Interconnection System Impact Study Report
REQUEST # GI-2004-4

280 MW Wind Generation Near Lamar, Colorado
Interconnecting at Lamar Substation

Xcel Energy Transmission Planning
May 2005

Executive Summary

This Interconnection System Impact Study Report summarizes the analyses performed by the Transmission Planning group of Public Service Company of Colorado (PSCo) to interconnect 280 MW of wind powered generation located in Prowers County near Lamar, Colorado. The point of interconnection is the Lamar PSCo 230 kV bus. The Customer proposed in-service date for commercial operation of the facility is December 31, 2006 with an assumed back-feed date of June 1, 2006. This request was studied as both an Energy Resource (ER) and a Network Resource (NR) with the power going to PSCo customers. The request was studied primarily as a "stand-alone" project, but some sensitivity analyses were also performed to consider other projects in the Rocky Mountain Area OASIS queue[1].

Energy Resource:

This study determined that the Customer could not provide any long-term firm energy without the construction of network reinforcements. This determination is based on existing limitations on the transmission path west of Lamar. Non-firm transmission capability may be available depending on marketing activities, dispatch patterns, demand levels and the status of transmission facilities. Sensitivity studies evaluated the system performance considering the higher queued project GI-2004-2[2]. If request GI-2004-2 and its associated proposed system upgrades are considered to be in place, studies showed that the proposed project could generate approximately 50 MW of firm energy before additional Network Upgrades would be required.
The estimated cost to interconnect the project is approximately **$1.18** million and includes:

- $0.37 million for Customer Interconnection Facilities at Lamar Station
- $0.81 million for PSCo Network Upgrades for Interconnection

The time required to engineer, permit, and construct all the required PSCo facilities for interconnection is estimated to be at least **9** months. Therefore, it is not feasible to interconnect the proposed project by the proposed in-service date.

[1] www.rmao.com
[2] 238 MW Wind Expansion of an Existing Facility

Network Resource:

For the Project to be considered a Network Resource, other studies have indicated that the integration of the full 280 MW of new generation would require transmission additions and modifications in order to prevent unacceptable conditions on the regional system. The estimated cost of the network upgrades to deliver the project is approximately **$139.17** million (for a total cost of $140.35 million) and would consist of:

- Construct a new 99 mile single-circuit 230 kV line on 345 kV-capable double-circuit structures from Lamar to Boone
- Construct a new Corner Point 230 kV substation 40 miles east of Smoky Hill and tap the existing Pawnee – Daniels Park 230 kV line at Corner Point
- Construct a new 183 mile single-circuit 230 kV line from Lamar to Corner Point

The estimated time required to engineer, permit, and construct the Network Upgrade facilities for delivery is at least **54** months; therefore, it is not feasible to implement the network upgrades for delivery of firm output by the proposed in-service date.

According to the interconnection request, the Customer will engineer, permit, construct, and finance the 230 kV transmission line to the proposed tap station.

A simple diagram of the Network Upgrades and the regional transmission system for this request is shown in Figure 1. Figure 2 shows the proposed interconnection one-line.

Sensitivity studies evaluated the system performance considering the higher queued Colorado Green expansion project GI-2004-2. If GI-2004-2 is considered to be in place, studies indicate that the total estimated cost of the recommended system upgrades to accommodate GI-2004-2 and GI-2004-4 at the PSCo Lamar 230 kV bus would result in costs of approximately $138.3 million [3] and include:

- $0.425 million for Customer Interconnection Facilities at Lamar Station
- $0.982 million for PSCo Network Upgrades for Interconnection
- $136.9 million for PSCo Network Upgrades for Delivery

Figures 3 and 4 are simple diagrams of the regional system and interconnection respectively if GI-2004-2 is accounted for.

[3] From Feasibility Study for GI-2004-4

Figure 1 - Regional Transmission Network with Recommended Upgrades for Delivery – Standalone

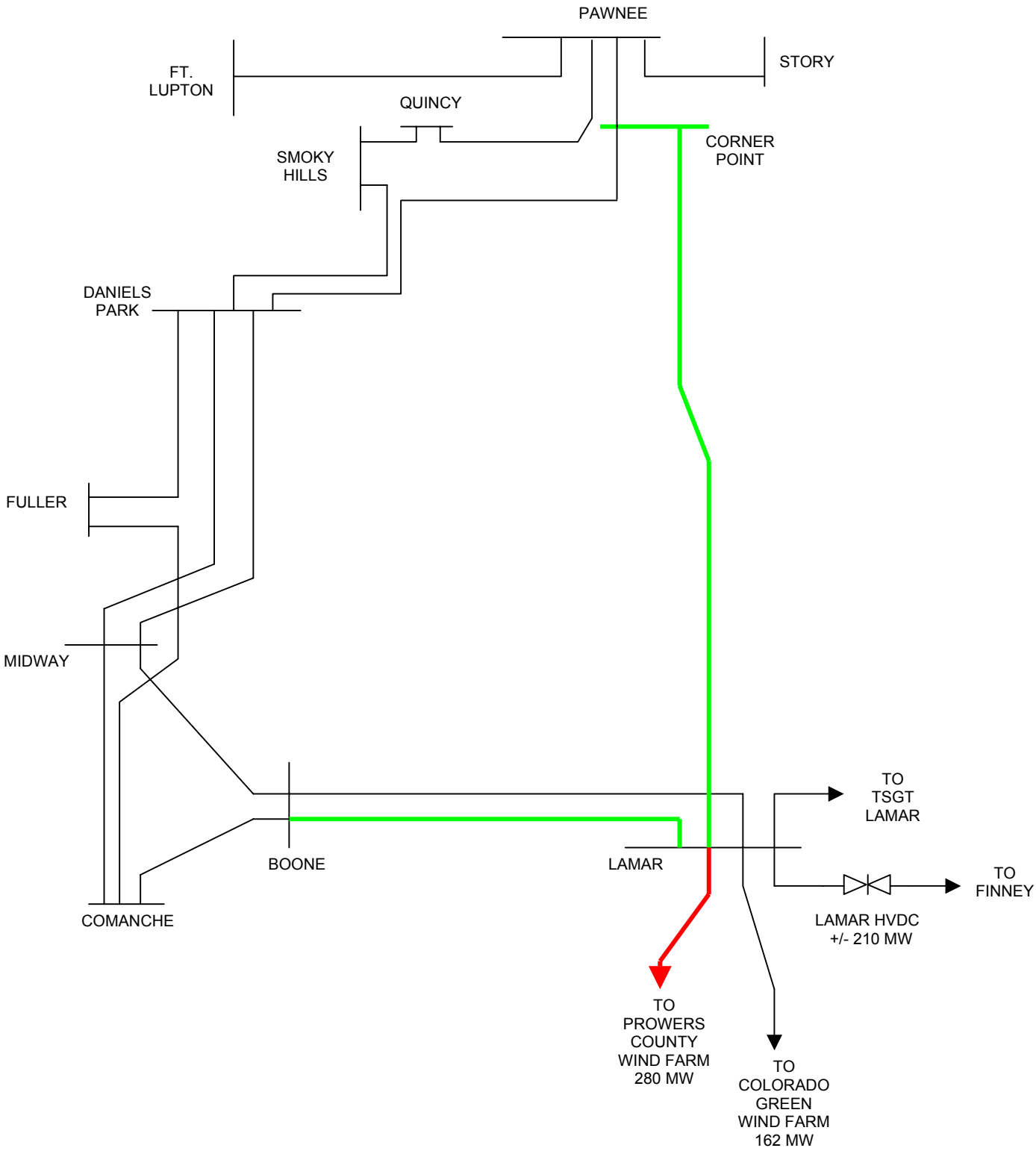


Figure 2 – Lamar Substation One-line with GI-2004-4

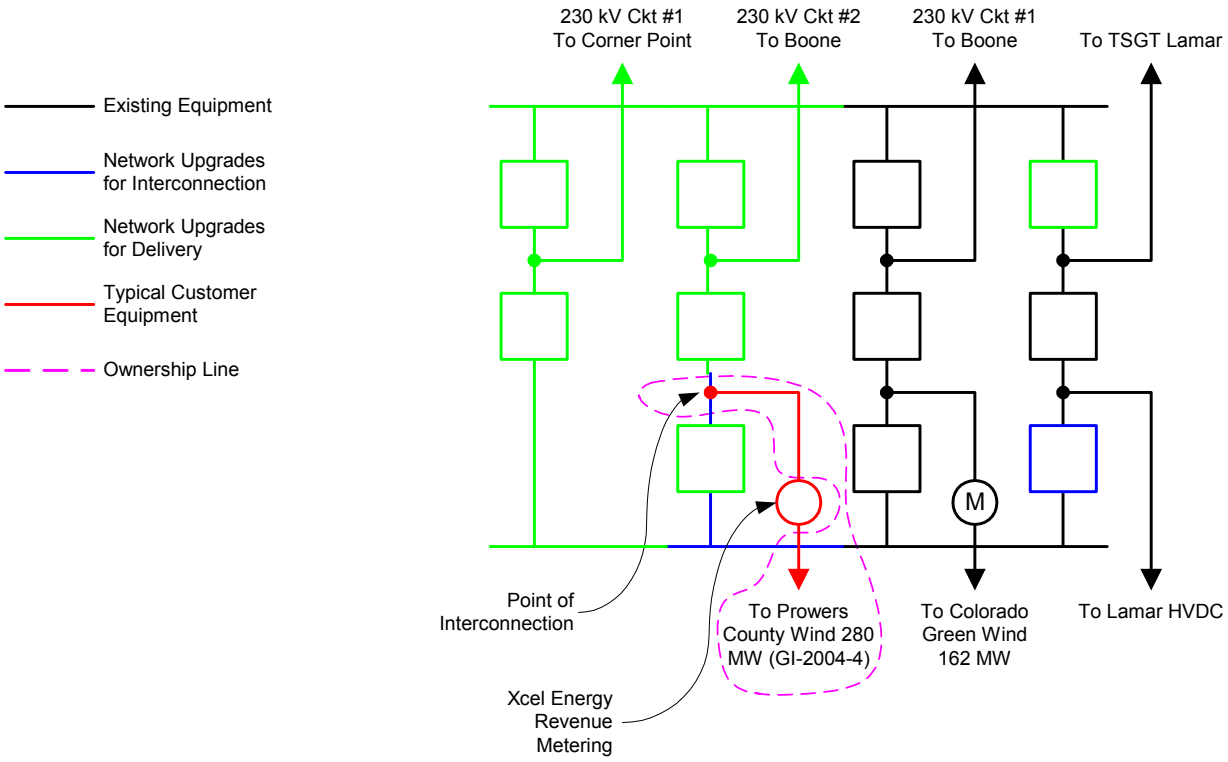


Figure 3 - Regional Transmission Network with Recommended Upgrades for Delivery – Considering GI-2004-2

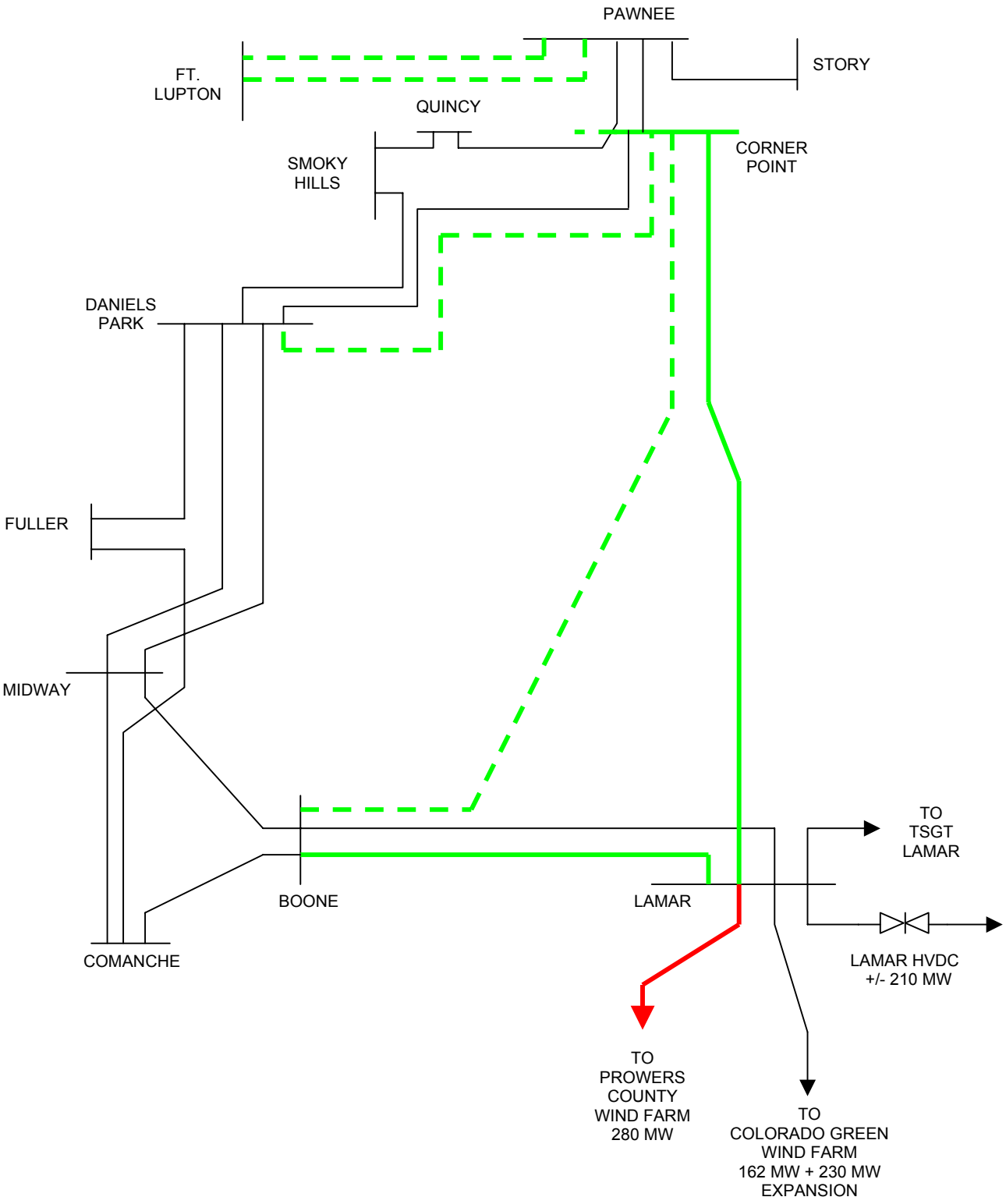
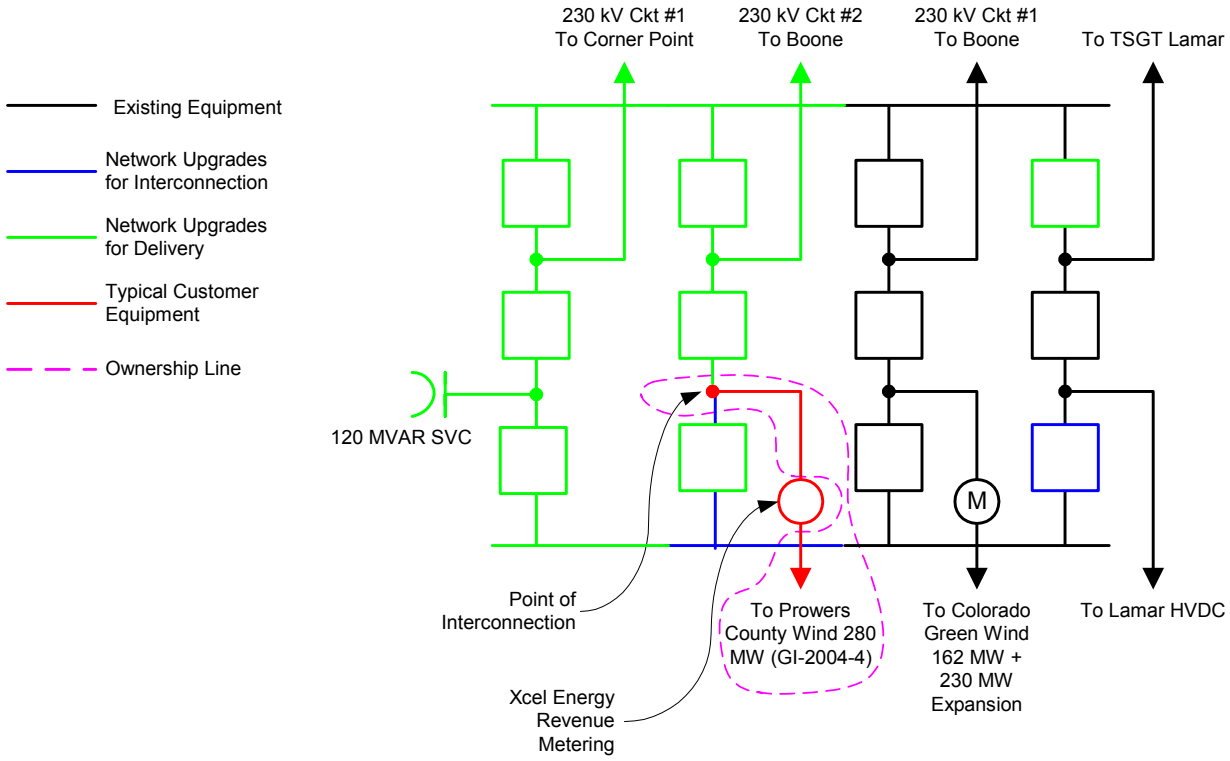


Figure 4 – Lamar Substation One-line with GI-2004-2 and GI-2004-2



Study Scope and Analysis

The Interconnection System Impact Study evaluated the transmission requirements associated with the proposed interconnection to the PSCo Transmission System.

The Study consisted of power flow, short circuit, and dynamic stability analyses. The power flow analysis identified thermal or voltage limit violations resulting for the interconnection, and identified Network Upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified circuit breaker short circuit capability limits exceeded because of the Interconnection, and the delivery of the proposed generation to PSCo loads. The dynamic stability analysis identified any limitations due to angular instability of the system for regional disturbances.

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 system normal conditions, and steady state power flows within 1.0 per-unit of all elements thermal (continuous current or MVA) ratings. Operationally, PSCo tries to maintain a transmission system voltage profile ranging from 1.02 per-unit or higher at generation buses, to 1.0 per-unit or higher at transmission load buses. Following a single contingency element outage, transmission system steady state bus voltages must remain within 0.90 per-unit to 1.10 per-unit, and power flows within 1.0 per-unit of the elements continuous thermal ratings.

Impacts on the neighboring utilities were monitored, and were addressed in the scope of this study. The proposed transmission for delivery alleviates the contingency overloads on affected utilities in the area of study. These results have been shared with Aquila, Arkansas River Power Authority (ARPA), Colorado Springs Utilities (CSU), Lamar Light and Power (LL&P), and Tri-State Generation and Transmission (TSGT).

Powerflow Study Models

For this analysis, a power flow model was developed to reflect 2007 heavy summer loading conditions. Data representation in the area of study was reviewed and modified to accurately reflect the Rocky Mountain regional transmission system. Power transfers from south to north through Colorado were increased to study the regional transmission system. The Lamar DC tie was modeled at its maximum rating of 210 MW east to west.

The 280 MW wind farm was modeled as a conventional generator with a 0.95 per unit (p.u.) lagging power factor (overexcited) and a 0.90 p.u. leading power factor (under-excited) capability to simulate the VAR requirements of the generators, assumed to be GE 1.5 MW DFIG turbines.

The proposed project was connected to the Lamar Substation 230 kV bus, via a single 20-mile 230 kV line, according to Customer provided data. The project generation was scheduled to PSCo peaking units located in and around the Denver-metro area.

Study Results

Power Flow Analysis

Energy Resource (ER) Study Results

The studies showed that there is insufficient transmission capacity in the region to accommodate any energy from the proposed project on a firm basis. This determination is based on existing limitations on the transmission path west of Lamar. Non-firm transmission capability may be available depending on marketing activities, dispatch patterns, demand levels and the status of transmission facilities. If GI-2004-2 and its associated proposed system upgrades are considered to be in place, studies showed that the proposed project could generate approximately 50 MW before additional Network Upgrades would be required.

Network Resource (NR) Study Results

This study determined the stand-alone network upgrades that would be required to accept the full 280 MW from the proposed project on a firm basis for the conditions studied. For the study, the project generation was scheduled to the northern PSCo system by reducing generation in that area. At 280 MW of generation, several contingencies near Lamar caused solution problems in the powerflow model.

The following network upgrades were implemented to accommodate the full output of the project.

- Construct a new 99 mile single-circuit 230 kV line on 345 kV-capable double-circuit structures from Lamar to Boone
- Construct a new Corner Point 230 kV substation 40 miles east of Smoky Hill and tap the existing Pawnee – Daniels Park 230 kV line at Corner Point
- Construct a new 183 mile single-circuit 230 kV line from Lamar to Corner Point

The Project was also evaluated taking into consideration the relevant projects ahead in the queue. The project considered GI-2004-2, which is 238 MW interconnected at the Lamar 230 kV substation. With both GI-2004-2 and GI-2004-4 in place, the following network upgrades would be required for delivery:

- Construct a new 183 mile single-circuit 230 kV line on 345 kV-capable double-circuit structures from Corner Point to Boone Substation
- Construct a new 60 mile single-circuit 230 kV line on 345 kV-capable double-circuit structures along existing right-of-way from Corner Point to Daniels Park Substation

- Upgrade the 64-mile 230 kV line from Pawnee Station to Ft. Lupton Station to a 230 kV double circuit, 800 MVA per circuit rated transmission line

The details of GI-2004-2 can be seen on the RMAO web page at www.rmao.com.

Short Circuit Analysis

The short circuit analysis from previous studies[4] consisted of calculating fault levels for the buses in the region of study. The results indicated that there are not any major increases in fault currents, and that current breaker ratings are sufficient to integrate this project into the PSCo system.

Stability Analysis

Transient stability analyses of the Lamar area were performed by modeling three-phase faults and single line to ground fault contingencies in the region of study. Dynamic models for the proposed project were prepared using Customer supplied data that modeled GE 1.5 MW DFIG turbines with low voltage ride through capability of 30% of nominal voltage. If the turbine characteristics are changed, the study results may be impacted. The analysis indicated The analysis indicated that the project and the proposed transmission modifications do not impact the transient stability of the region and that the system is stable before, during, and after contingencies.

Sixteen fault scenarios were simulated to analyze system performance. The cases were run using the existing system as a benchmark case. Next, the effect of the network upgrades was gauged in comparison with the transient response of existing system. The generator was then added at full output to determine the impact of the new generation on transient stability. The WECC disturbance criteria for voltage and frequency is used to evaluate the results. Table 1 compares the response of the existing system (benchmark case) with the response of the system with network upgrades. The table lists violations of the WECC disturbance criteria for single contingencies. All of the fault scenarios showed improvements in system stability with network upgrades in place. The Project generator did not cause criteria violations, or significantly worsen system stability when scheduled at full output.

The benchmark results shown in Table 1 indicate that the existing transmission system is relatively weak east of Boone Substation. Specifically, the 115 kV system experiences voltage collapse when the Boone-Lamar 230 kV line is removed from service. The model was unable to solve in three of the scenarios due to flows exceeding the transfer limit of the 115 kV system between Lamar and Boone. The addition of the second Boone-Lamar line, which is one of the required network upgrades for delivery of the Project, significantly improves stability and prevents voltage collapse.

[4] GI-2004-2 Feasibility Study and System Impact Study

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Table 1 - Transient Stability Results – Comparison of Existing System (Benchmark Results) with System Including Network Upgrades and Project Generation Lamar DC tie is scheduled at 210 MW East to West.

	Fault Location	Action	Benchmark Results	Results with Project at 280 MW
1	3PH at Lamar 230 kV bus, 4 cycles	Trip Boone-Lamar 230 kV line, ckt 1 or 2	Colorado Green Trips System unstable	Colorado Green Wind Tripped System Stable
2	3PH at Boone 230 kV bus, 6 cycles	Trip Boone-Lamar 230 kV line, ckt 1 or 2	Colorado Green Trips System unstable	Colorado Green Wind Tripped, Prowers County Wind Tripped System Stable
3	3PH at Lamar 115 kV bus; 6 cycles	Trip Lamar 230-115 kV transformer	Colorado Green Tripped System Stable Post-transient voltage deviations	Colorado Green Wind Tripped System Stable Post-transient voltage violations are unchanged. No New Violations
4	3PH at Colorado Green 230 kV bus; 4 cycles	Trip Lamar-Colorado Green 230 kV line	Colorado Green Trips System Stable	Colorado Green Wind Tripped System Stable
5	3PH at Prowers County Wind 230 kV bus; 6 cycles	Trip Prowers-Lamar 230 kV line	System Stable	Colorado Green Wind Tripped, Prowers County Wind Tripped System Stable
6	3PH at Midway 230 kV bus; 6 cycles	Trip Boone-Midway 230 kV line	Colorado Green Trips System Stable	Colorado Green Wind Tripped, Prowers County Wind Tripped System Stable
7	3PH at Comanche Station 230 kV bus; 6 cycles	Trip Comanche Unit 1	Colorado Green Trips System Stable	Colorado Green Wind Tripped, Prowers County Wind Tripped System Stable
8	SLG at Boone 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, ckt 1 or 2	Colorado Green Trips, Lamar DC Tie Trips System Stable Post-transient voltage deviations	System Stable
9	SLG at Comanche Station 230 kV bus; 20 cycles	Trip Comanche Unit 1	System Stable	System Stable

	Fault Location	Action	Benchmark Results	Results with Project at 280 MW
			No Criteria Violations	No Criteria Violations
10	SLG at Midway 230 kV bus; 20 cycles	Trip Boone-Midway 230 kV line	System Stable No Criteria Violations	System Stable No Criteria Violations
11	SLG at Lamar 230 kV bus; 20 cycles	Trip Boone-Lamar 230 kV line, ckt 1 or 2	Colorado Green Trips, Lamar DC Tie Trips System Stable Post-transient voltage deviations	Colorado Green Wind Tripped, Prowers County Wind Tripped System Stable No Criteria Violations
12	3PH at Boone 230 kV bus; 6 cycles	Trip Boone 230-115 kV transformer	Colorado Green Trips System Unstable	Colorado Green Wind Tripped; Prowers County Wind Tripped System Stable Voltage Violations are unchanged. Post-transient violations are unchanged. No New Violations.
13	3PH at Lamar 230 kV bus, 6 cycles	Trip Lamar-Corner Point 230 kV line	Not applicable to the Benchmark Case	Colorado Green Wind Tripped; Prowers County Wind Tripped System Stable No Criteria Violations
14	SLG at Lamar 230 kV bus, 20 cycles	Trip Lamar-Corner Point 230 kV line	Not applicable to the Benchmark Case	Colorado Green Wind Tripped; Prowers County Wind Tripped System Stable No Criteria Violations
15	3PH at Corner Point 230 kV bus, 6 cycles	Trip Lamar-Corner Point 230 kV line	Not applicable to the Benchmark Case	Colorado Green Wind Tripped System Stable No Criteria Violations
16	SLG at Corner Point 230 kV bus, 20 cycles	Trip Lamar-Corner Point 230 kV line	Not applicable to the Benchmark Case	Colorado Green Wind Tripped System Stable No Criteria Violations

Cost Estimates and Assumptions

The estimated total cost for the upgrades for interconnection and delivery is $140.3 Million.

The estimated costs shown are "indicative" (+/-30%) preliminary budgetary costs in 2006 dollars and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the engineering, design, and construction of these new PSCo facilities. The estimates do not include any costs for any Customer-owned, supplied, and installed equipment and associated design and engineering, other than the transmission line between the generation and Lamar. This estimate also does not include any costs that may, or may not be required for other entities' systems. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines

Based upon the System Impact Study performed here, in order for PSCo to provide an interconnection for the Customer, facilities must be constructed at the PSCo Lamar Substation.

PSCo Network Upgrades for Interconnection:
Table 2 and Table 3 describe the costs associated with providing an interconnection and network upgrades to PSCo's system for interconnection. This does not include all of the costs required for full delivery of the generation.

Table 2 - Customer Interconnection Facilities

Element	Description	Cost Est. (Millions)
Lamar (PSCo) Switching Station	Interconnect Customer to tap PSCo's 230kV bus. The new equipment includes 230kV bi-directional transformer metering, relaying and associated equipment and material.	**$0.330**
	Transmission tie line into substation.	**$0.020**
	Siting and Land Rights for required easements, reports, permits and licenses.	**$0.020**
	Total Cost Estimate for Customer Interconnection Facilities	$0.370

Table 3 - PSCo Network Upgrades for Interconnection

Element	Description	Cost Est. (Millions)
Lamar (PSCo) Switching Station	Interconnect Customer's 230 kV line by converting the Lamar 230 kV four-breaker ring bus into a three bay, five-breaker ring-bus. The new equipment required includes: • One 230 kV, 3000 A, 50 kA circuit breakers • Four 230 kV switches • required electrical bus work, relaying and wiring, and steel supporting structures	**$0.807**
	Total Cost Estimate for PSCo Network Upgrades for Interconnection	$0.807

Element	Description	Cost Est. (Millions)
	Total Cost for Interconnection	**$1.177**
Time Frame		**9 Months**

Table 4 describes the costs associated with providing network upgrades for delivery to PSCo Customers.

Table 4 - PSCo Network Upgrades for Delivery

Element	Description	Cost (Millions)
Lamar Substation (PSCo)	New line terminals for 230 kV circuit # 2 to Boone and new line terminal for new circuit to Corner Point . The new equipment required includes: • six 230 kV, 3000 A, 50 kA circuit breaker • twelve 230 kV switches	**$3.568**
Boone Substation	New line terminal for 230 kV circuit #2 to Lamar and new terminal equipment for circuit #2 to Midway. The new equipment required includes: • Two 230 kV, 3000 A, 50 kA circuit breaker • Two 230 kV switches	**$1.300**
Corner Point Switching Sation	Install a new three breaker ring bus switchyard approximately adjacent to PSCo's existing 230kV Pawnee-Daniels Park Trans Line. The following equipment will be required: • three (3) 230kV 3000 amp 50kA circuit breakers • eight (8) 230kV switches • CCVT's • site development • control building • misc. supporting steel • electrical bus work • associated metering control and relaying • land • transmission line tap	**$3.279**
Transmission	Construct a new 99-mile, single-circuit, 230 kV line from Lamar to Boone, built to 345 kV specifications on double-circuit structures.	**$40.814**
	Construct a new 183-mile, single-circuit, 230 kV line from Lamar to Corner Point, built to 345 kV specifications on double-circuit structures.	**$81.596**
Siting and Permitting	Obtain necessary siting, permits, and ROW as required.	**$8.611**
	Total Cost Estimate for PSCo Network Upgrades for	**$139.168**

Element	Description	Cost (Millions)
	Delivery	
	Total Cost of Project	**$140.345**
Time Frame		**54 Months**

Assumptions

- The cost estimates provided are "scoping estimates" with an accuracy of +/- 30%.
- Estimates are based on 2006 dollars.
- PSCo (or it's Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- The estimated time for design and construction of PSCo network upgrades for interconnection at the Lamar Substation is at least 9months, and is completely independent of other queued projects and their respective ISD's.
- It is anticipated that in order to construct the PSCo network upgrades for delivery, a Certificate of Public Convenience and Necessity (CPCN) will be required by the Colorado Public Utilities Commission (CPUC). The application for a CPCN will not be submitted until the Interconnection Agreement is fully executed. The estimated time frame for the CPCN process, siting, permitting, easement and right-of-way acquisition, design and construction for the PSCo network upgrades is at least 36 months from the time the Interconnection Agreement is fully executed. This time frame is also based on other identified assumptions for Siting and Land Rights, Substation Engineering and Transmission Engineering as listed below.
- The Customer will be responsible for funding and constructing the transmission line from the wind farm to the point of interconnection (Lamar Substation).
- The last span into Lamar Substation from the Customer owned 230 kV line will be a slack span between the PSCo substation dead-end and the Customer's last structure, which is assumed to be a dead-end tangent structure.
- A siting study will not be required if network upgrades for delivery (transmission line construction) is in existing right-of-way. Extensive public involvement is anticipated. Permit applications and possible minor right-of-way acquisition will be required. Land use permits will be required from multiple local jurisdictions.