Interconnection Feasibility Study Report
Request # GI-2004-5

Generation Interconnection Request for a 402 MW Wind Farm Near Grover, Colorado

Xcel Energy Transmission Planning
November 2004

Executive Summary

PSCo Transmission received a generation request to determine the feasibility of interconnecting 402 MW of new Customer wind turbine generation into the PSCo transmission system at a new tap on the Fort Saint Vrain (St. Vrain) to Green Valley 230 kV line 3 miles west of Weld County Road 49 and 2 miles North of Weld County Road 20. After analysis of the original point of interconnection (POI), PSCo studied a new interconnection point, 4 miles south of the original point of interconnection, on the Rocky Mountain Energy Center (RMEC) to Green Valley double circuit 230kV lines. The Customer proposed commercial operation date is December 1, 2006 with a back feed date of June 1, 2006.

This request was studied as both an Energy Resource (ER) and as a Network Resource (NR). The ER portion of this study determined that as a stand-alone project, the Customer could not provide any energy without the construction of network reinforcements. This determination is based on existing reservations across the TOT 7 transfer path.

As a Network Resource request, PSCo evaluated the system requirements to deliver the full 402 MW of the wind facility to PSCo native load customers. Power flow studies show that injection of 402 MW into the PSCo system will create a number of overloads on the PSCo transmission system. To alleviate those overloads, the following facilities are recommended for interconnection and delivery:

- Interconnect the proposed project to a new switching station that would tie into both RMEC – Green Valley 230kV lines.
- From the new station to Green Valley, convert the existing 230kV double circuit lines from 230kV to 345kV operation.
- Upgrade the Green Valley – Spruce single-circuit 230kV line to double-circuit 345kV operation. This can be accomplished using existing right-of-way and structures. The new double circuit 345kV lines will not tie into the Spruce substation.

- From Spruce to Daniels Park, construct new double-circuit 345kV transmission, adjacent to the existing Spruce – Smoky Hill – Daniels Park double-circuit 230kV transmission.
- Construct a 10-mile Fordham to Niwot 230kV line

The total estimated cost for the project is approximately **$89.3** million and consists of the following:

- **$0.3** million for Customer Interconnection Facilities.
- **$7.3** million for PSCo Network Upgrades for Interconnection.
- **$81.7** 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 **23** months. The estimated time required to engineer, permit, and construct the Network Upgrades required for delivery is at least **56** months based upon other identified assumptions for Siting and Land Rights, Substation Engineering and Transmission Engineering. According to the interconnection request, the Customer will engineer, permit, construct and finance the 55-mile 230kV transmission line to the proposed Customer tap switching station.

A simple diagram of the regional transmission system with recommended Network Upgrades is shown in Figure 1. A basic diagram of the interconnection is shown in Figure 2.

Figure 1 Regional Transmission Network with Recommended Upgrades

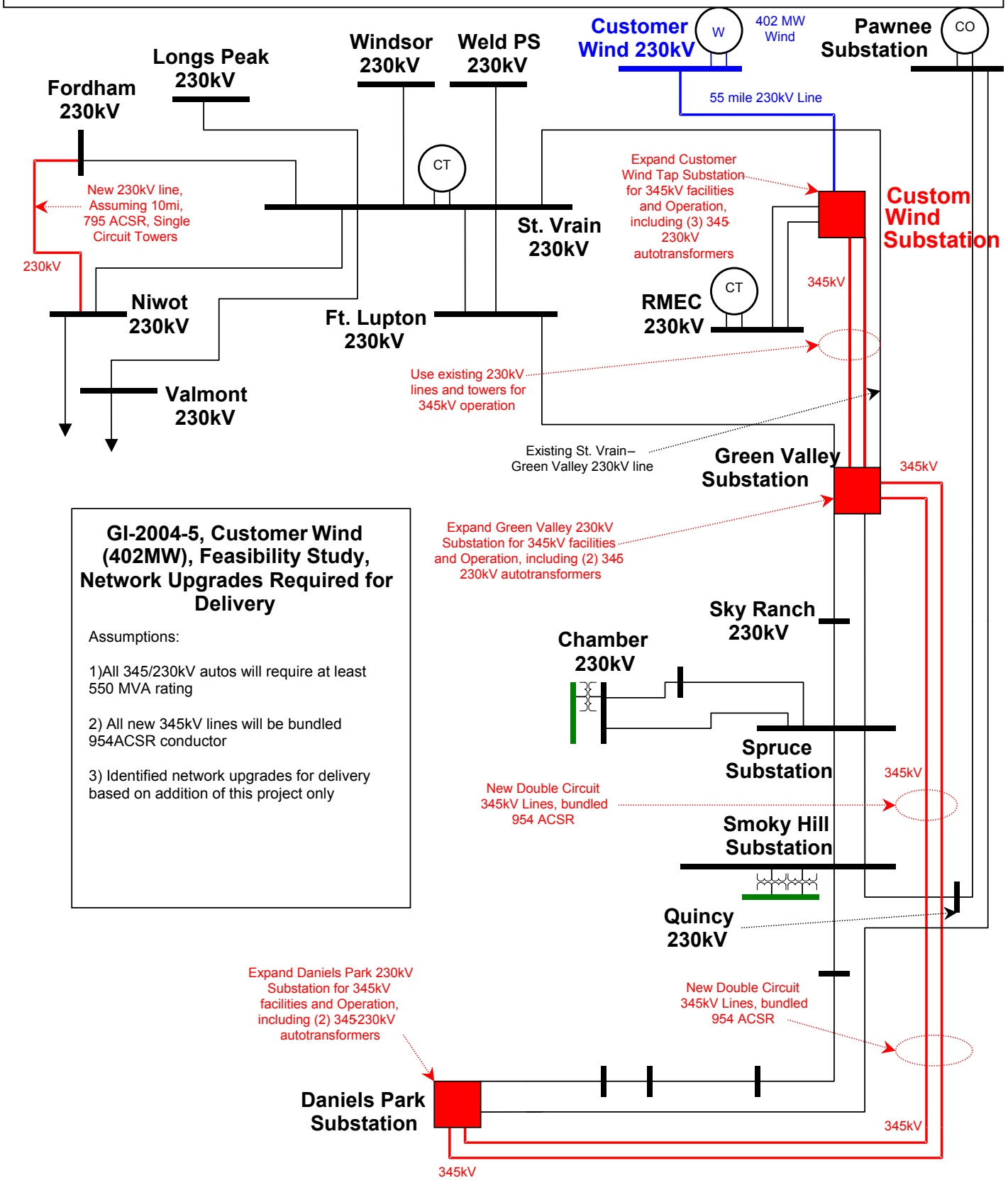
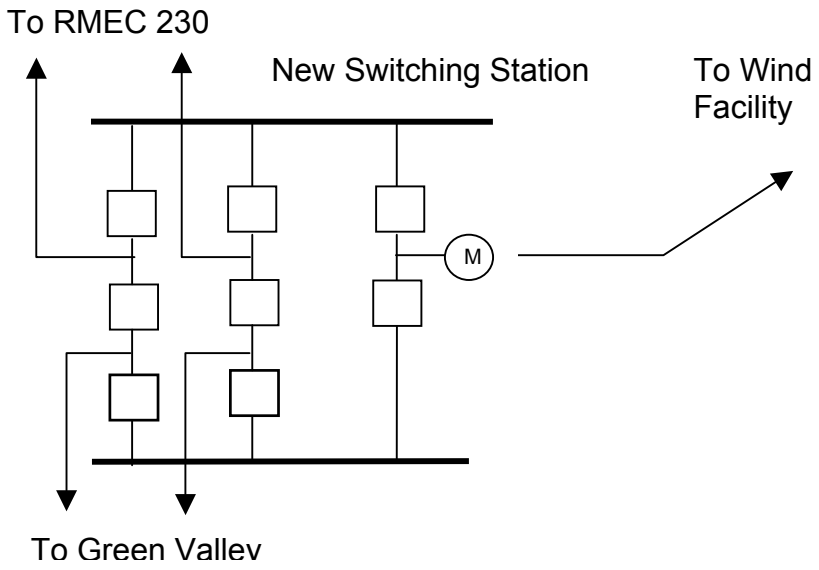


Figure 2 PSCo Proposed Interconnection: New 230kV Switching Station between RMEC and Green Valley



Introduction

PSCo Transmission received a large generator interconnection request (GI-2004-5) to interconnect two hundred sixty-eight (268) 1.5 MW, GE doubly fed induction generator (DFIG) wind turbines for a total 402 MW generation, with a commercial operation date of December 1, 2006 and a back feed date of June 1, 2006. The location of the proposed wind farm is located near Grover, Colorado and was originally proposed to interconnect via a 55-mile 230 kV line at a location on the St. Vrain to Green Valley 230 kV line 3 miles west of Weld County Road 49 and 2 miles North of Weld County Road 20.

During the preliminary analysis of the interconnection request, it was determined that upgrades to accommodate the proposed POI would be extensive and costly. Therefore, studies sought to determine a more feasible point of interconnection. The POI evaluated for this study was located at a point four miles south of the original POI on the RMEC to Green Valley double circuit 230kV line. This will be described in more detail in the Power Flow and Study Results section.

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 also identified 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 TOT 7 and TOT3 and the neighboring utilities were monitored, but not addressed in the scope of this study. Should the Customer continue this request and move on to the System Impact Study, all impacts on the PSCo system and neighboring utilities will be identified. Affected parties may include Western Area Power Administration (WAPA) and Platte River Power Authority (PRPA).

Power Flow Study Models:

The power flow study models were created from an existing Western Electricity Coordinating Council (WECC) 2007 heavy summer base case. The studies were performed using GE's PSLF software to do power transfer limit and contingency analysis. The 402 MW wind farm was modeled as two (2) 201 MW conventional generators with a 0.95 pu lagging power factor (overexcited) and a 0.90 pu leading power factor (underexcited) capability to simulate the VAR requirements of the generators. This is on the assumption that Customer will be using the GE 1.5 MW DFIG turbines. Customer generation was scheduled to the southern PSCo system by southern generation reduction.

The Point of Interconnection (POI) between the Customer and PSCo is assumed to be the point at which the 55-mile 230 kV transmission line meets the new Customer tap station on the RMEC to Green Valley 230kV double circuit line.
The 55-mile line was modeled per Customer provided information:

- A single-circuit 55-mile, 230 kV line using conventional 230 kV "H-frame" wood pole construction and a single 954 ACSR conductor per phase with a 540 MVA rating.
- Two (2) 230-34.5 kV, 200/266 MVA Customer GSU transformers, located at the Customer collector site

This study assumed 2007 peak summer demand conditions for the PSCo system and neighboring utilities in Colorado. To evaluate the capabilities and system requirements for firm transfer levels, the power flow models were modified to simulate high TOT 7 path flows. The TOT 7 path flows were modeled with a North to South flow of 845 MW (TOT 7 Limit = 890MW). Transmission projects expected to be in-service for the 2007 summer season were represented in the models.

Power Flow Study Results and Conclusions

Preliminary evaluation of the customer requested POI indicated that numerous and extensive transmission upgrades would be required throughout the PSCo transmission system. The necessary upgrades would experience difficulties with routing, take more time, and cost significantly more than other alternatives. Therefore, remaining studies evaluated a POI that was four miles south of the original interconnection and connected to the RMEC to Green Valley double circuit 230kV transmission.

Energy Resource (ER) Study Results:

The results of the ER study indicate that for the conditions studied, and with only the Customer Wind Facilities considered, the maximum amount of generation capability that can be accommodated with the existing system and existing firm path reservations is **40 MW**. For the same conditions, ER studies indicated that for the originally proposed POI there would be no capability.

There may be non-firm transmission capability depending on marketing activities, dispatch patterns, customer demand levels and the status of transmission facilities. This study did not attempt to determine the ER or NR for any other set of conditions.

Network Resource (NR) Study Results:

The NR study determined the network upgrades that would be required to accept the full 402MW from the proposed wind farm and interconnecting on the RMEC to Green Valley 230kV double circuit line. Modeling the customer wind generation at 402MW created several contingency overloads on the PSCo system. Table 1 shows contingency results with the full 402MW injected at the new point of interconnection.

Table 1

Critical Contingency	Limiting Element	Rating (MVA)	Pre-Load %	Cont-Load %
SmokyHill-Spruce 230 Ckt1	SmokyHill-Spruce 230 Ckt2	637	72	121
SmokyHill-Spruce 230 Ckt2	SmokyHill-Spruce 230 Ckt1	637	72	121
GrnValley-CustWindTap 230 Ckt1	GreenVall-CustWindTap 230 Ckt2	834	58	117
GrnValley-CustWindTap 230 Ckt2	GreenVall-CustWindTap 230 Ckt2	834	58	117
Buckley1-SmokyHill 230 Ckt1	MeadowHill-Orchard 230 Ckt1	428	76	105
Ft.Lupton-HenryLake 230 Ckt1	Ft.Lupton-JLGreen 230 Ckt1	495	85	105
Ft.Lupton-JLGreen 230 Ckt 1	Reunion-BarrLake 230 Ckt 1	434	84	103
Ft.Lupton-HenryLake 230 Ckt1	JLGreen-Washington 230 Ckt1	495	84	103
Ft.Lupton-JLGreen 230 Ckt1	Cherokee-Reunion 230 Ckt1	434	85	101

The preferred upgrades to accommodate the 402 MW of wind generation were determined after studying several transmission alternatives utilizing peak demand conditions, high TOT 7 path flows, and expected generation and area interchange schedules for the 2007 summer peak season. The following is a general description of the recommended network upgrades required to alleviate the overloads and accommodate the generation for delivery:

- Convert the existing RMEC to Green Valley 230kV double circuit lines from 230kV to 345kV operation. This will begin from the new Customer point of interconnection to the Green Valley switchyard.

- Using existing right-of-way and structures, construct a second 345kV line on the spare arms of the Green Valley to Spruce towers and operate both Green Valley to Spruce circuits at 345kV.
- At a point outside the Spruce 230kV switchyard, the new double circuit 345kV lines will not tie into the Spruce substation, but will continue South towards Smoky Hill and eventually connecting to the Daniels Park substation.
- Construct a 10-mile Fordham to Niwot 230kV line.

The required Network Upgrades for delivery assumes that a St. Vrain to Fordham 230kV line will be constructed by PRPA prior to summer of 2007. Since the proposed Network Upgrades for delivery either directly affect or depend on the construction of facilities by PRPA, coordination will be required with PRPA in subsequent studies.

Short Circuit Study Results

The short circuit analysis was conducted at the affected switchyards in the study area including faulting the 230kV busses at the St. Vrain, Customer Wind Tap, and other busses with three-phase and phase-to-ground faults. Due to the lack of Customer-supplied, or other available wind-turbine generator short circuit model data, all fault values calculated for this Feasibility Study assume no fault current contribution from the Customer wind-turbine generators. More detailed short circuit models, and associated possible Customer generation fault contribution may need to be addressed in later studies.

For all of the fault cases studied, the wind turbines were modeled as conventional synchronous generators. A more accurate short circuit model is not currently available for such short circuit programs as Aspen or CAPE. This study was performed on CAPE. Table 2 shows how the fault currents change with the addition of the Customer Wind project.

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Table 2

Case[1]	Wind Gen[2] (MW)	Fault Location[3]	Fault Type[4]	Fault Current[5] (A)
Existing	0	230kV Green Valley	3 phase	27,653
Existing	0	230kV Green Valley	SLG	19,168
Existing	0	230kV Daniels Park	3 phase	25,336
Existing	0	230kV Daniels Park	SLG	20,374
Existing	0	230kV Spruce	3 phase	26,198
Existing	0	230kV Spruce	SLG	23,931
Existing	0	230kV St. Vrain	3 phase	32,775
Existing	0	230kV St. Vrain	SLG	34,023
Existing	0	230kV Niwot	3 phase	9221
Existing	0	230kV Niwot	SLG	6891
Existing	0	230kV Smoky Hill	3 phase	27,316
Existing	0	230kV Smoky Hill	SLG	24,333
Existing	0	230kV Pawnee	3 phase	19,298
Existing	0	230kV Pawnee	SLG	22,213
Interconnect	0	230kV Customer Wind Tap	3 phase	19,003
Interconnect	0	230kV Customer Wind Tap	SLG	17,496
Interconnect	0	230kV Green Valley	3 phase	28,324
Interconnect	0	230kV Green Valley	SLG	19,467
Delivery	0	230kV Customer Wind Tap	3 phase	15,841
Delivery	0	230kV Customer Wind Tap	SLG	19,308
Delivery	0	230kV Green Valley	3 phase	27,701
Delivery	0	230kV Green Valley	SLG	27,752
Delivery	0	230kV Daniels Park	3 phase	28,563
Delivery	0	230kV Daniels Park	SLG	29,063
Delivery	0	230kV Spruce	3 phase	24,443
Delivery	0	230kV Spruce	SLG	23,081
Delivery	0	230kV St. Vrain	3 phase	37,253
Delivery	0	230kV St. Vrain	SLG	37,766
Delivery	0	230kV Niwot	3 phase	12,432
Delivery	0	230kV Niwot	SLG	9337
Delivery	0	230kV Smoky Hill	3 phase	27,035
Delivery	0	230kV Smoky Hill	SLG	24,568
Delivery	0	230kV Pawnee	3 phase	25,809
Delivery	0	230kV Pawnee	SLG	27,262
Delivery	0	345kV Customer Wind Tap	3 phase	11,225
Delivery	0	345kV Customer Wind Tap	SLG	12,068

[1] Existing case is for current Xcel Energy system configuration. Interconnect case is for connecting customer only, without infrastructure upgrades. Delivery case is for customer interconnected and infrastructure upgrades in service.
[2] Initial cases were studied with the wind generators offline. Wind generation only introduced after infrastructure upgrades in service.
[3] Customer Wind Tap is the location where the wind generation from the customer ties into the Xcel Energy system (see Figure 1). In addition the Customer Wind tap sectionalizes two 230kV transmission lines between the Calpine Rocky Mountain Energy Center generation plant and Xcel Energy's Green Valley substation.
[4] SLG stands for single line to ground fault.
[5] Fault current for 3 phase faults is represented as positive sequence current. Fault current for single line to ground faults is represented as 3Io (where Io is zero sequence current). These fault studies were performed assuming all customers higher in the queue have been placed in-service.

Case[1]	Wind Gen[2] (MW)	Fault Location[3]	Fault Type[4]	Fault Current[5] (A)
Delivery	0	345kV Green Valley	3 phase	15,439
Delivery	0	345kV Green Valley	SLG	14,224
Delivery	0	345kV Daniels Park	3 phase	13,781
Delivery	0	345kV Daniels Park	SLG	12,879
Delivery	402	230kV Cedar Wind	3 phase	9973
Delivery	402	230kV Cedar Wind	SLG	6970
Delivery	402	230kV Customer Wind Tap	3 phase	18,032
Delivery	402	230kV Customer Wind Tap	SLG	20,860
Delivery	402	230kV Green Valley	3 phase	28,419
Delivery	402	230kV Green Valley	SLG	28,111
Delivery	402	230kV Daniels Park	3 phase	28,855
Delivery	402	230kV Daniels Park	SLG	29,216
Delivery	402	230kV Spruce	3 phase	24,700
Delivery	402	230kV Spruce	SLG	23,196
Delivery	402	230kV St. Vrain	3 phase	37,403
Delivery	402	230kV St. Vrain	SLG	37,845
Delivery	402	230kV Niwot	3 phase	12,451
Delivery	402	230kV Niwot	SLG	9342
Delivery	402	230kV Smoky Hill	3 phase	27,442
Delivery	402	230kV Smoky Hill	SLG	24,758
Delivery	402	230kV Pawnee	3 phase	25,839
Delivery	402	230kV Pawnee	SLG	27,280
Delivery	402	345kV Customer Wind Tap	3 phase	12,375
Delivery	402	345kV Customer Wind Tap	SLG	12,706
Delivery	402	345kV Green Valley	3 phase	16,170
Delivery	402	345kV Green Valley	SLG	14,528
Delivery	402	345kV Daniels Park	3 phase	13,958
Delivery	402	345kV Daniels Park	SLG	12,956

The above table shows how the fault currents change with the addition of the Customer Wind project. Of particular interest is the noticeable increase in fault current with the infrastructure upgrades in service and the wind generation offline (producing 0 MW) at St. Vrain, Pawnee, Niwot, and Daniels Park. Also the removal of the Green Valley line at Spruce appears to lower the available fault current at the 230 kV bus.

Costs Estimates and Assumptions:

The estimated total cost for the required upgrades is **$89,295,000.**

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. This estimate also does not include any costs that may be required for other entities' systems.

The following 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 3 Customer Interconnection Facilities

Substation	Description	Cost
New Customer Wind Farm Tap Switchyard	Interconnect Customer's 230kV line to a new 230kV switchyard. The new equipment required includes: • 230kV bi-directional revenue metering • required steel supporting structures • associated metering, control and relaying	$335k
	Total Estimated Cost for Interconnection Facilities	**$335k**

Table 4 PSCo Network Upgrades for Interconnection

Substation	Description	Cost
New Customer Wind Farm Tap 230kV Switchyard	Install a new Breaker-and-Half 230kV switchyard, which will sectionalize PSCo's two 230kV RMEC-Green Valley Transmission Lines. The following equipment will be required: • site development • control building • eight (8) 230kV 3000 amp 50kA circuit breakers • sixteen (16) 230kV switches • CCVT's • misc. supporting steel • electrical bus work • associated metering, control and relaying	$6,634k
	Transmission line tap structures & tap	$409k
	Siting and Land Rights acquisition & permitting	$243k
	Total Estimated Cost for Network Upgrades for Interconnection	**$7,286k**
Time Frame		**23 Months**

Table 5 PSCo Network Upgrades Required for Delivery of 402MW

Substation	Description	Cost
New Customer Wind Farm Tap 345kV Switchyard	Install a new Breaker-and-Half 345kV switchyard, which will interconnect with the New Customer Wind Farm Tap 230kV Switchyard via 345/230kV autotransformers. The following equipment will be required: • site development • (3) 345/230kV 560MVA autotransformers • (8) 345kV 3000 amp 40kA circuit breakers • (16) 345kV switches • (1) 230kV 3000 amp 50kA circuit breaker • (2) 230kV switches • CCVT's • misc. supporting steel • electrical bus work • associated control and relaying	$18,715k
PRPA's Fordham Substation (future)	New 230kV line termination for new trans line to the Niwot Substation. The following equipment will be required: • (1) 230kV 3000 amp 50 kA circuit breaker • (2) 230kV switches • misc. supporting steel • electrical bus work • associated metering, control and relaying	$658k
Niwot Substation	New 230kV line termination for new trans line from PRPA's Fordham Substation. The following equipment will be required: • one (1) 230kV 3000 amp 50 kA circuit breaker • two (2) 230kV switches • misc. supporting steel • electrical bus work • associated control and relaying	$658k
Green Valley 345kV Switchyard	Install a new Breaker-and-Half 345kV switchyard, which will interconnect with the existing Green Valley 230kV Switchyard via 345/230kV autotransformers. The following equipment will be required: • site development • two (2) 345/230kV 560MVA autotransformers • nine (9) 345kV 3000 amp 40kA circuit breakers • eighteen (18) 345kV switches • CCVT's • misc. supporting steel • electrical bus work • associated control and relaying	$15,760k
Spruce 230kV Switchyard	• Remove one existing 230kV line termination for transmission line from Green Valley.	$51k
Daniels Park	Install a new Breaker-and-Half 345kV switchyard, which will	$18,489k

Substation	Description	Cost
345kV Switchyard	interconnect with the existing Daniels Park 230kV Switchyard via 345/230kV autotransformers. The following equipment will be required: • site development • (2) 345/230kV 560MVA autotransformers • (4) 345kV 3000 amp 40kA circuit breakers • (10) 345kV switches • one new bay in 230kV switchyard with two (2) 230kV 3000 amp 50kA circuit breakers and four (4) 230kV switches • upgrade one existing bay in 230kV switchyard with two (2) 230kV 3000 amp 50kA circuit breakers and five (5) 230kV switches • CCVT's • misc. supporting steel • electrical bus work • associated control and relaying	
Transmission		
New Trans Line from PRPA's Fordham Substation to the Niwot Substation	Install new single circuit 230kV transmission line from PRPA's Fordham Substation to the Niwot Substation (approx. 10 miles). 795 kcmil "Drake" conductor with OPGW on tubular steel poles with foundations.	$2,650k
Green Valley to Spruce 345kV Circuit	String one new 345kV circuit from Green Valley to Spruce. New conductor to be strung on existing double circuit structures.	$2,364k
Spruce to Daniels Park New D/C 345kV Trans Line	Install new double circuit 345kV transmission line from the Spruce Switchyard to the Daniels Park Switchyard (approx. 30 miles). 954 kcmil "Cardinal" conductor on tubular steel poles with foundations.	$18,845k
Siting, Permitting and Acquisition	Siting and Land Rights activities including siting study, necessary acquisition & permitting.	$3,484k
	Total Estimated Cost for PSCo Network Upgrades for Delivery	**$81,674k**
	Total Estimated Cost for all PSCo Network Upgrades	**$88,960k**
	TOTAL ESTIMATED COST OF PROJECT	**$89,295k**

Study Assumptions:

- The estimated costs provided are "Scoping Estimates" with an accuracy of ± 30%.
- Estimates are based on 2006 dollars.
- PSCo (or its contractor) crews will perform all construction and wiring associated with PSCo-owned and maintained equipment.
- It is anticipated that to construct the Network Upgrades required for the interconnection (switchyard only) a Certificate of Public Convenience and Necessity (CPCN) will not be required from Colorado Public Utility Commission (CPUC). The estimated time for siting, permitting, acquisition, design and construction for the PSCo network upgrades required for the interconnection (230kV switchyard only) is at least 23 months after the Interconnection Agreement has been signed.
- It is anticipated that a Certificate of Public Convenience and Necessity (CPCN) will be required from Colorado Public Utility Commission (CPUC) for the network upgrades required for delivery. The application for a CPCN will not be submitted until after the Customer has executed an Interconnection Agreement.
- A siting study and public involvement will be required for the network upgrades required for delivery. Land use permits will be required from multiple local jurisdictions. Permitting is expected to be difficult and potentially controversial. Local permit denial has been assumed for the portion of new double circuit 345kV transmission line from Spruce to Daniels Park. This will require an appeal of the denial decision to the PUC. No further litigation has been assumed.
- The estimated time for siting, permitting, acquisition, design and construction for the PSCo network upgrades required for delivery is at least 56 months after the Interconnection Agreement has been signed, and based upon other identified assumptions for Siting and Land Rights, Substation Engineering and Transmission Engineering (see below).
- New switchyard for the wind farm interconnection will be located adjacent to or under the existing 230kV RMEC to Green Valley transmission lines.
- PRPA's Fordham Substation is a proposed new substation, and it is assumed that this new facility will be in service prior to PSCo's new network upgrades required for delivery. There will be adequate space available at PRPA's Fordham Substation for the new 230kV line termination, and PRPA will agree to allow this new installation.
- Fault duty ratings at PRPA's Fordham Substation and the Niwot Substation are adequate.
- The last span into the new 230kV wind farm switchyard from the Customer owned 230kV 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 structure.
- Acquire a 35-40 acre site in fee for the ultimate general arrangement anticipated for the new Customer Wind Switchyard.