Interconnection Feasibility Study Report
Request # GI-2004-7

200 MW Wind Generation Facility in S.W. Elbert County, CO

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 200 MW of new Customer wind turbine generation into the PSCo transmission system at a new tap on the Daniels Park – Jackson Fuller 230 kV line, approximately eleven miles north of the Jackson Fuller Substation in S.W. Elbert County, CO (see Figure 1). The Customer proposed commercial operation date is December 1, 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 PSCo queue, as posted on the Rocky Mountain Area OASIS web site[1], but some sensitivity analysis was also performed to consider some higher queued projects.

Energy Resource:

The ER portion of this study determined that as a stand-alone project, the Customer could provide approximately 96 MW of power on a firm basis before Network Upgrades for delivery would be required. Sensitivity studies evaluated the system performance considering other higher queued interconnection requests. If those projects and their associated proposed system upgrades are considered to be in place, studies showed that this project could deliver the entire 200 MW of firm energy.

Network Resource:

As an NR request, PSCo evaluated the network upgrades required to deliver the full 200 MW of the wind turbine generation facility to PSCo customers. As a stand-alone project, the total estimated cost of the recommended upgrades required to accommodate the project is **$ 36.6 million** and includes:

- $ 0.335 million for PSCo-Owned, Customer Funded Interconnection Facilities
- $ 3.778 million for PSCo Network Upgrades for Interconnection
- $32.496 million for PSCo Network Upgrades for Delivery

The time required to engineer, permit, and construct the facilities required for interconnection is estimated to be at least **18** months. The estimated time required to

[1] www.rmao.com

engineer, permit, and construct the Network Upgrades required for delivery is at least **54** months. Based upon the results of this Study, the June 1 back-feed date is feasible. However, due to the estimated 54-month schedule, the Customer may not be able to deliver full 200 MW firm output by the requested December 1, 2006 Commercial Operation date.

It is assumed that the Customer will engineer, permit, construct, and pay for their 230kV transmission tap and associated 230 – 34.5kV facilities required to up to the point of interconnection, which was assumed to be at the new 230kV switching station.

The basic Network Upgrades required to accommodate firm 200 MW delivery as a stand-alone project are shown in Figure 1, and include:

- Replace the existing 44-mile PSCo Daniels Park – Jackson Fuller 230kV, 394 MVA (989A) single-circuit line, with new double-circuit 800 MVA lines. The lines would be constructed for 345kV capability, but operated at 230kV. The west circuit of this new double circuit line would be tapped with the new PSCo switching station for the Customer Generation tie. The east side circuit would pass by the new PSCo switching station, without tying into the new switching station's 230kV buses.
- Replace any 230kV line termination equipment, and associated protective relaying and communication equipment as necessary at the Daniels Park and Jackson Fuller substations.

An alternative to the recommended upgrade is discussed as Alternative 1 under the Power Flow Study Results.

A one-line diagram of the proposed new 230kV PSCo interconnection switching station is shown in Figure 2.

The impacts on the neighboring utilities were monitored, and addressed using PSCo estimating procedures and assumptions, but the neighboring utilities were not involved with the Feasibility Study at this time. Should the Customer continue this request and move on to subsequent studies, neighboring utilities, including Colorado Springs Utilities (CSU) will be contacted and offered the opportunity to participate.

Figure 1 Regional Transmission System

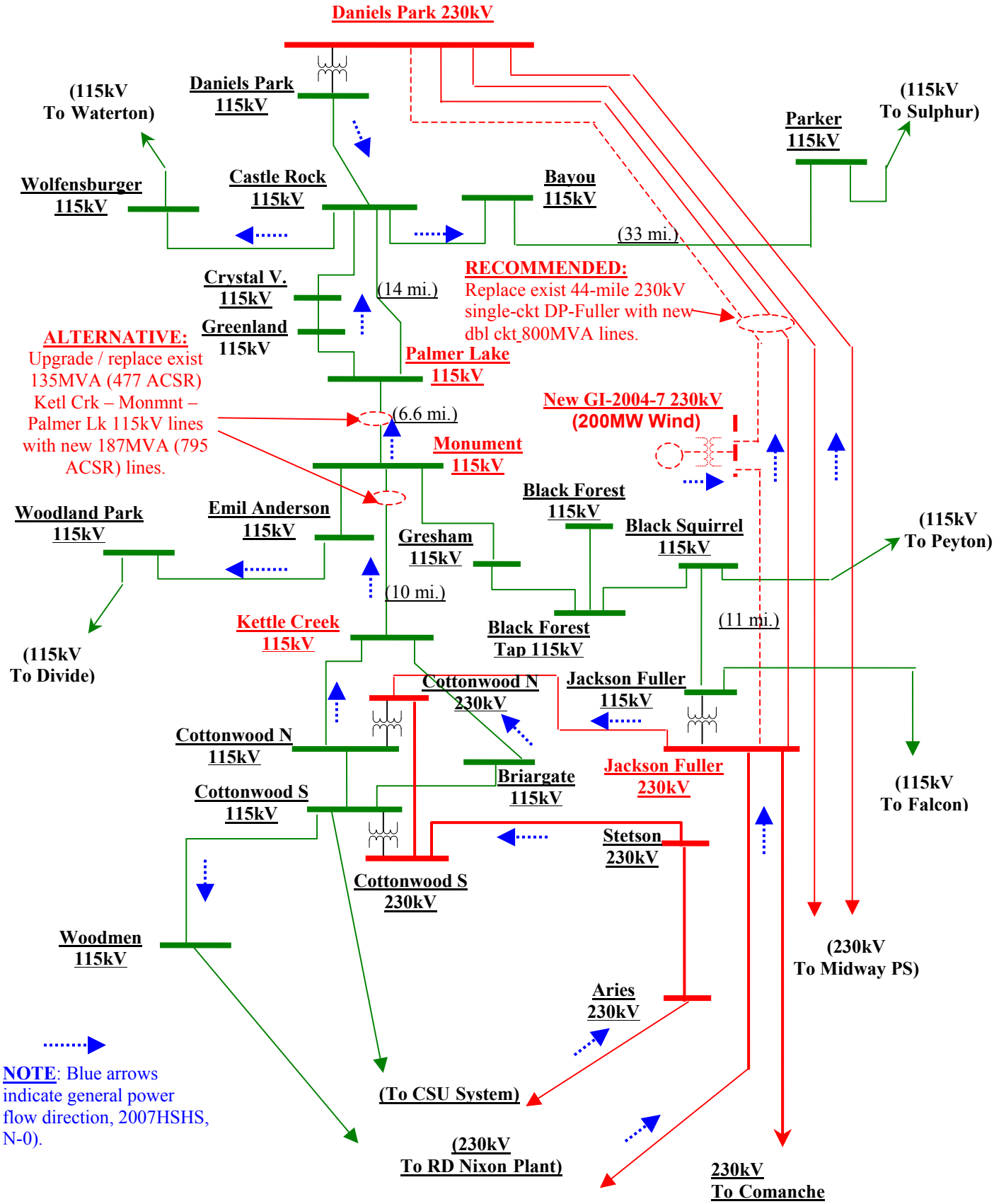
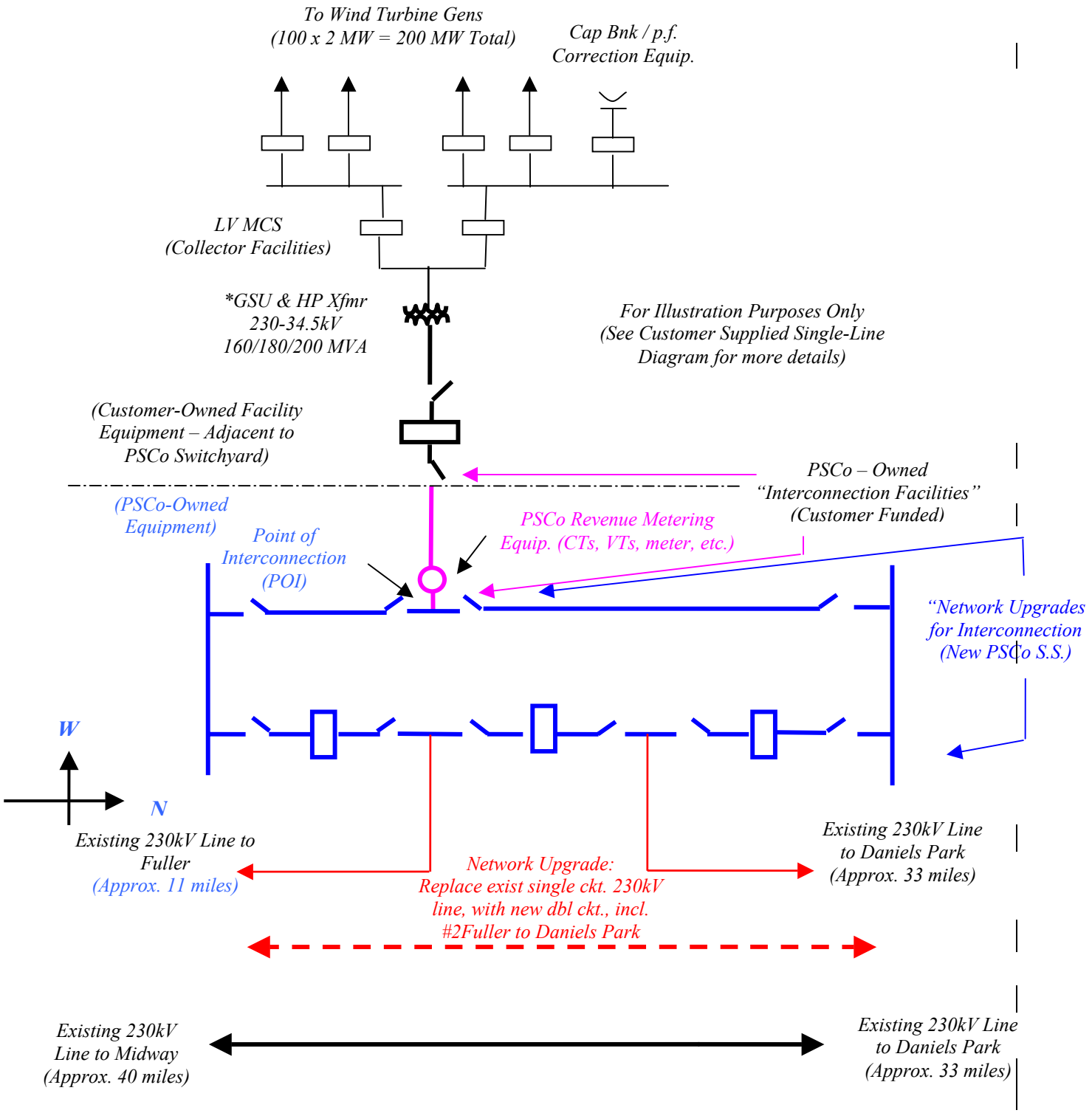


Figure 2. Interconnection One-Line Diagram



Introduction

PSCo Transmission received this large generator interconnection request (GI-2004-7) to interconnect one hundred 2.0 MW, doubly fed induction generator (DFIG) wind turbines, for a total of 200 MW of generation, with a commercial operation date of December 1, 2006 and an assumed back-feed date of June 1, 2006. The proposed wind farm would be located in S.W. Elbert County, Colorado. The point of interconnection (POI) would be at a new PSCo switching station, sectionalizing the existing PSCo Daniels Park – Jackson Fuller 230kV transmission line, and located approximately 11 miles north of Jackson Fuller Substation. The specific site for the new PSCo switching station has yet to be determined, but is assumed to be adjacent to the existing 230kV PSCo transmission line. The customer requested that this project be evaluated as an ER and as an NR with the energy going to PSCo customers. The Customer would engineer, permit, construct, pay, and fund their 230 – 34.5kV transformation and associated substation facilities and land, to be located adjacent to the new PSCo 230kV switching station to be constructed for this interconnection request.

Study Scope and Analysis

The Interconnection Feasibility Study evaluated the feasibility of the proposed interconnection to the PSCo Transmission System. The Study consisted of power flow and short-circuit analyses. The power flow analysis identified any thermal or voltage limit violations resulting from the interconnection and was also used to identify 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.

Power Flow Study Models

Due to the location of this Customer's interconnection into the southern part of the PSCo system (near Jackson Fuller), the power flow study simulated 2007 heavy summer peak loads, and modeled maximum south-to-north flows. Models were created from an existing Western Electricity Coordinating Council (WECC) 2007 heavy summer

base case. Transmission projects expected to be in-service for the 2007 summer season were represented in the models.

The interconnection was modeled as a new 3-breaker ring bus, located approximately 11 miles north of Jackson Fuller Substation. The proposed generation was modeled based upon Customer data supplied with this request. The 200 MW wind turbine generation facility was modeled as a single 200 MW equivalent conventional generator, with a 0.96 P.U. lagging power factor (Qmax = 58.3 MVAR, overexcited) and a 0.98 P.U. leading power factor (Qmin = -40.6 MVAR, under excited). This is on the assumption that Customer will be using 100 of the Gamesa G87-2.0 MW doubly fed machines, with the active and reactive power control option. In order to meet the expected PSCo requirement for +/- 0.95 power factor as measured at the 230kV POI, and account for the MVAR losses in the Customer's 230 – 34.5kV main step-up transformer, a 3-block, (3 x 10 MVAR) switched capacitor bank was included on the Customer's 34.5kV bus.

Power Flow Study Results and Conclusions

Energy Resource Study Results:

Studies indicated that the amount of generation that the new Customer wind turbine generation project can inject at the tap station for delivery to load, without requiring additional PSCo network (infrastructure) upgrades, is 96 MW.

Sensitivity Results for Higher Queued Projects

This Project was also evaluated taking into consideration all projects ahead in the PSCo LGIR queue. The associated network upgrades for each of the queued projects were also included in the studies. The details of the upgrades for those projects can be seen in their associated studies on the RMAO web page www.rmao.com. If all of the higher-queued projects are considered to be implemented, studies showed that the proposed project could generate the full 200 MW on a firm basis.

Network Resource Study Results:

Studies showed that if the stand-alone project generated over 96 MW, there would be two CSU 115kV transmission lines with the potential for contingency overloading. The Kettle Creek – Monument 115kV line exhibited loadings of approximately 10% over its continuous rating, and the Monument – Palmer Lake 115kV line exhibited loadings of approximately 16% over its rating. The study also revealed some contingency loadings of the Waterton Substation 230/115kV autotransformers, for the loss of the parallel auto. The transformer contingency loadings were on the order of 102% of their maximum continuous ratings, and are well below the acceptable 15% temporary overload capability typical for these transformers

Two alternatives were evaluated to resolve the contingency overloads. The recommended alternative would involve replacing the existing 44-mile PSCo Daniels Park – Jackson Fuller 230kV, 394 MVA (989A) single-circuit line, with new double-circuit 800 MVA (2,000A, bundled 954 ACSR) lines. The line would be constructed for 345kV capability, but operated at 230kV. The west circuit of this new double circuit line would be tapped with the new PSCo switching station for the Customer Generation tie. The east side circuit would pass by the new PSCo switching station. The power flow model was revised to include the new impedances and ratings for these two lines, and contingency analysis was done again. There were no remaining overloaded elements for this configuration. The total estimated cost for the recommended alternative is approximately $36.6 million. The costs are described in more detail in the Cost Estimates section.

Alternative

The alternative studied would involve rebuilding some of the existing 115kV lines that run parallel to the 230kV transmission path. The modifications include:

- Rebuild the existing 10.5-mile CSU Kettle Creek – Monument 115kV, 132 MVA (663A) line, to a new higher capacity, approximate 187 MVA (937A) 115kV line. This section of line would likely have to be constructed underground.
- Rebuild the existing 3.6-mile CSU + 3-mile PSCo (6.6 mile total) Monument – Palmer Lake 115kV, 135 MVA (677A) line, to a new higher capacity, approximate 187 MVA (937A) 115kV line. This line section is assumed to remain as overhead line construction.
- Replace any 115kV line termination and associated protective relaying and communication equipment as necessary at the Palmer Lake, Monument, and Kettle Creek substations.

The power flow model was revised to include the new impedances and ratings for these two lines, and contingency analysis was done again. There were no remaining overloaded elements for this configuration. The total estimated cost for this alternative is approximately $21.1 million, and the estimated time for completion at least 54 months.

According to the estimates, the recommended upgrades carry a higher initial cost than the alternative studied. However, the recommendation is based upon consideration of the total ultimate costs, in combination with the preference to develop upgrades to the PSCo system, rather than imposing impacts to neighboring utilities. Upgrading the Daniels Park – Jackson Fuller 230kV line to double-circuit is also consistent with PSCo's long-range transmission plans for system upgrades in this region of the system.

The recommended upgrades are shown in Figure 1. Power flow contingency results and tables are available upon request.

Short Circuit Study Results

The short circuit analysis was conducted for switchyards in the study area and consisted of 3-phase and single line-to-ground (SLG) faults at the 230kV buses at the Daniels Park, Jackson Fuller, and new PSCo Customer interconnection switching station. Due to the lack of Customer-supplied, or other available wind-turbine generator short circuit model data at this time, all fault values calculated for this Feasibility Study utilize a conventional short-circuit study program (CAPE), and assume that the generators contribute insignificant sustained fault current, as if they were conventional wound rotor type induction generators. More detailed short circuit models, and associated programs (e.g., PSCAD) may need to be utilized to calculate the Customer generation fault contributions. This may need to be addressed in later studies. PSCo may require that the Customer supply the wind TG fault current contribution data for these studies, and supplement this information to its CAPE study results. The following table shows the fault currents calculated at the 230kV POI located at the new PSCo switching station.

Table 1. Short-Circuit Data

Model	Wind Gen (MW)	Fault Location	Max Symmetrical Fault Current (A)	
			3-Phase	SLG (3I0)
2007 System Base Case ER (w/o DP-Fuller 230 Dbl Ckt)	0	PSCo Customer Tap SS 230kV Bus POI	8,991	6,677
2007 System Stand Alone Case NR (w/ DP-Fuller 230 Dbl Ckt)	0	PSCo Customer Tap SS 230kV Bus POI	11,535	10,383

Note: Due to the limited availability of detailed Customer Wind TG short-circuit model data, these studies assumed that the fault contribution from the Customer's wind TGs is insignificant (several hundreds of amps at 230kV), relative to the typically 40kA or higher interrupt ratings of nearby PSCo 230kV transmission station equipment (breakers). Later studies will require that the Customer supply additional short-circuit contribution information.

Costs Estimates (Details and Assumptions):

The estimated total cost for the PSCo Network Upgrades for 200 MW of delivery is **$36.6 million**

The estimated cost shown is an "indicative" (+/-30%) preliminary budgetary cost in 2004 dollars (no escalation applied), 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 three tables describe the network upgrades for interconnection that would be required for both ER and NR requests. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines.

Table 2. Interconnection Facilities (PSCo-Owned, Customer Funded)

Element	Description	Cost (Millions)
Design and construction PSCo interconnection facilities, "sole-use" dedicated for Customer interconnection at new PSCo 230kV Switching Station.	**Substations:** Design and construct 230kV bus-tap and revenue metering at this station to interconnect the Customer's 230-34.5kV transformer and associated equipment necessary to interconnect the Customer's 200 MW Wind turbine generation facility to the PSCo transmission system. This includes: • Tap line dead-end structures, associated bus and connectors; • 230kV CT / VT metering units with associated secondary revenue metering equipment;	$ 0.335
	Transmission Relocation (if needed)	$ 0
	Siting & Land Rights	$ 0
TOTAL	**Total Cost**	**$ 0.335**
	Time Frame	**18 months**

Table 3. PSCo Network Upgrades for Interconnection

Element	Description	Cost (Millions)
Design and construction of new PSCo 230kV Switching Station at POI.	Substations: Design and construct a new PSCo 230kV, 3-breaker ring bus switching station that will sectionalize the PSCo Daniels Park – Jackson Fuller 230kV line (# 5105), approx. 11 miles north of Jackson Fuller Sub in S.W. Elbert County, CO. This provides the station necessary to interconnect the Customer's 200 MW Wind turbine generation facility to the PSCo transmission system. The equipment required includes: • Site development and acquisition; • Control building; • Three 230kV circuit breakers, and associated gang disconnect switches; • Line dead-end structures, associated bus and connectors; • 230kV bus voltage transformers and line synchronizing transformers (CCVTs); • Protective relaying and associated pilot communication equipment for 230kV lines and buses.	$ 3.050
	Transmission Relocation (if needed)	$ 0.228
	Siting & Land Rights	$ 0.500
TOTAL	**Total Cost**	**$ 3.778**
	Time Frame	**18 months**

Table 4. PSCo Network Upgrades Required for Firm Delivery of 200 MW

Element	Description	Cost (Millions)
Alt. 2: Design and construction to replace existing Daniels Park – Jackson Fuller 230kV single ckt. Line, with new double-ckt. 230kV oper. (345kV capable) DP-Customer-Fuller, DP – Fuller lines.	**Substations**: Daniels Park Sub • Design review and upgrade or replacement as needed of existing #5105 (Fuller) 230kV line termination equipment at Daniels Park Sub for new 2,000A line rating; • Design and construction of new line termination at Daniels Park Sub for new DP-Fuller 2nd 230kV ckt.	$ 1.884
	Substations: Jackson Fuller Sub • Design review and upgrade or replacement as needed of existing #5105 (DP) line termination equipment at Jackson Fuller Sub for new 2,000A line rating; • Design and construction of new line termination at Jackson Fuller Sub for new DP-Fuller 2nd 230kV ckt.	$ 0.732
	Transmission: Remove and replace the existing 230kV, 44-mile, 506 MVA (1,270A verify) rated single circuit Daniels Park – Jackson Fuller (#5105) line, with new double circuit, 230kV operated / 345kV capable, 800 MVA (2,000A, bundled 954 ACSR) rated Daniels Park – new PSCo Customer Intercon. Switching Station – Jackson Fuller (west ckt), and Daniels Park – Jackson Fuller (east ckt) lines. To include: • Removal as required of existing 230kVine and structures; • Design and construction of new double ckt lines.	$ 28.876
	Siting & Land Rights: Acquisition of any line ROW needed to accommodate possible future 345kV operation of east ckt.	$ 1.004
TOTAL	**Total Cost**	**$ 32.496**
	Time Frame	**54 months**

Assumptions:

Substation Design / Construction:

- A new site can be located that will accommodate the new PSCo and Customer 230kV switching station / substation requirements for size and other factors, preferably adjacent to the existing 230kV PSCo line.
- The demarcation point between PSCo and the Customer will be between PSCo's 230kV metering units and the Customer's high-side 230kV fault interrupting device (Circuit Switcher, breaker, or equivalent).
- Minor line protective relaying changes are required at the remote breaker stations (Daniels Park, Jackson Fuller).
- Scoping cost estimates are supplied by PSCo for this Study based upon PSCo (or its contractor) crews performing all construction and wiring associated with PSCo and/or Western-owned and maintained equipment. It is assumed that these are within +/- 30% accuracy.
- The estimated time for design and construction for the new PSCo 230kV switching station, and associated PSCo Network Upgrades at this Switching Station is 18 months after authorization to proceed has been received, and

based upon other identified assumptions for Siting and Land Rights, and Transmission.
- A CPCN filing with the Colorado PUC is not required for the construction of this new PSCo Switching Station.

Transmission Engineering and Line Construction:

- Transmission modifications will be required to tie into the existing 230kV Daniels Park – Jackson Fuller line, and terminate into the new switching station. Assume that the distance from the existing 230kV line to the new switching station is minimal.
- The estimated time for design and construction for the new PSCo Daniels Park – Jackson Fuller 230kV double circuit transmission line upgrades (Alt. 2) is 54 months after authorization to proceed has been received, and based upon other identified assumptions for Siting and Land Rights, and Transmission.

Siting and Land Rights:

- The new PSCo Daniels Park – Jackson Fuller 230kV double circuit transmission line upgrades (Alt. 2) will likely be difficult to permit, estimated at 12 months.
- Based upon the details provided in discussions with the Customer as part of this request, it is assumed that the site for the new Customer tap switching station would be located somewhere along the route of the 8-mile section of the existing Daniels Park – Jackson Fuller 230kV line, within S.W. Elbert County. PSCo would work with the Customer to locate and obtain the land and permits associated with obtaining a sub site large enough to accommodate the new PSCo and Customer substation equipment at this tap location.