Feasibility Study Report Request # GI-2004-4

280 MW Wind Generation Facility Near Lamar, Colorado

Xcel Energy Transmission Planning
December 2004

Executive Summary

Public Service Company of Colorado (PSCo) Transmission received a generation interconnection request to determine the feasibility of interconnecting **280** MW of new Customer owned wind turbine generation near Lamar, Colorado within Prowers County. The point of interconnection to the PSCo transmission system is at the PSCo Lamar 230 kV substation bus. The Customer proposed commercial operation date 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). The request was studied primarily as a "stand-alone" project, without considering other projects in the Rocky Mountain Area OASIS queue[1], but some sensitivity analysis was also performed to consider some higher queued projects

The ER portion of 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.

As an NR request, PSCo evaluated the upgrades required to deliver the full 280 MW of the wind facility to PSCo customers. As a stand-alone project, the total estimated cost of the recommended system upgrades to accommodate the project is approximately **$123.9** million and includes:

- $0.425 million for Customer Interconnection Facilities at Lamar Substation
- $0.982 million for PSCo Network Upgrades for Interconnection
- $122.5 million for PSCo Network Upgrades for Delivery

[1] www.rmao.com
[2] 238 MW Wind Facility at Lamar

The basic upgrades for a stand-alone project consist of the following:

- Construct a new 99 mile double circuit 230 kV line, 345 kV capable from Lamar to Boone;
- Construct a new 43 mile single circuit 230 kV double circuit and 345 kV capable line from Boone to Midway;
- Install three 560 MVA 345/230 kV auto transformers at Midway Substation
- Install three 560 MVA 345/230 kV auto transformers at Daniels Park Substation
- Operate the two Midway to Daniels Park 230 kV transmission lines at 345 kV.

The regional transmission system is shown in Figure 1 along with the recommended upgrades. The time required to engineer, permit, and construct these PSCo facilities is at least **54** months.

According to the interconnection request, the Customer would engineer, permit, construct, and finance their 20 mile 230 kV transmission line that will interconnect their facilities to the PSCo Lamar Substation.

If GI-2004-2 and its associated upgrades are considered to be in place, sensitivity studies indicate that the total estimated cost of the recommended system upgrades to accommodate this project (GI-2004-4) would be approximately **$**138.3 million and include:

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

Additional details of the studies can be found under the Power Flow Study Results.

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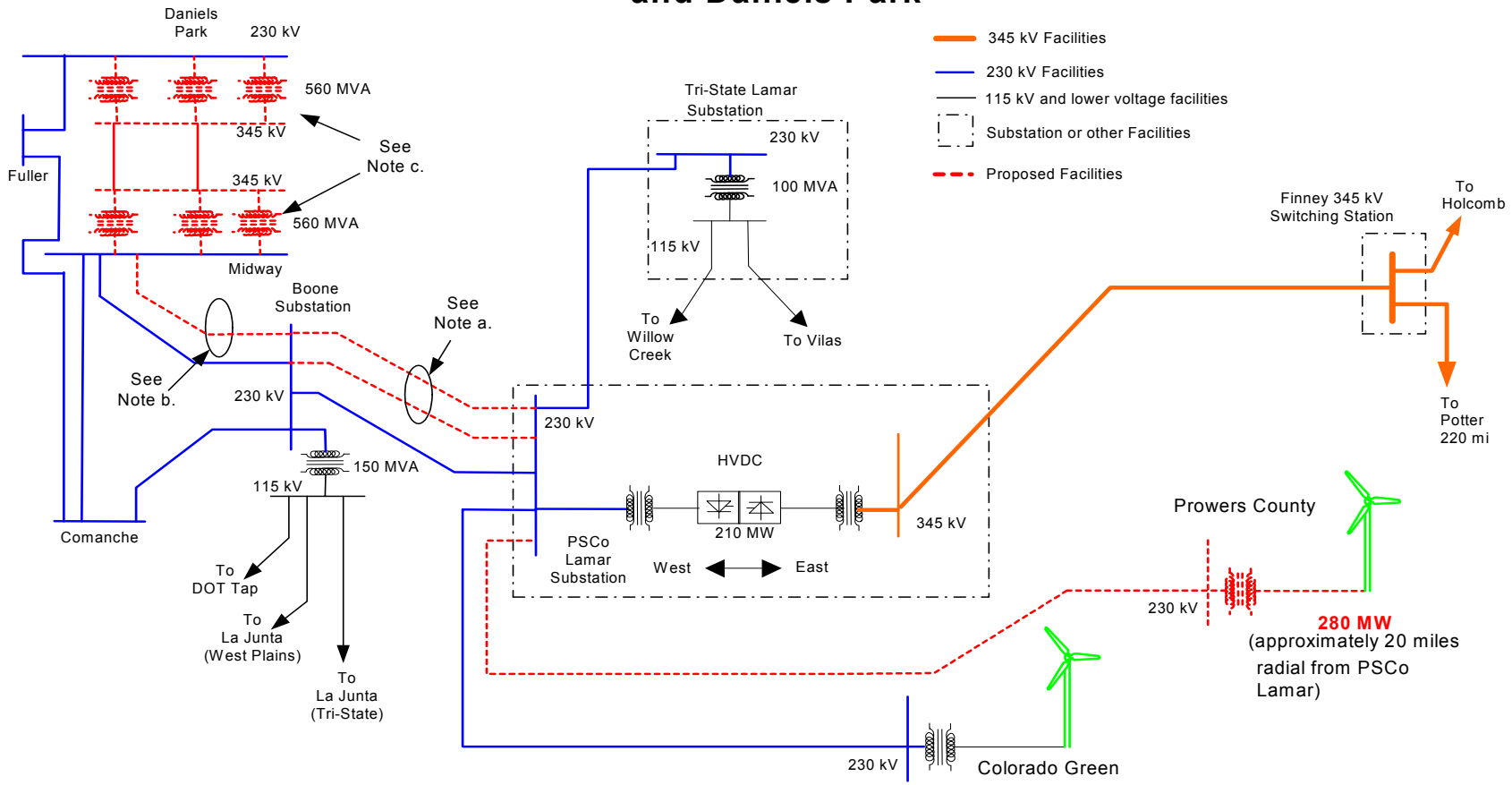
Figure 1

Regional Transmission System Between Finney and Daniels Park



a. A new 99 mile 230 kV double circuit line from Lamar to Boone built to 345 kV specifications and requires additional ROW from Lamar to Boone
b. Build a new single circuit 230 kV line double circuit capable with 345 kV specificationsm adjacent to the existing line providing ROW is attainable.
c. Add three 230/345 kV 560 MVA autotransformers at Midway and Daniels Park and operate the two existing Midway-Daniels Park 230 kV lines at 345 kV.
d. Substation expansion at Boone, Midway, Daniels Park, and Lamar.

Introduction

PSCo Transmission received this large generator interconnection request (GI-2004-4) on August 9, 2004, to interconnect one hundred eighty-seven 1.5 MW, GE doubly fed induction generator (DFIG) wind turbines, for a total of 280 MW of generation, with a commercial operation date of December 31, 2006. The proposed wind farm would be located south of Lamar, Colorado and would interconnect into the PSCo transmission system via a Customer-owned and constructed 20-mile radial 230 kV line terminating at the PSCo Lamar Substation. The customer has requested that this Project be evaluated as a Network Resource (NR) and an Energy Resource (ER) with the energy going to PSCo customers.

Study Scope and Analysis

The Interconnection System Impact Study evaluated the transmission requirements associated with the proposed interconnection to the PSCo Transmission System. It consisted of power flow and short circuit analyses. The power flow analysis identified thermal or voltage limit violations resulting from the interconnection, and was also used to develop the Network Upgrades required to deliver the full amount of proposed generation to PSCo customers. The short circuit analysis identified circuit breaker short circuit capability limits exceeded as a result of the Interconnection and delivery 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 system nominal / 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 addressed in the course of this study. Should the Customer continue this request and move on to the System Impact Study, all utilities with the potential to be impacted by the project and the propose upgrades will be notified and invited to participate. For this project, potentially affected parties could include Aquila, Arkansas River Power Authority (ARPA), Western Area Power Administration (WAPA), and Tri-State Generation and Transmission (TSGT).

Power Flow Study Models:

The power flow study models were created from an existing Western Electricity Coordinating Council (WECC) 2004 Heavy Summer Operating case that was modified to model 2007 heavy summer loading conditions. Data representation in the area of study

was reviewed and modified to reflect the 2007 transmission system. This study included a cursory analysis of the impacts to neighboring transmission systems.

The proposed 280 MW wind project was modeled as two 140 MW conventional generators with a 0.95 pu lag power factor and a 0.9 pu lead power factor (+46/-68 MVAR) to simulate the VAR capabilities of the generators. The modeling was based on the assumption that Customer will be using the General Electric (GE) 1.5 MW DFIG turbines that will have power factor and voltage control capability, as stated in their request. The proposed generation was scheduled to PSCo peaking units located in and around Denver. The existing Colorado Green generation was modeled at full output and the Lamar DC Tie was scheduled at 210 MW into the region to model full power transfers in the regional transmission system.

The Point of Interconnection (POI) between the Customer and PSCo is assumed to be the point at which the 20-mile 230 kV transmission line meets the Lamar Substation.
The 20-mile line was modeled per Customer provided information:

- A single-circuit, 230 kV line using conventional 230 kV "H-frame" wood pole construction and a single 954 ACSR conductor per phase with a 400 MVA rating.

Power Flow Study Results and Conclusions

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 is primarily due to the existing generation in the area utilizing the capacity of the single bulk power transmission line out of Lamar. However, non-firm capacity may be available depending upon the regional generation and load patterns and the flow on the Lamar HVDC Tie.

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:

The NR study determined the network upgrade alternatives to accept the full 280 MW from the proposed project. The studies simulated maximum injections into Lamar substation, including a full 210 MW east to west schedule over the Lamar DC tie and 162 MW of injection from Colorado Green. Denver-metro area generation was reduced to simulate heavy power transfers from Lamar to the Front Range. The analysis revealed transmission paths that exhibited unacceptable contingency performance. The areas of concern are described in the following sections.

Lamar - Boone

Under existing conditions, and heavy east to west flows from Lamar, loss of the Lamar to Boone 230kV line results in overloading the Tri-State 230/115 kV autotransformer. Operating procedures have been implemented to alleviate those overloads until additional transmission can be built. The current operating procedures for the loss of the Boone to Lamar 230 kV line are:

1. Trip the existing Colorado Green Wind Farm off-line and
2. Shut down power injections from the Lamar HVDC tie[3].

Studies have shown that the addition of a second 230kV transmission line from Lamar to Boone will not eliminate all N-1 overload violations. Loss of either Lamar – Boone 230kV line overloads the remaining line and the underlying 115 and 69kV system. Therefore, a third line from Lamar to Boone is required to alleviate the contingency overloads.

Boone – Midway

The proposed generation increase at Lamar also revealed transmission capacity limitations between Boone and Midway. Outages modeled in the Comanche and Midway area resulted in thermal overloads on the Aquila and Colorado Springs Utilities (CSU) systems up to 139 percent of some equipment ratings. A new 230 kV line from Boone to Midway took care of the contingency overloads on the Aquila transmission system.

Midway – Denver

Studies indicated that an outage of either of the 230 kV lines from Midway to Daniels Park would overload parts of the CSU system. Upgrading the two 230 kV lines from Midway to Daniels Park to 345 kV operation removed those contingency overloads. The 345kV upgrade was achieved by adding autotransformers at both Midway and Daniels Park Substations.

In summary, the following upgrades are recommended:

- Between Lamar and Boone Substations, construct a new double circuit 230 kV line. To allow for future capacity, the line should be capable of 345 kV operation, but initially operated at 230kV.
- Between Boone and Midway Substations, construct a new single circuit 230 kV line. To allow for future capacity, the line should be capable of double circuit 345 kV operation
- Upgrade the two Midway – Daniels Park 230kV lines to operate at 345kV. This will require the installation 345/230 kV autotransformers: three at Midway Substation, and three at Daniels Park Substation.

[3] The Lamar DC Tie has controls to rapidly (10 cycles) reduce the output to 0 MW, and at the same time provide voltage support to the 230kV west-side system.

- The 230 KV metering unit at Lamar needs to be replaced since it is sized for the original 162 MW Colorado Green Facility.
- The Customer should investigate upgrading the Colorado Green – Lamar line.

The recommended upgrades are shown in Figure 1.

Consideration of Higher-Queued Projects

Sensitivity studies also considered relevant projects with a higher queue position than this request. These studies considered request GI-2004-2, which is a 238 MW expansion of the existing Colorado Green project. The details of GI-2004-2 can be found at the RMAO web page www.rmao.com

Sensitivity study results show that this 280 MW request would require additional infrastructure upgrades including:

- Construct a 0-120 MVAR SVC at Lamar Substation
- Construct a **110** Mile double circuit 345 kV line operated at 230 kV from a location north of La Junta tapping one of the new 230 kV lines from Lamar to Boone and extending to a new Corner Point Substation. This will make a 230 kV line from Boone to Corner Point along with a Lamar to Corner Point 230 kV line.
- Construct a new Corner Point Substation near Deer Trail, Colorado connecting to the Pawnee-Daniels Park 230 kV line.

The estimated cost for these network upgrades is $138.3 Million. Figure 2 shows the details of the recommended upgrades.

Further interaction of the new wind turbines with the Lamar HVDC link during fault and steady state conditions will be addressed as part of the System Impact Study.

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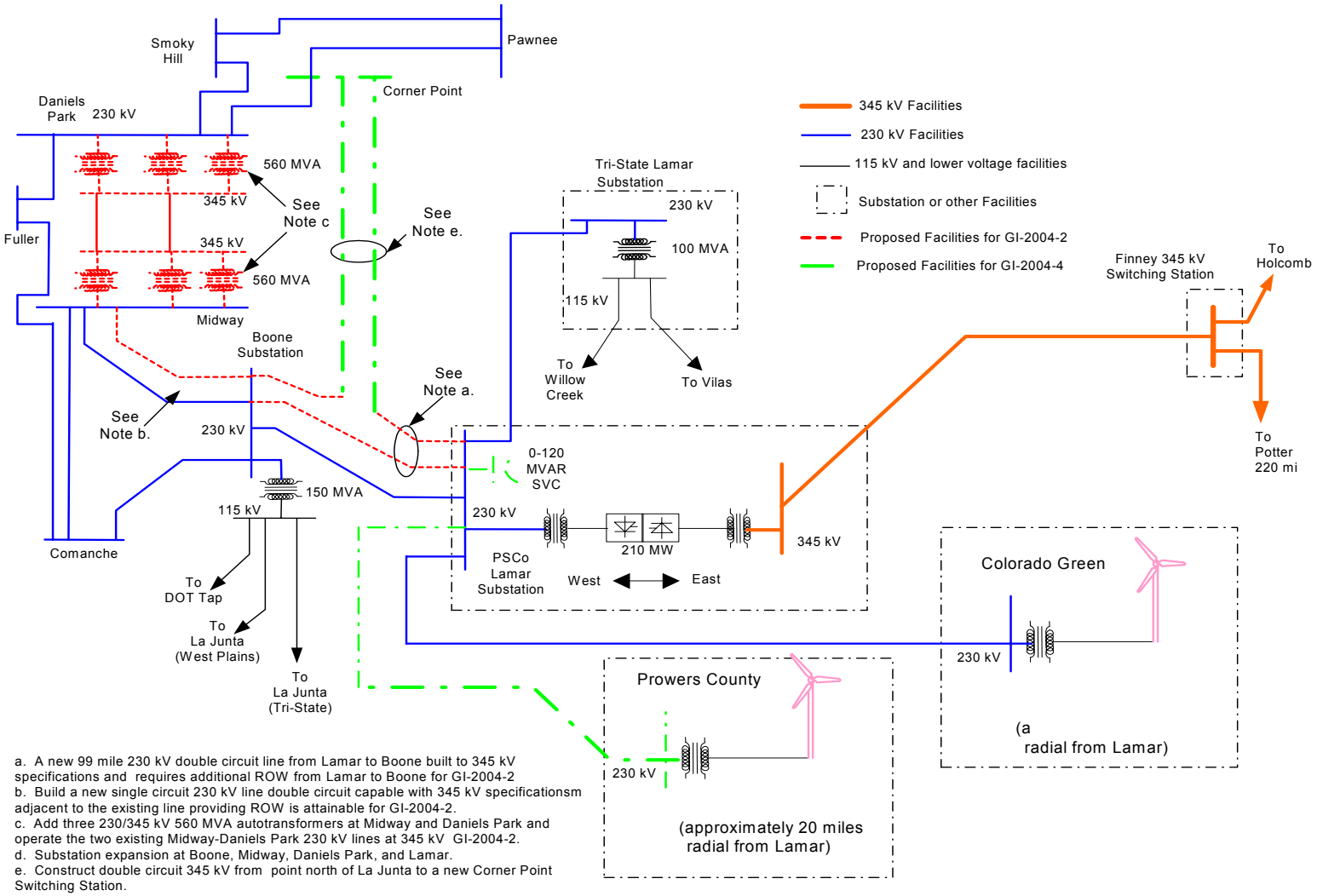
Figure 2: Regional Transmission System with GI-2004-2 and GI-2004-4



a. A new 99 mile 230 kV double circuit line from Lamar to Boone built to 345 kV specifications and requires additional ROW from Lamar to Boone for GI-2004-2
b. Build a new single circuit 230 kV line double circuit capable with 345 kV specificationsm adjacent to the existing line providing ROW is attainable for GI-2004-2.
c. Add three 230/345 kV 560 MVA autotransformers at Midway and Daniels Park and operate the two existing Midway-Daniels Park 230 kV lines at 345 kV GI-2004-2.
d. Substation expansion at Boone, Midway, Daniels Park, and Lamar.
e. Construct double circuit 345 kV from point north of La Junta to a new Corner Point Switching Station.

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Short Circuit Study Results

The short circuit analysis consisted three-phase and phase to ground faults at the Lamar, Boone, and Colorado Green 230kV buses with. The short circuit analysis performed for request (GI-2004-2) will also apply for this request when considered a stand-alone project. The results show that this 280 MW Prowers County Wind Farm GI-2004-4 and its associated transmission line would not adversely impact the ratings of any existing equipment on the PSCo transmission system. The results are described in the following tables.

Table 1 Short Circuit Results (kA) for a stand-alone project

Fault	Fault Description	Fault Current @ 6 Cycles (kA, RMS)	CO GRN 1	DC Link
1	LLLG at Lamar 230 kV	1.45	Trip	Blocked
2	LLLG at Boone 230 kV	7.25	Trip	0 power
3	LLLG at CO Grn 230 kV	1.23	Trip	0 power
4	LLLG at Lamar 115 kV	2.5	Trip	0 power
5	LLLG at Boone 230 kV	7.6	Trip	Voltage Control (High Q)
6	SLG at Lamar 230 kV	2.7	Delayed Trip	Low PQ
7	SLG at Boone 230 kV	7.1	No Trip	Voltage Control (High Q)
8	SLG at Co Grn 230 kV	1.52	No Trip	Voltage Control (High Q)
9	SLG at Lamar 115 kV	4.1	No Trip	Voltage Control (High Q)
10	SLG at Boone 230 kV	7.1	No Trip	Voltage Control (High Q)

Table 2 Short Circuit Results (kA) with consideration of 2004-02

Fault	Fault Description	Fault Current @ 6 Cycles (kA, RMS)	CO GRN 1	CO GRN 2	DC Link
1	LLLG at Lamar 230 kV	1.45	Trip	No Trip	Blocked
2	LLLG at Boone 230 kV	7.25	Trip	No Trip	0 power
3	LLLG at CoGrn 230 kV	1.23	Trip	No Trip	Low Power, Voltage Control
4	LLLG at Lamar 115 kV	2.5	Trip	No Trip	Low Power, Voltage Control
5	LLLG at Boone 230 kV	7.6	Trip	No Trip	Voltage Control (High Q)
6	SLG at Lamar 230 kV	2.7	Trip	No Trip	Low Power
7	SLG at Boone 230 kV	7.1	Trip	No Trip	Low Power
8	SLG at Co Grn 230 kV	1.52	Trip	No Trip	Voltage Control (High Q)
9	SLG at Lamar 115 kV	4.1	No Trip	No Trip	Voltage Control (High Q)
10	SLG at Boone 230 kV	7.1	No Trip	No Trip	Voltage Control (High Q)

As shown in the tables, the Colorado Green Wind Farm will contribute minimal current to the total fault current at Lamar and will not exceed any of the 40 kA circuit breaker fault duty interrupting capabilities.

Costs Estimates and Assumptions:

The estimated total cost for the PSCo network upgrades for 280 MW of delivery is **$123,902,000**

The estimated cost shown is an "indicative" (+/-30%) preliminary budgetary cost in 2006 dollars and is 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. This estimate does not include any costs for any Customer-owned, supplied, and installed equipment and associated design and engineering.

The following tables list the improvements required to accommodate the interconnection and the delivery of the proposed 280 MW increase of the existing Colorado Green facility. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines.

Table 3 Customer Interconnection Facilities

Element	Description	Cost Est. ($Million).
Lamar 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.	**$335k**
	Transmission tie line into Lamar Substation.	**$40k**
	Siting and Land Rights for required easements, reports, permits and licenses.	**$50k**
	Total Cost	**$425k**

Table 4 PSCo Network Upgrades required for interconnection the proposed 280 MW Wind Generation Facility

Element	Description	Cost Est. ($Million)
Lamar	Convert the existing 4-breaker ring bus into a breaker and a half station and add a new 230 kV bay on the west side of the station. The equipment required includes: • Site development • 2 circuit breakers • 6 disconnect switches • 1 dead-end structures, associated bus and connectors • Bus voltage transformers and line synchronizing transformers (See One-line in Appendix B)	**$0.982**
	Total Cost	**$0.982**
Time Frame		**9 months**

Table 5 PSCo Network Upgrades required to deliver the proposed 280 MW increase from Wind Generation Facility as an NR Request

Element	Description	Cost Est. ($Million)
Lamar	Two new 230 kV Line terminals to Boone requiring the following equipment: • four (4) 2000 Amp, 40 kA circuit breakers • eight (8) 230 kV switches • two steel transmission deadends • Associated steel • Electrical bus work • Associated metering, control, and relaying (See One-line in Appendix B)	**$2.168**
Boone Substation	Three new 230 kV 2000 Amp Line Terminals; two to Lamar and one to Midway. The following equipment will be required: • (5) 2000 Amp, 40 kA circuit breakers • (8) 230 kV switches • Misc. supporting steel • Electrical bus work • Associated metering control and relaying (See One-line in Appendix B)	**$ 2.674**
Midway Substation	One 230 kV line terminal for the new Boone Line; three 345/230 kV 560 MVA autotransformers, two 345 kV line terminations all of which includes the following: • six 2000 Amp, 40 kA, 230 kV circuit breakers • ten 230 kV switches • eight 3000 Amp, 50 kA, 345 kV circuit breakers • fourteen 345 kV switches • Misc. supporting steel • Electrical bus work • Associated metering, control, and relaying (See One-line in Appendix B)	**$17.605**
Daniels Park Substation	Three 345/230 kV 560 MVA autotransformers, two 345 kV line terminations all of which includes the following: • six 2000 Amp, 40 kA, 230 kV circuit breakers • ten 230 kV switches • eight 3000 Amp, 50 kA, 345 kV circuit breakers • fourteen 345 kV switches • Misc. supporting steel • Electrical bus work • Associated metering, control, and relaying (See One-line in Appendix B)	**$21.046**

Element	Description	Cost Est. ($Million)
Transmission	Construct a new double circuit 230 kV line, 345 kV capable from Lamar to Boone requiring new ROW	**$55.952**
	One new 230 kV line from Boone to Midway requiring new ROW.	**$23.049**
	TOTAL COST	**$122.495**
Time Frame		**54 Months**
	TOTAL INTERCONNECTION AND DELIVERY COST	**$123.902**

Assumptions:

Substations

- PSCo (or its contractor) crews will perform all construction and wiring associated with PSCo-owned and maintained equipment.
- Siting, permitting and land acquisition is included in the substation estimates
- Detailed field investigations have not been conducted and could increase these estimates.
- No screening has been estimated at any of the substations. If this is required the cost will be significant at each location.
- The estimated time for design and construction for the PSCo network upgrades is at least 54 months after authorization to proceed has been received, and based upon other identified assumptions for Siting and Land Rights, and Transmission (see below). If there are problems with local and state approvals, this could require an additional year.

Transmission Engineering and Line Construction:

- Any NEPA requirements imposed on transmission as a result of the generation addition will most likely have adverse effects on schedule and deliverables.
- Detailed field investigations have not been conducted and could increase these estimates.
- New transmission ROW is assumed to be adjacent to the existing transmission lines.
- All necessary transmission line outages can be obtained. If not, construction duration times will be longer.

Siting and Land Rights:

- New transmission ROW is adjacent existing transmission lines.
- Colorado State Land board issues will need to be addressed in future studies.

- Siting, Permitting, and Land Acquisition costs are covered in the Transmission and Substation Costs for each Item above.
- Permitting the new double circuit 345kV trans line from Midway to Daniels Park will be difficult and could require legal action.

The substation arrangements for these estimates are shown in the Figures 3-6.

Tables 6 through 8 describe costs associated with interconnection and delivery for GI-2004-4 taking into consideration that GI-2004-2 is also interconnected at Lamar. Tables 6 and 7 describe the costs associated with providing an interconnection and network upgrades to PSCo's system for interconnection. It does not include all of the costs required for full delivery of the generation.

Table 6 Customer Interconnection Facilities

Element	Description	Cost Est. ($Million)
Lamar 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.	**$335k**
	Transmission tie line into Lamar Substation.	**$40k**
	Siting and Land Rights for required easements, reports, permits and licenses.	**$50k**
	Total Cost	**$425k**

Table 7 PSCo Network Upgrades required for interconnection the proposed 280 MW Wind Generation Facility

Element	Description	Cost Est. ($Million)
Lamar	Convert the existing 4-breaker ring bus into a breaker and a half station and add a new 230 kV bay on the west side of the station. The equipment required includes: • Site development • 2 circuit breakers • 6 disconnect switches • 1 dead-end structures, associated bus and connectors • Bus voltage transformers and line synchronizing transformers (See One-line in Appendix B)	**$0.982**
	Total Cost	**$0.982**
Time Frame		**9 months**

Table 8 PSCo Network Upgrades Required for Power Delivery

Element	Description	Cost Est. ($Million)
Lamar	Add a 0 to 120 MVAR Static VAR Compensator (SVC) to include: • Site development • 0-120 MVAR SVC • 1 circuit breakers • 2 disconnect switches • Associated bus and connectors • High voltage metering and relaying	**$7.72**
Corner Point Substation	Construct a three-breaker ring substation that will sectionalize the Pawnee – Daniels Park 230kV line and interconnect the 230kV line to the Project. The equipment required includes: • Site development • Control building • 3 circuit breakers • 8 disconnect switches • 3 dead-end structures, associated bus and connectors • High voltage metering with associated revenue metering equipment • Bus voltage transformers and line synchronizing transformers • Siting and Land Rights for misc. permits	**$4.5**
Transmission	• Construct a **110** Mile double circuit 345 kV line operated at 230 kV from a location north of La Junta tapping one of the new 230 kV lines from Lamar to Boone and extending to a new Corner Point Substation. This will make a 230 kV line from Boone to Corner Point along with a Lamar to Corner Point 230 kV line. • Siting and Land Rights for misc. permits	**$124.7**
TOTAL		**$129.2**
	TOTAL PROJECT COST FOR INTERCONNECTION AND DELIVERY	**$138.3**
Time Frame		**54 Months**

Figure 3: LAMAR SUBSTATION

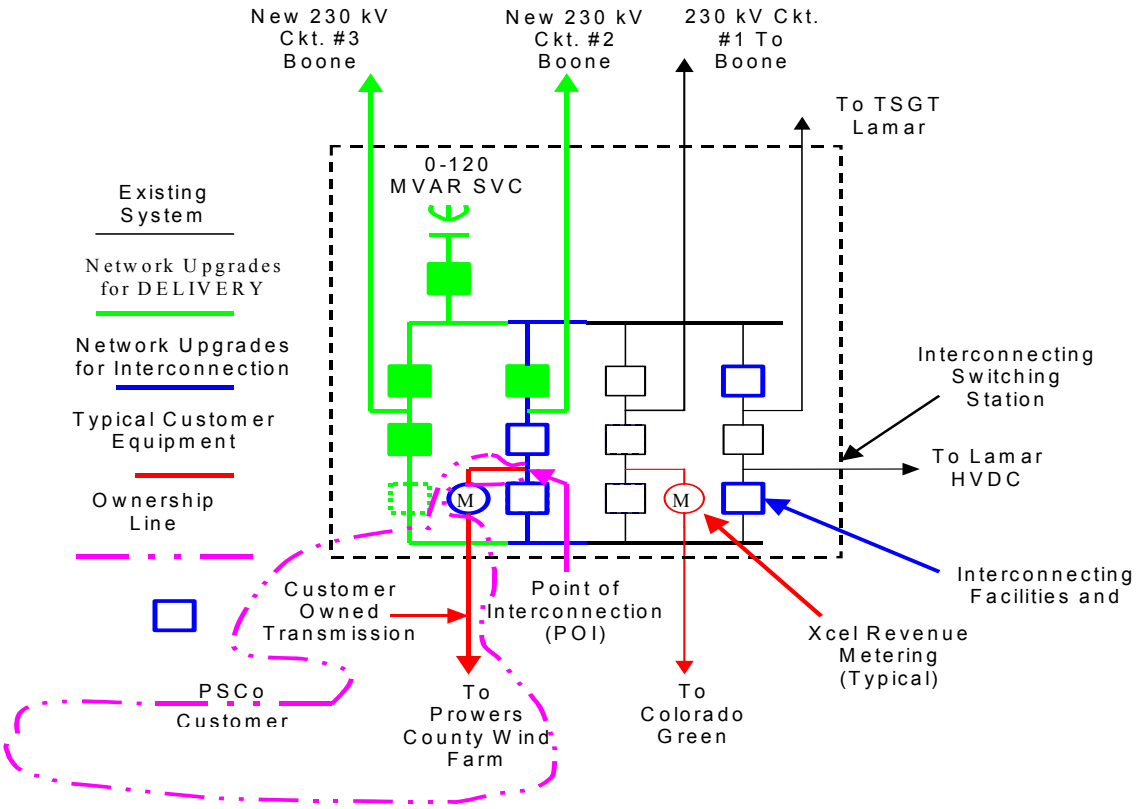

Figure 4 BOONE SUBSTATION

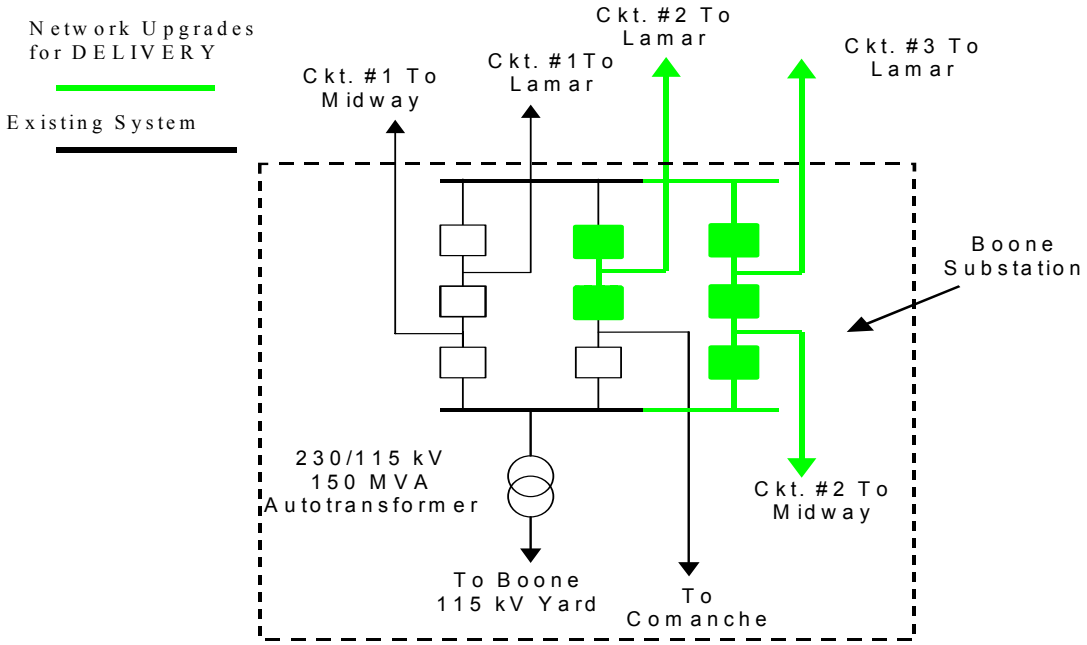

Figure 5: MIDWAY SUBSTATION

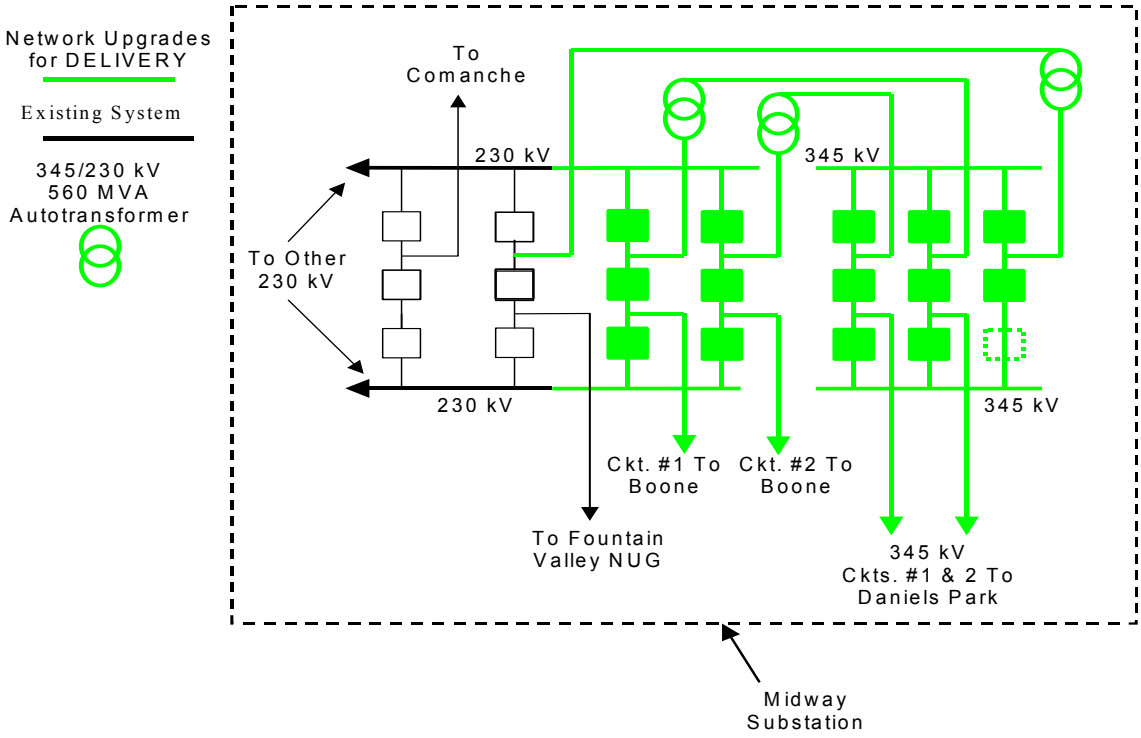

Figure 6: DANIELS PARK SUBSTATION