PSCO POWER INJECTION STUDY
October 31, 2003

I. Power Injection Study

This power injection study was performed for PSCo Energy by Shaw Power Technologies, Inc.™ (PTI) , to help identify and quantify transmission system limitations that may impact the operation of proposed facilities that are connected to PSCo's transmission system.

A. Methodology

The PTI analysis was based on Western Electricity Coordinating Council (WECC) load flow model that represented 2008 heavy summer loading conditions. The model was provided by PSCo. In addition to the bulk western interconnected transmission grid, the system represented in this model reflected the generation and transmission facilities in the Colorado region coupled with committed and planned projects that are expected to be in service by 2008. The analysis was conducted using steady-state tools only. No evaluations of transient stability or short circuit duties were made. The analysis was conducted using PTI's PSS/E power flow modeling software to establish the base case, and its MUST (Managing and Utilizing System Transmission) software to determine the maximum incremental firm transfer capability from various locations throughout PSCo's transmission system. The software tools are proprietary, commercial products of PTI.

The resulting incremental transfer limits are either based on system limits found without contingencies (all equipment in normal service), or for single contingency (N-1) conditions. For this analysis linear power flow calculating techniques were used to identify path limitations for source to sink transfers. For this study, a (generation) source was placed at each PSCo transmission bus to represent the output from a potential facility. The sinks for this analysis were specific groups of PSCo generating units located in three geographic regions in Colorado to represent the target areas. In each target area, the combined output from the group of generators was reduced by the same capacity amount as was injected at the source bus.

The PTI transfer analysis calculated the maximum amount of capacity that could be transferred between the source bus and the sink area without overloading transmission facilities for both system intact and single contingency conditions. The contingencies that were considered in this analysis were single facility outages of each transmission line or transformer within the Colorado transmission system, and each tie to and from the PSCo powerflow control area.. Transmission line or transformer loadings above equipment operating ratings for these single contingencies were used to determine the transfer limit. The impact on the transmission system from the loss of multi-terminal lines or multiple contingencies, such as two parallel circuits on the same tower, was not examined. Branches in

the WECC, consisting of PSCo's transmission facilities as well as those of Tri-State Generation and Transmission Association, Inc. (TSGT), Colorado Springs Utilities (CSU) and other utilities in Colorado, operating at 69 kV and above, were monitored for overloads.

B. Injection Points and Sinks

For purposes of this study, the PSCo system was regionalized to determine potential generation injection locations. The studies provided an indication of how much power can be injected at a bus before certain criteria are violated. The values do not always give a precise amount of power that could actually be generated at the location, due to other factors, such as available transfer capability on paths away from the bus. ***Any request for an actual proposed interconnection would require additional studies in order to more accurately determine power injection capabilities.***

The lists of buses used as sinks for the power injection were developed based on engineering judgment and were located away from the region of the injection buses studied. The PSCo system was split into three regions, West, South, and North. Each PSCo bus operating at 115 or 230 kV from the southern edge of the Denver metropolitan area northward and east of the Continental Divide was considered in the North area. The South area consists of the Front Range region south of Denver and includes the Canon City and Tarryall areas. The West region covered the western part of the state. In order to evaluate the capability of the transmission system to deliver the injected power on a reliable basis, the additional power injected at buses in one area was generally assumed to displace power generated in a different area. All power injected at buses located in the West area was used to displace generation from existing facilities located to the east. For each 100 MW injected in the West, Table 1 shows the reduction in generation modeled at existing PSCo plants.

Table 1 Sinks for West Area Injections

Bus No.	Facility	%
70106	CHEROKEE	30.00
70119	COMANCHE 1	15.00
70120	COMANCHE 2	15.00
70409	ST.VRAIN	20.00
70577	FOUNTAIN VALLEY 1-2	6.67
70578	FOUNTAIN VALLEY 3-4	6.67
70579	FOUNTAIN VALLEY 5-6	6.67
TOTAL		100.00

Table 2 shows the generators in the North area that were reduced for power injections that were made in the South area. Table 3 shows the generators in the South area that were reduced for injections made in the North area.

Table 2 Sinks for North Area Injections

Bus No.	Facility	%
70119	COMANCHE 1	25.0
70120	COMANCHE 2	25.0
70560	LAMAR DC	28.0
70577	FOUNTAIN VALLEY 1-2	7.5
70578	FOUNTAIN VALLEY 3-4	7.5
70579	FOUNTAIN VALLEY 5-6	7.5
TOTAL		100.00

Table 3 Sinks for South Area Injections

Bus No.	Facility	%
70106	CHEROKEE 4	20.0
70310	PAWNEE	20.0
70409	FT. ST. VRAIN	30.0
70446	VALMONT	10.0
70588	RMEC 1	20.0
TOTAL		100.00

C. Analysis and Results

As previously indicated, analyses were performed to determine the maximum power that could be injected at each bus without exceeding thermal limits of the transmission lines and transformers within the Colorado system. In order to detect whether some contingencies could result in low voltages that violate criteria, AC transfer analyses were also performed to take into account the nonlinear aspects of the transmission network. While this process does not directly determine voltage violations, large differences in transfer capabilities between the linear and nonlinear methodologies for the same system configuration may indicate potential voltage problems. Based on the results that were observed, the transfer capabilities for 115 and 230-kV buses in the PSCo transmission system as modeled do not appear to be voltage constrained.

The generation levels in the power flow model for PSCo plants represent the expected dispatch of resources to meet load during the summer peak period. While most PSCo generation will be operating at or near full output, there are a number of units that will operate at less than maximum output under normal conditions. However, generating plant maintenance, unscheduled outages, and other factors could cause some of these units to operate at their full capacity. Since these units could be called on to operate at higher levels during peak

loading periods, the maximum injections at buses with under-dispatched PSCo generation were reduced to reflect the potential full output of those units.

The second impact of the under-dispatched capacity is the potential to overstate the injection capability on nearby buses. Therefore, additional analyses were performed for those locations where there was a positive transfer capability for buses with under-dispatched PSCo generation nearby. Those locations included Cabin Creek, Zuni, Arapaho, Valmont, Spruce, and Plains End.

1. Injection from North system

Tables 4-9 summarize the Northern Region results of the injection analysis. The first table, Table 4, lists major buses that have no injection capacity. Subsequent tables indicate capacity in 50 MW increments. ***Although precise values of injection capacity are shown, the actual capacity at a particular bus would require additional interconnection studies.***

Table 4 Major Buses in the North Region with No Capacity

BUS	KV	BUS	KV
Argo	115	Lookout	230
Arsenal	115	Mapleton	115
Arvada	115	North	115
Capitol Hill	115	Platte Valley	115
Chambers	115	Plainview	115
Cherokee	115	Platte PS	115
Conoco	115	Ralston	115
Denver Terminal	115	Ridge	115
Derby	115	Rocky Flats	115
East	115	Russell	115
Federal Heights	115	Sandown	115
Fitzsimmons	115	Semper	115
Havana	115	Tollgate	115
Isabelle	230	West PS	230

Table 5 Major North Region Buses in the 20-50 MW Injection Range

Bus	KV	Injection (MW)	Bus	KV	Injection (MW)
Quincy	230	19	Smoky Hill	115	40
Smoky Hill	230	32	Strasburg	115	40
Cherokee	230	33	Sky Ranch Tap	230	40
Riverdale	230	35	Reunion	230	42
Murphey Creek	230	35	Reunion	115	42
Glenn_PS	230	36	Prairie TS	115	42
Washington	230	38	Buckley Bus 2	230	49
Spruce	230	38	Sulphur	115	49
Tower	230	39	Green Valley	230	49
Chambers	230	39	RMEC	230	49
Sky Ranch	230	40			

Table 6 Major North Region Buses in the 50-100 MW Injection Range

Bus	KV	Injection (MW)	Bus	KV	Injection (MW)
Sulphur	230	58			
Hogback	115	61			
Barr Lake	230	62			
Tollgate	230	70			
Federal Center	115	84			
Lacombe	230	98			
Buckley Bus 1	230	99			
Jewell Bus 1	230	100			

Table 7 Major North Region Buses in the 100-150 MW Injection Range

Bus	KV	Injection (MW)	Bus	KV	Injection (MW)
Jewell Bus 2	230	102	Gray Street	115	130
Lookout	115	106	Quaker Bus 1	115	134
Lemon Gulch	230	108	Quaker Tap	115	134
California Bus 1	115	115	Federal Center Tap	115	135
California Bus 2	115	117	Leetsdale	115	137
Quaker Bus 2	115	117	University	115	141
Martin Bus 2	115	118	Meadow Hill	230	143
California Bus 3	115	118	Bancroft	115	144
Lakewood Bus 1	115	119	Daniels Park	115	145
Lakewood Bus 2	115	124	South Bus 2	115	147
Ridge	230	124	University Bus 1	115	148
Harris PS	115	125	University Bus 2	115	148
Jordan	230	127	Orchard	230	150
Martin Bus 1	115	127			

Table 8 Major North Region Buses in the 150-200 MW Injection Range

Bus	KV	Injection (MW)	Bus	KV	Injection (MW)
Air Liquide	115	150	Elati Bus 3	230	163
Arapahoe A	115	151	Elati Bus 1	230	166
Englewood	115	151	Dakota	230	168
Sheridan	115	151	Elati Bus 2	230	169
Kendrick	115	152	Soda Lakes	115	170
South Tap	115	153	Englewood Tap	115	172
South Bus 1	115	153	Englewood Bus 3	115	172
Denver Terminal	230	155	Deer Creek	115	190
Arapahoe Bus B	115	159	Soda Lakes	230	191
Englewood Bus 2	115	159	Monroe PS	230	193
Allison	115	162	Arapahoe	230	199

Table 9 Major North Region Buses in the 200-250 MW Injection Range

Bus	KV	Injection (MW)	Bus	KV	Injection (MW)
Leetsdale	230	207	Monaco Bus 3	230	217
Daniels Park	230	214	Littleton Bus 1	230	218
Surrey Ridge	230	215	Sullivan	230	218
Prairie	230	216	Monaco Bus 12	230	218
Marcy	230	217	Santa Fe	230	218
Littleton Bus 2	230	217	Waterton	230	220
Greenwood Village	230	217	Chatfield	230	222
Clark	230	217	Waterton	115	225
Tech Center	230	217			

2. Injection from the West

Results from the PTI analysis indicated some positive injection points, primarily on the 230kV system between Rifle and Malta, and on the 230kV system between Malta and Dillon. Positive injection was also indicated southwest of the Denver-metro area in the regions of Tarryall, Divide, and Castle Rock. Table 10 summarizes the major buses in the West system. However, any actual injection at those sites would likely require additional transmission, due to other limitations. All power that flows from the west to the Front Range must travel across the transmission path known as Tot 5. The Tot 5 transmission path is constrained by both physical and contractual limitations. The section on Transfer Capability Limitations includes a more detailed discussion of path limitations. The studies that were performed did not attempt to maximize the Tot 5 path and therefore, some physical limitations were not revealed. Regardless of the physical limitations, the path does not have any firm transfer capability available for west to east schedules. PSCo is only one of several entities with rights to path schedules.

Table 10 West Injection Buses

Bus	KV	Injection (MW)	Bus	KV	Injection (MW)
Parachute	230	0	Mill	115	87
Cameo	230	0	Blue River	115	91
Smelter	115	0	Carbondale	115	117
Poncha	115	0	Malta	230	123
Otero	115	0	Climax	115	129
Buena Vista	115	0	Cooley Mesa	230	129
Clifton	230	0	Blue River	230	139
Grand Junction	230	0	Hopkins	115	142
Horizon	230	0	Carbondale	115	142
Uintah	230	0	Breckenridge	230	143
Shoshone	115	47	Stillwater	115	155
Summit	115	64	Roaring Fork	115	161
Leadville	115	65	New Castle	115	163
Robinson	115	65	Malta	115	166
Gilman	115	65	Mitchell Creek	115	166
Mayflower	115	69	Glenwood Springs	115	167
Aspen	115	71	Woodland	115	172
Basalt	115	71	Mount Harris	138	185
Twin Lakes	115	74	Hopkins	230	229
Dillon	115	82	Dillon	230	240
Portal	115	83	Rifle_(PSCo)	230	365

3. Injection from the South

Results from the PTI analysis indicated no positive injection on PSCo buses in the southern system. Following implementation of the 1999 IRP generation in the southern system, the transmission is that region is utilized to maximum capacity. Table 11 lists the major PSCo buses in the South Region of study.

Table 11 Major Buses in the South Region with No Capacity

Bus	KV	Injection (MW)
Boone	115,230	0
Castle Rock	115	0
Comanche	115,230	0
Divide	115	0
Lamar	115,230	0
Midway	115,230	0
Pueblo	115	0
Reader	115	0
Tarryall	115,230	0

D. Conclusions and Limitations of the Study

The results of this transfer analysis provide an indication of the capability of the transmission system to accommodate the connection of new generating resources at the various points in PSCo's transmission system that were studied. Those locations with a positive transfer capability for the 2008 summer peak could be considered as a potential site for the connection of a new generating resource from the transmission system perspective. These results are based on the assumption that a potential generating facility is connected directly to the bus. There are a number of assumptions and factors that should be recognized in using these results. These include:

1. Dispatch of PSCo's existing and future resources will likely be different than those reflected in the analysis and could increase power flows on facilities that are critical for the injection point.
2. Load growth or characteristics (such as light loads or seasonality) significantly different than those reflected in the model will impact the results.
3. Power from the addition of other generators in the same timeframe could utilize the transmission capability that has been identified here.
4. While voltage criteria does not appear to be a limitation for the injection points with a positive transfer capability, a detailed contingency analysis would need to be performed to confirm that there were no voltage issues and that sufficient reactive power is available to maintain voltages.

5. Delays in completion of construction of generation or transmission facilities may impact certain transfer capabilities.
6. Planned additions of transmission facilities by other utilities in Colorado that are different from those shown in the current transmission model can significantly limit transfer capabilities.
7. Tapping a line connecting two buses with adequate transfer capability may not provide the same level of capability.
8. The results of stability analyses, which have not been performed for this study, could require system modifications in order to attain the indicated transfer levels.

As stated previously, these results can be considered preliminary indicators of injection capabilities. However, for any proposed site of generation injection detailed interconnection studies must be performed to determine system limitations.