0.150 0.030 0.000 0.000 99.000 -99.000 99.000 -99.000 0.100 -0.100

** ESST4B ** BUS X-- NAME --X BASEKV MC CONS STATES

70147 CHEROKEE7 18.000 G7 129466-129482 56286-56289

TR KPR KIR VRMAX VRMIN TA KPM KIM VMMAX VMMIN KG KP KI VBMAX KC XL THETAP

0.000 3.560 3.560 1.000 -0.800 0.010 1.000 0.000 1.000 -0.800 0.000 5.620 0.000 7.030 0.150 0.0000 0.000

** GGOV1 ** BUS X-- NAME --X BASEKV MC CONS STATES VARS ICONS

70147 CHEROKEE7 18.000 G7 190422-190454 73168-73177 33965-33985 12646-12647

R TPELEC MAXERR MINERR KPGOV KIGOV KDGOV TDGOV VMAX VMIN TACT KTURB WFNL TB TC TENG TFLOAD

0.040 1.000 0.050 -0.050 10.000 2.000 0.000 1.000 1.000 0.150 0.150 1.500 0.200 0.100 0.000 0.000 3.000

KPLOAD KILOAD LDREF DM ROPEN RCLOSE KIMW ASET KA TA TRATE DB TSA TSB RUP RDOWN

2.000 0.670 1.050 0.000 0.100 -0.100 0.000 0.010 10.000 0.100 254.700 0.000 4.000 5.000 99.000 -99.000

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