10-12 Year (Year 2022) Transmission Planning Study for the Denver-Boulder Area Load Serving Network

(Required per CPUC Decision No. C10-1328)

Final Report

(Submitted within PSCo 2011 ERP Filing)

Executive Summary

The purpose of the study is to review the Denver Boulder load serving Network in the year 2022 to evaluate overloads on Table 5 of Attachment TWG-1 in the CACJA docket. The scenarios in Table 5 (attached) were repeated for a 2022 summer peak case with higher loads and similar contingencies. The scenarios evaluated in Table 5, and re-evaluated for 2022 system conditions, are quite extreme since they assume the outage of one or both generating plants at Cherokee (#4 and the new 2×1 CC) followed by a transmission facility outage occurring during a summer peak load period. Nevertheless, the results of these studies indicate that even under these extreme scenarios it is feasible to achieve adequate reliability of the PSCo transmission system in the Denver Boulder area in year 2022.

The results listed in this report indicate thermal overloads of 14 transmission facilities in the Denver Boulder metro area. Seven of these can be mitigated by making changes to substation termination equipment (such as switches, jumpers, and breakers) to achieve the design thermal rating of the transmission line conductor. Mitigating the remaining overloads requires the following transmission improvements/upgrades — three overloads can be mitigated by providing additional 230/115 transformation capacity in the metro area; another three overloads can be mitigated by replacing existing 115kV underground cable (8 miles in total) with higher ampacity cable, and one overload can be mitigated by replacing several miles of overhead 115kV line conductor with higher ampacity conductor. The majority of these overloads occur in the unlikely

scenario of no generation available at Cherokee during a summer peak day and a transmission element concurrently forced out of service. Several of these overloads can also be mitigated by redispatch of generation in the Denver Boulder metro area.

Importantly, this 2022 transmission planning study gives PSCo a look ahead into potential thermal constraints and system conditions that must be monitored in future transmission studies. Per prudent transmission planning practice, PSCo does not initiate projects for upgrades to transmission facilities that are required for extreme scenarios until there is more certainty in the 10 year planning horizon assumptions. The uncertainties in load forecasts and generation capacities and locations will become more defined in the 5-7 year time horizon. All transmission upgrades identified in this study can be normally implemented within 3-5 years lead time.

Background

In consideration of Docket No. 10M-245E on Public Service Company of Colorado's (PSCo) Emissions Reduction Plan for compliance with House Bill 10-1365 (Clean Air Clean Jobs Act), the Public Utilities Commission of Colorado (PUC) rendered its Final Order in Decision No. C10-1328 on December 15, 2010. Item 27 of the Final Order requires PSCo to "*develop a 10- to 12-year study of the Denver-Boulder load serving network, after soliciting input from Staff of the Commission regarding the scope of the study.*" The motivation, need and objectives for this study are discussed in Section K – Transmission, paragraphs 234–236 on page 80 in the Final Order. The Final Order directs PSCo to submit the study as part of its next ERP filing.

Study Scope

PSCo developed the Denver-Boulder area transmission planning study scope in April, 2011 after seeking input from the Colorado PUC Staff. To satisfy the recommended 10-12 year study horizon in the Order, PSCo conducted this planning study for the projected system conditions in year 2022. This was accomplished by building a 2022 Heavy Summer PSS/E power flow base case that models the following:

- Projected 2022 Summer Peak Load magnitudes using the PSCo 10-Year Demand Forecast dated April 2011,
- Projected 2022 PSCo Resources and Firm Purchases using the PSCo Loads & Resources Balance for Summer 2011-2022 dated April 2011,
- Normal Ratings (Rate A) consistent with the latest available PSCo FAC-009 Facility Ratings dated July, 2011.

The analysis performed in this study comprised of the following:

I. Develop the 2022 Heavy Summer Case for the following three scenarios:
   - Cherokee 4 plus Cherokee 2x1CC plants in service (2022HS_BM) – the Benchmark Case
   - After Forced outage of Cherokee 4 (2022HS_C1) – the Study Case 1,
     lost generation replaced by generators in the Calumet/Comanche area (available renewable resources and/or operating reserves)
   - Prior outage of Cherokee 4 plus forced outage of Cherokee 2x1CC plant (2022HS_C2) – the Study Case 2,
     lost generation replaced by generators in the Calumet/Comanche area (available renewable resources and/or operating reserves)

II. Perform Steady State (Power Flow) Contingency Analysis

System performance analyzed by simulating the forced outage of each transmission element (NERC Category B2 and B3) and the forced outage of each generator plant/unit (NERC Category B1) within the Denver-Boulder metro area (zone 700 in PSS/E model).

III. Identify significant thermal violations seen in each of the three scenarios – this includes verification of the thermal violations noted in Table 5 on page 18 of the Transmission Report for CACJA (Attachment TWG-1)

IV. Identify potential transmission improvements needed to address the significant thermal violations seen in benchmark and study cases.

System Performance Criteria

Thermal Violation (Overload) Criteria

Use normal continuous facility ratings (not short-time or emergency) in PSS/E model for both system intact and contingency simulations. Elements/branches with thermal loading >100% are identified as facilities requiring overload mitigation solutions/projects. In addition, elements with thermal loading > 97% are also monitored as potential candidates for mitigation.

Voltage Limit Violation Criteria

- At Regulated buses – use Ideal voltage range specified in the latest approved version (December 2010) of CCPG Rocky Mountain Voltage Coordination Guidelines for both system intact and contingency conditions.
- At Non-regulated buses – use 95–105% of nominal voltage for system intact condition and 90–105% of nominal for contingency conditions.

2022 Heavy Summer Case Description

The 2022HS benchmark case was developed by starting from the WECC approved 2017HS1 base case by updating the peak load, generation dispatch, firm purchases net interchange for the PSCo control area to reflect the projected 2022 system conditions in accordance with the latest available forecast of PSCo Loads & Resources Balance for Summer 2010-2022.

The resulting 2022HS benchmark case is characterized by the following :

PSCO Balancing Authority (BA) Load = 8968 MW
System Losses = 209 MW

PSCO Balancing Authority Generation = 8564 MW
PSCO Net Interchange (negative is Import) = –622 MW

The Denver-Boulder metro area generation dispatch used in 2022HS cases is tabulated below:

Table I Generation Dispatch for 2022HS Benchmark Case

Generation Plant	Unit Nos.	Pgen (MW)	Net Summer Pmax (MW)
Arapahoe	4	0	109
Arapahoe (SW Gen)	5, 6, 7	0	119
Valmont	6	0	43
Valmont (SW Gen)	7, 8	0	74
Cherokee	4	352	352
Cherokee	5,6,7 (2x1 CC)	570	570
Ft Lupton	1, 2	89.4	89.4
QF TC-TI	T1–T4	206	217
Blue Spruce EC	1, 2	270	278
Blue Spruce EC	3 (future)	135	139
Rocky Mountain EC	1, 2, 3	601	601
Rocky Mountain EC	4 (future)	135	139
Ft St Vrain	1	300	301
Ft St Vrain	2, 3, 4	300	379
Ft St Vrain	5, 6	290	290
Ft St Vrain	7 (future)	300	300
Spindle NUG	1, 2	2×100	2×134
Plains End NUG	G1, G2	2×48	2×55
Plains End NUG	G3, G4	2×50.4	2×58.8

Retired Units: Arapahoe #3, Valmont #5, Cherokee #1-3, Zuni #1-2

The three scenario cases used in the steady-state analysis differ in the following respects:

Table II Cherokee Generation Availability Scenarios

Case	Cherokee Generation Scenario	Total Generation at Cherokee 115kV	Cherokee 115kV Bus Tie
22-BM	All Cherokee units in service	352 + 570 = 922 MW	Open
22-C1	After Forced Outage of Cherokee 4 unit	0 + 570 = 570 MW	Closed
22-C2	Forced Outage of Cherokee 2x1CC plant during Prior Outage of Cherokee 4 unit	0 + 0 = 0 MW	Closed

Steady-state Contingency Analysis Results

Results from the N–1 contingency analysis performed on each of the three scenario cases are tabulated in Table III (next page). The 2018 thermal analysis results provided in Table 5 of Exhibit TWG-1 of the CACJA filing are reproduced below for easy reference. Note that the scenario cases 22-BM, 22-C1 & 22-C2 correspond to the cases 18-1, 18-2 & 18-4 respectively; however, the updated Cherokee 2x1CC capability of 570 MW is assumed in the 2022 analysis.

Exhibit TWG-1

Table 5 2018 Contingency Loading Results

		Cherok 3	Cherok 4	Cherok 5	Total Cherok	Contingency / Loaded Element	Leetsdale 230/115 Cap Hill – Den Tem115	Valmont 230/115 #1 Valmont 230/115 #2	Chambers 230/115 BarrLake-Reunion 230	Cherokee 230/115 #1 Cherokee 230/115#2	Ridge 230/115#1 Ridge 230/115#2	Arapahoe 230/115 Leetsdale 230/115	Lookout 230/115#1 Lookout 230/115#2
Description	**Case**					**MVA Rating →**	131	280	280	120	100	280	150
18-0	Benchmark	152	351	0	503		102%	<99%	<99%	<99%	<99%	<99%	<99%
18-1	Cherok 4 + 5	0	351	500	851		<99%	103%	<99%	<99%	<99%	<99%	<99%
18-2	Cherokee 4 out	0	0	500	500		<99%	110%	<99%	<99%	<99%	<99%	<99%
18-3	Cherokee 5 reduced	0	0	250	250		119%	117%	119%	<99%	<99%	<99%	<99%
18-4	No gen at Cherokee	0	0	0	0		156%	128%	156%	117%	114%	103%	101%
18-5	No gen at Cherokee Increase loads 5%	0	0	0	0		165%	133%	165%	118%	122%	110%	105%

Table III *2022 Contingency Analysis Thermal Overload Results*

Facilities with Thermal Violations	Existing Facility Rating (MVA)	Thermal Overload (%)			Worst Contingency	Resolved by Upgrade to Conductor Rating ?	Transmission Reinforcement Solution (see Table IV)
		22-BM	22-C1	22-C2			
Cherokee – Arvada 115kV Line (9556)	120	131%	118%	---	Denver Term – Gray St 115kV Line	Yes (159 MVA)	**
Cherokee – (North) – California 115kV Line (9542)	137	128%	---	---	Cherokee – Mapleton1– Capitol Hill 115kV Line	**No** (137 MVA)	**UG1**
Cherokee – Mapleton1– Capitol Hill 115kV Line (9547)	156	121%	---	---	Cherokee – Argo 115kV Line OR Cherokee – (North) – California 115kV Line	Yes (241 MVA)	**
Cherokee – Mapleton2 – Sandown 115kV Line (9546)	158	104%	---	---	Cherokee – North – Sandown 115kV Line	Yes (241 MVA)	**
Cherokee – Federal Heights 115kV Line (9558)	144	130%	127%	120%	Valmont – Spindle 230kV Line	Yes (187 MVA)	**
Cherokee – Semper 115kV Line (9055)	120	109%	---	---	Cherokee – Federal Heights 115kV Line	Yes (159 MVA)	**
Denver Term – Capitol Hill 115kV UG Line (9007UG)	131	---	127%	163%	Leetsdale 230/115kV Xfmr	**No** (131 MVA)	**TX2**
Denver Term – Capitol Hill 115kV UG Line (9007UG)	131	---	112%	108%	Leetsdale – Harrison 115kV Line	**No** (131 MVA)	**UG2**
Leetsdale – University 115kV Line (9338)	120	180%	172%	150%	Arapahoe 230/115kV Xfmr	**No** (191 MVA)	**TX3**
Leetsdale – Harrison 115kV UG Line (9955UG)	141	---	115%	114%	Denver Term 230/115kV Xfmr	**No** (141 MVA)	**UG3**

Ft Lupton – JL Green 230kV Line (5183)	452	---	114%	121%	Riverdale – Henry Lake 230kV Line	Yes (574 MVA)	**
JL Green – Washington 230kV Line (5527)	480	---	102%	109%	Riverdale – Henry Lake 230kV Line	Yes (579 MVA)	**
Valmont 230/115kV Xfmr T1 (T2)	280	113%	122%	131%	Valmont 230/115kV Xfmr T2 (T1)	N/A	**TX4**
Chambers 230/115kV Xfmr T1 (T2)	280	---	103%	114%	Chambers 230/115kV Xfmr T2 (T1)	N/A	Various♦
Chambers – Havana 115kV Line section (9543/9544)	158	---	108%	119%	Chambers – Havana 115kV Line section (9544/9543)	**No** (159 MVA)	**OH1**

♦ Utilize 322 MVA 4-hour Emergency Rating and/or system readjustment such as Blue Spruce generation redispatch to reduce loading within Normal Rating

Recommended Transmission Reinforcements

Following transmission system reinforcements are necessary to ensure that the Denver-Boulder metro area transmission facilities have adequate thermal capability to achieve reliable operation over the entire range of Cherokee generation dispatch levels from 922 MW to 0 MW.

Table IV Recommended Transmission Reinforcement Projects

TX1	Add Chambers 230/115 Auto-transformer – Budgeted project
TX2	Add Leetsdale 230/115 Auto-transformer – Planned project
TX3	Add Arapahoe 230/115 Auto-transformer
TX4	Add Valmont 230/115 Auto-transformer
UG1	Replace♠ 9542UG (2.69 mi) North – California 115kV Cable
UG2	Replace♠ 9007UG (2.17 mi) Denver Term – Capitol Hill 115kV Cable
UG3	Replace♠ 9955UG (3.27 mi) Leetsdale – Harrison 115kV Cable
OH1	Rebuild 9543/9544 OH Chambers – Havana 115kV double-ckt line
****	Upgrade termination equipment limiters to achieve line conductor ratings

♠ Cost-Benefit evaluation may dictate installing 230kV Cable

Equivalent generation dispatch solutions can be used as alternatives for some of these transmission reinforcement solutions – in particular, the installation of additional 230/115kV auto-transformers at Arapahoe and Valmont can be deferred or avoided by dispatching approximately 110-120 MW of generation available (see below) at each of these locations.

Generating Units	Cumulative MW Rating
Arapahoe #4	109
Arapahoe #5, #6, #7	119
Valmont #6, #7, #8	117

Discussion of Results

The results indicate thermal overloads of 14 transmission facilities in the Denver Boulder metro area. The majority of these overloads occur in the unlikely scenario of no generation available at Cherokee during a summer peak day and a transmission element concurrently forced out of service. Several of these overloads can also be mitigated by redispatch of generation in the Denver Boulder metro area.

Importantly, this 2022 transmission planning study gives PSCo a look ahead into potential thermal constraints and system conditions that must be monitored in future transmission studies. Per prudent transmission planning practice, PSCo does not initiate projects for upgrades to transmission facilities that are required for extreme scenarios until there is more certainty in the 10 year planning horizon assumptions. The uncertainties in load forecasts and generation capacities and locations will become more defined in the 5-7 year time horizon. All transmission upgrades identified in this study can be normally implemented within 3-5 years lead time.

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