Pueblo County 750 MW Generation Addition
Interconnection Feasibility Study Report
September 2003
INTERCONNECTION REQUEST # GI-2003-3

Public Service Company of Colorado
Transmission Planning, Denver

I. Executive Summary

On July 17, 2003 a formal request was submitted to Xcel Energy Delivery to conduct a feasibility study that would evaluate the integration of a 750 MW coal fired generating unit near Pueblo, Colorado. The generation was modeled at the Comanche Station, and was assumed to be in service by 2008. This Transmission Impact Study Report documents the results of the feasibility analysis to determine the necessary infrastructure to accommodate the additional generation.

Figure 1 shows the basic 230kV and 115kV transmission network between Pueblo and Denver. Studies indicated that the existing transmission system is not adequate to accommodate the proposed generation. Integration of the 750 MW generation resulted in system overloads for both system intact and contingency conditions. This study indicated that the least cost method to accommodate that 750 MW of generation was to build new 230kV transmission from the Comanche Station to the Daniels Park Substation. The new transmission should be constructed for 345kV, but initially operated at 230kV. The primary transmission, Alternative A, consists of the following:

1. Between Comanche Station and Midway Substation, build a new 230kV transmission line. The line will have a termination at Comanche, but will not tie into Midway. The line should be built to accommodate future 345kV operation, using appropriate tower structures and bundled conductor capable of at least 800 MVA at 230kV.

2. The line will continue north of Midway Substation by rebuilding the existing Comanche – Fuller – Daniels Park single-circuit 230kV line to double-circuit configuration. Following the rebuild, one circuit north of Midway Substation will be an upgrade of the existing 230kV line. The other circuit will continue the new transmission from Comanche and terminate at Daniels Park Substation. The construction will be similar to the planned Midway – Daniels Park Rebuild Project. The new transmission should be capable of 345kV operation, using appropriate tower structures and bundled conductor capable of at least 800 MVA at 230kV.

Other system alternatives were also evaluated and are listed in the Results section, but studies revealed that the infrastructure listed above provides the best system performance at the least cost. The estimated cost for the basic transmission infrastructure is approximately $115 Million. The estimate is in 2003 dollars and includes a 25% contingency allowance. It is based on typical construction costs and engineering estimates and should not be considered a detailed estimate. The timeline to complete all required transmission and substation facilities is expected to require a minimum of 48 months. If there are problems with local and state approvals, an additional year could be required.

Alternative A provides the primary transmission reinforcements for PSCo's system to accommodate additional generation at Comanche. It does not fully address some remaining contingency overloads on regional systems. This study did not address transfer capability or attempt to quantify a precise amount of generation for which the additional infrastructure would be able to accommodate. The study did not address any impacts to regional transmission paths, such as Tot 5. This study was performed using powerflow analysis, and no transient stability or fault analyses were performed. For any additional pursuit of this project, it is recommended that all of the above analyses be thoroughly evaluated.

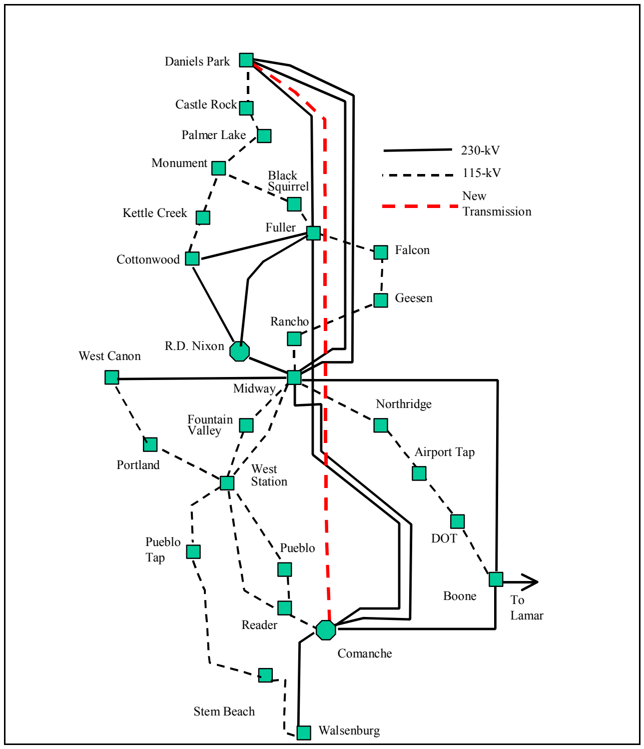

Figure 1

II. Bench Mark Results

Studies were initiated by adding a 750 MW unit at Comanche Station and no additional transmission infrastructure to the base powerflow model. In order to stress the transmission path from south to north, the added generation was offset by reducing generation north of Daniels Park. The powerflow base case modeled all of the southern (Colorado Springs & Pueblo) system generation at or near maximum output. The benchmark analyses revealed that the transmission network as it is planned to exist in 2008 would be insufficient to accommodate the 750 MW of added generation. Most of the deficiencies were manifest on the lower voltage (115kV) parallel transmission systems.

The following sections describe the deficiencies found on the lower voltage networks prior to implementation of any transmission alternatives. Included with each deficiency is a list of potential solutions for consideration. Not all of the ideas were explored in detail.

A. Pueblo Area Parallel 115kV Network

There were two 115kV networks in this region that exhibited loading problems following the addition of 750 MW of generation at Comanche. One is the 115kV transmission between Comanche and West Station. The other problematic region was the 115kV line between Boone and Midway.

The 115kV system between Comanche and West Station exhibited overloads for system intact (no contingency), as well as contingency conditions. From Comanche, PSCo owns the line between Comanche and Reader. That line has been identified in other studies to require upgrade and for this study is considered to be an existing problem to be addressed in other studies. There are two single-circuit 115kV lines from Reader to West Station, and both belong to Aquila. One line goes directly from Reader to West Station and the other goes through the Pueblo Substation. Table 1 lists the system intact (N-0) and single contingency (N-1) overloads on the Reader – West Station system. There were several 230kV contingencies that compounded the Comanche – West Station 115kV overloads. Other than the Comanche – Reader 115kV line, the Pueblo – West Station 115kV line exhibited the highest overloads.

Table 1 Comanche – West Station Contingency Loading

Contingency	Element Loading			
	Comanche-Reader 115kV (300 MVA)	Pueblo–WStation 115kV (120 MVA)	Pueblo–Reader 115kV (159 MVA)	Reader – West Station 115kV (100 MVA)
System Intact (N-0)	132%	127%	124%	103%
Comanche – MidwayPS 230kV	165%	175%	160%	137%
Comanche – Walsenburg 230kV	159%	165%	153%	130%
Boone – MidwayPS 230kV	155%	160%	149%	127%
Comanche – Boone 230kV	141%	141%	135%	113%
Comanche – Fuller 230kV	157%	163%	151%	129%

Studies also showed that contingencies of the Boone – Midway 230kV line would overload sections of the Boone – Midway 115kV line. In particular the section between Boone and DOT Tap exhibited the highest contingency loading, followed by the DOT Tap – Airport line section. Loss of the Boone – Midway 230kV line appeared to cause the highest contingency loadings, which are shown in Table 2.

Table 2 Boone – Midway Contingency Loading

Contingency	Element Loading	
	Boone – DOT Tap 115kV (100 MVA)	DOT Tap – Airport Tap 115kV (103 MVA)
Boone – Midway 230kV	125%	116%

B. Midway – Daniels Park Parallel 115kV Network

The 115kV system between Daniels Park and Cottonwood has been shown to be a limiting element in previous studies. The transfer capability of the high-voltage (230kV) path into Daniels Park has been determined based on this limitation. This high-voltage path has been referred to as the Front Range Path, or FRP. The 115kV system between Daniels Park and Cottonwood is electrically in parallel to the FRP. PSCo owns the 115kV line from Daniels Park to Palmer Lake. From Palmer Lake south, the network is owned by Colorado Springs Utilities (CSU). Figure 1 also shows the 115kV path from Midway to Fuller to Monument. That network is owned by Mountain View Electric Association.

The most severe contingency for the network between Daniels Park and Cottonwood is generally one of the Front Range Path elements and this study showed the Daniels Park – Fuller 230kV contingency to be the worst outage. The sections that exhibit the highest overloads for that contingency are those between Castle Rock, Palmer Lake, Monument, and Kettle Creek. Table 3 summarizes the contingency results for the Daniels Park – Cottonwood 115kV network.

Table 3

Contingency	Element Loading		
	Monument - Palmer Lake 115kV (135 MVA)	Palmer Lake - Castle Rock 115kV (134.8 MVA)	Monument – Kettle Creek 115kV (135 MVA)
Daniels Park – Fuller 230kV	122%	122%	115%
Daniels Park – Midway 230kV	115%	115%	106%

In previous FRP studies this 115kV network was not allowed to exceed 100% of any continuous element ratings.

There is another 115kV network in parallel to the 230kV Front Range Path lines that runs from Monument to Midway owned by MVEA. Several contingencies caused sections of the 115kV network to overload, the worst being the loss of CSU's Cottonwood 230/115kV transformer. The MVEA Midway – Rancho 115kV line section exhibited the highest contingency overloads, followed by MVEA's Black Squirrel – Fuller 115kV line. Table 4 summarizes the contingency loading for that path.

The Midway – Rancho 115kV line section is 2.1-miles long and has a continuous rating of only 80 MVA. The line has 477 kcmil conductor and other sections of the line are rated at 95 MVA.

Table 4

Contingency	Element Loading				
	Midway – Rancho 115kV (80 MVA)	Black Squirrel – Fuller 115kV (146 MVA)	Black Forest – Black Squirrel 115kV (146 MVA)	Black Forest – Gresham 115kV (146 MVA)	Rancho – Geesen 115kV (95 MVA)
Cottonwood 230/115kV	130%	123%	115%	109%	108%
Comanche – Fuller 230kV	123%	--	--	--	101%
Daniels Park – MidwayPS 230kV	122%	--	--	--	101%

C. North of Daniels Park

By scheduling the 750 MW of additional generation to the north, a high percentage of that power was delivered through the Daniels Park Substation. As a result, an outage of one of the double-circuit lines from Daniels Park to Greenwood overloads the parallel circuit. The overloads were of the order of 115-120%. Those overloads were observed regardless of the alternatives studied between Comanche and Daniels Park. The 8-mile double-circuit line has single 1272 kcmil conductor and in the models has a continuous thermal rating of 495 MVA. Table 5 summarizes the contingency overloads on that path.

Table 5

Contingency	Loaded Element	% Load
Daniels Park – Greenwood 230kV	Daniels Park – Prairie 230kV (495MVA)	116%
Daniels Park – Prairie 230kV	Daniels Park – Greenwood 230kV (495 MVA)	113%

Preliminary investigation by Transmission Engineering indicates that the line can be operated at a higher conductor temperature and may be capable of at least 600 MVA. This would have to be verified for any additional study work.

III. Results

From the benchmark analysis, it was apparent that the contingency overloads were of such magnitude as to require additional transmission between Comanche and Daniels Park. This was determined to offer the greatest potential for achieving the goals of integrating the new generation into the system. Solutions that included transfer tripping of lines or other remedial action schemes were not evaluated for this study. In most instances, rebuilding lower voltage, load-serving transmission owned by other entities was also not considered.

A. <u>Comanche – Daniels Park Line (Fuller Line Rebuild)</u>

1. Configuration

Build new transmission from Comanche Station to Daniels Park Substation as follows: For the section between Comanche and Midway, build new single-circuit transmission. For the section between Midway and Daniels Park, rebuild the Comanche – Fuller – Daniels Park 230kV line to double-circuit configuration. The new (second) Comanche – Daniels Park line would not tap into Midway or Fuller substations.

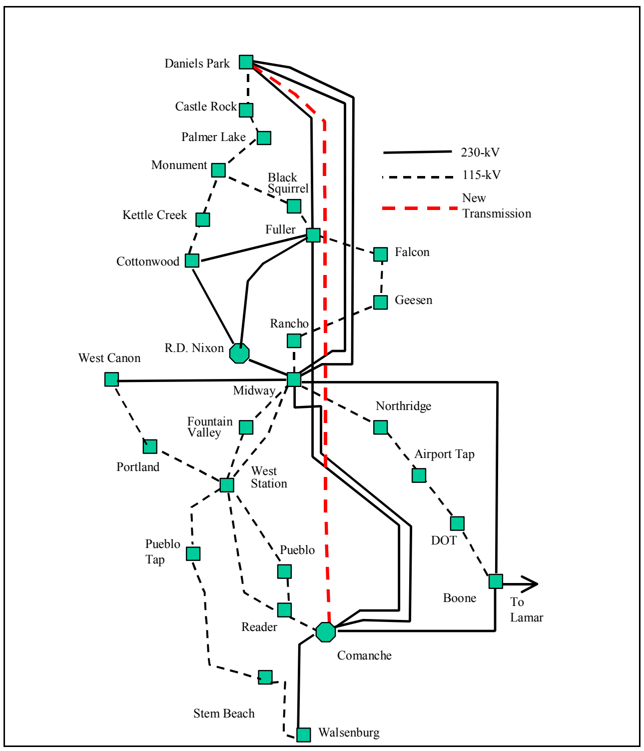

Figure 2

2. Results:

This alternative significantly reduced all of the contingency overloads that were seen in the benchmark case, but did not eliminate some of them. The results for this alternative are summarized in Table 6. The benchmark overloads are also shown for comparison as case a8c2a. The table distinguishes the performance for each of the regions as described in the Benchmark section.

Under the conditions studied, very little power flowed on the Comanche – Boone 230kV line. In an attempt to increase the flows on that line and provide a better flow balance on the lines out of Comanche, sensitivity cases were run to model series compensation on that line, and on the line from Boone to Midway. Case e8d4a shows that with the series compensation modeled on both lines, contingency overloads on Aquila's Pueblo – West Station 115kV transmission line were reduced to less than 105%.

Table 6

Contingency Results		Contingency / Loaded Element	Comanche - Midway 230 'Pueblo - W.Station 115	Comanche - Midway 230 'Pueblo - Reader 115	Comanche - Fuller 230 'Pueblo - W.Station 115	Comanche - Fuller 230 'Pueblo - Reader 115	Midway - Boone 230 Boone DOT Tap 115	Midway - Boone 230 Airport Tap- DOT Tap 115	Daniels Park - Fuller 230 Monument - Palmer 115	Daniels Park - Fuller 230 Palmer - Caslte Rock 115	Cottonwood 230/115 MidwayBR - Rancho 115	Cottonwood 230/115 Fuller - Black Squirrel 115
Case:	Alt	MVA Rating →	120	159	120	159	100	103	135	135	80	146
a8c2a	Base		175%	160%	165%	153%	125%	116%	122%	122%	130%	123%
e8d2a	Add Comanche-Fuller – Daniels Park 230kV Line. **New** Com-Mid line		109%	110%	116%	116%	102%	94%	97%	96%	109%	102%
e8d4a	Add Series Compensation Comanche – Boone 50% Boone – Midway 50%		91%	97%	100%	104%	95%	<90%	96%	96%	109%	101%

The worst overload for the final configuration, e8d4a, was loss of CSU's Cottonwood 230/115kV transformer and subsequent loading of MVEA's Midway – Rancho 115kV line to 109%.

This alternative reduced the Boone – Airport Tap 115kV and the Monument – Castle Rock 115kV contingency overloads to less than 100%.

3. Conclusion:

This alternative reduced most of the contingency overloads to acceptable levels. Some contingency overloads of less than 110% remain on regional systems.

Series compensation was required on the Comanche – Boone – Midway 230kV lines to get the Reader – West Station 115kV system overloads to less than 105%.

Alternatives

The following sections briefly describe some of the other alternative transmission alternatives that were evaluated. The first two are variations of the first alternative and detailed analysis could reveal additional benefits to them. The remaining did not provide adequate transmission to meet the goals of the study.

B. Comanche – Daniels Park 230kV Line by way of Midway

This alternative is essentially the same as Alternative A, except the line would be tied into the Midway Substation. This alternative reduced all of the contingency overloads, but the performance was not quite as good as Alternative A, which had no connection to Midway. This alternative would have a higher cost due to the connections at Midway.

C. Comanche – Daniels Park 345kV Line

This alternative is the same as Alternative A, except it would initially be operated at 345kV. 345/230kV transformation would be required at Comanche and Daniels Park. This alternative performed comparably to Alternative A but would require additional expense.

D. Comanche – Midway, Upgrade Midway – Daniels 230 to 345.

This configuration would add new 230kV transmission between Comanche and Midway. However, from Midway to Daniels Park, no new transmission would be added, but the existing Midway – Daniels Park 230kV lines would be upgraded to operate at 345kV. This would be achieved in part by adding parallel 345/230kV transformers at Midway and Daniels Park. The thought was that this could provide a lower cost alternative by upgrading existing lines. However, studies showed that this alternative was not adequate to accommodate the additional generation.

E. Comanche – Boone 230kV Line; Boone – Denver 345kV Line

This alternative would require a new 230kV line from Comanche to Boone. From Boone, build a 345kV line to a new substation near Deer Trail, Colorado. The new substation (referred to in studies as Corner Point Substation) would be built to terminate the 345kV line and would also bisect the 230kV lines from Pawnee into Smoky Hill and Daniels Park. An additional 230kV line would be build from Corner Point to Smoky Hill. 345/230kV transformation is required at Boone and Corner Point. Due in part to the increased line lengths for transmission, this alternative was not adequate to accommodate the additional generation and it is expected that the costs would be significantly higher than Alternative A.

IV. Study Criteria

1. WECC/NERC Criteria

As a member of WECC, PSCo adheres to the WECC and NERC Reliability Criteria. Excerpts of the System Performance Tables from the latest Criteria, dated August 2002 are provided in Appendix D. The complete Reliability Criteria document can be found on the WECC web site at www.wecc.biz.

2. System Normal Condition:

- Line loading monitored for 100 percent of the continuous seasonal rating, the established equipment rating, or applicable operating limits.
- Transformer loading monitored to 100 percent of the highest name plate rating or appropriate owner's top rating.
- Transmission bus voltages maintained between 0.95 p.u. and 1.05 p.u. of nominal system voltage.

3. Contingency Conditions

- Line loading monitored for 100% of the continuous seasonal rating, or an established equipment rating.
- Transformer loading monitored for 115% of the system normal rating or an established emergency rating.

V. Preliminary Cost Estimates

The estimated cost for the recommended transmission infrastructure is $115 Million. The estimate is based on typical construction costs and previous projects. It is based on 2003 dollars and includes a 25% contingency allowance. Many factors can influence the estimate and this should in no way be considered to be a detailed engineering estimate.