Interconnection Feasibility Study Report
Request # GI-2004-3

275 MW Wind Facility

Xcel Energy Transmission Planning
November 2004

Executive Summary

PSCo Transmission received a generation interconnection request to determine the feasibility of interconnecting 275 MW of new Customer wind turbine generation into the PSCo transmission system at a new tap on the Ault-Windsor 230 kV line approximately one mile south of the Ault Substation. 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 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 network reinforcements for delivery being constructed. Due to existing reservations and limitations across the TOT 7 transfer path no additional firm power injections can be made at the Project location.

As a Network Resource request, PSCo evaluated the Network Upgrades required to deliver the full 275 MW to PSCo native load customers. Powerflow studies show that the 275-MW injection into the PSCo system would create a number of overloads on the PSCo and neighboring systems. The recommended Network Upgrades to alleviate the overloads include the following:

- Construct a new single-circuit 55-mile 230 kV transmission line from Ault Substation to the Ft. St. Vrain Substation.
- Construct a new 10-mile Fordham-Niwot 230 kV line.

The total estimated cost for the project is approximately $32.4 million and includes the following:

- $0.335 million for Customer Interconnection facilities;
- $3.325 million for PSCo Network Upgrades for interconnection;
- $28.706 million for PSCo Network Upgrades to deliver generation to native load.

The time required to engineer, permit, and construct the facilities required for interconnection is estimated to be at least 20 months. The estimated time required to engineer, permit, and construct the Network Upgrade facilities for delivery is at least 42 months. According to the interconnection request, the Customer will engineer, permit, construct, and finance the 30-mile 230 kV transmission line to the proposed tap station.

The regional transmission system is shown in Figure No. 1 along with the recommended upgrades.

Introduction

PSCo Transmission received this large generator interconnection request (GI-2004-3) to interconnect one hundred eighty-three (183) 1.5 MW, GE doubly fed induction generator (DFIG) wind turbines, for a total of 275 MW generation, with a commercial operation date of December 1, 2006 and a back feed date of June 1, 2006. The proposed interconnection is at a new tap station on the Ault-Windsor 230 kV line approximately one mile south of the Ault Substation near Ault, Colorado. The proposed generation would connect to the PSCo transmission system via a 30-mile radial 230 kV line.

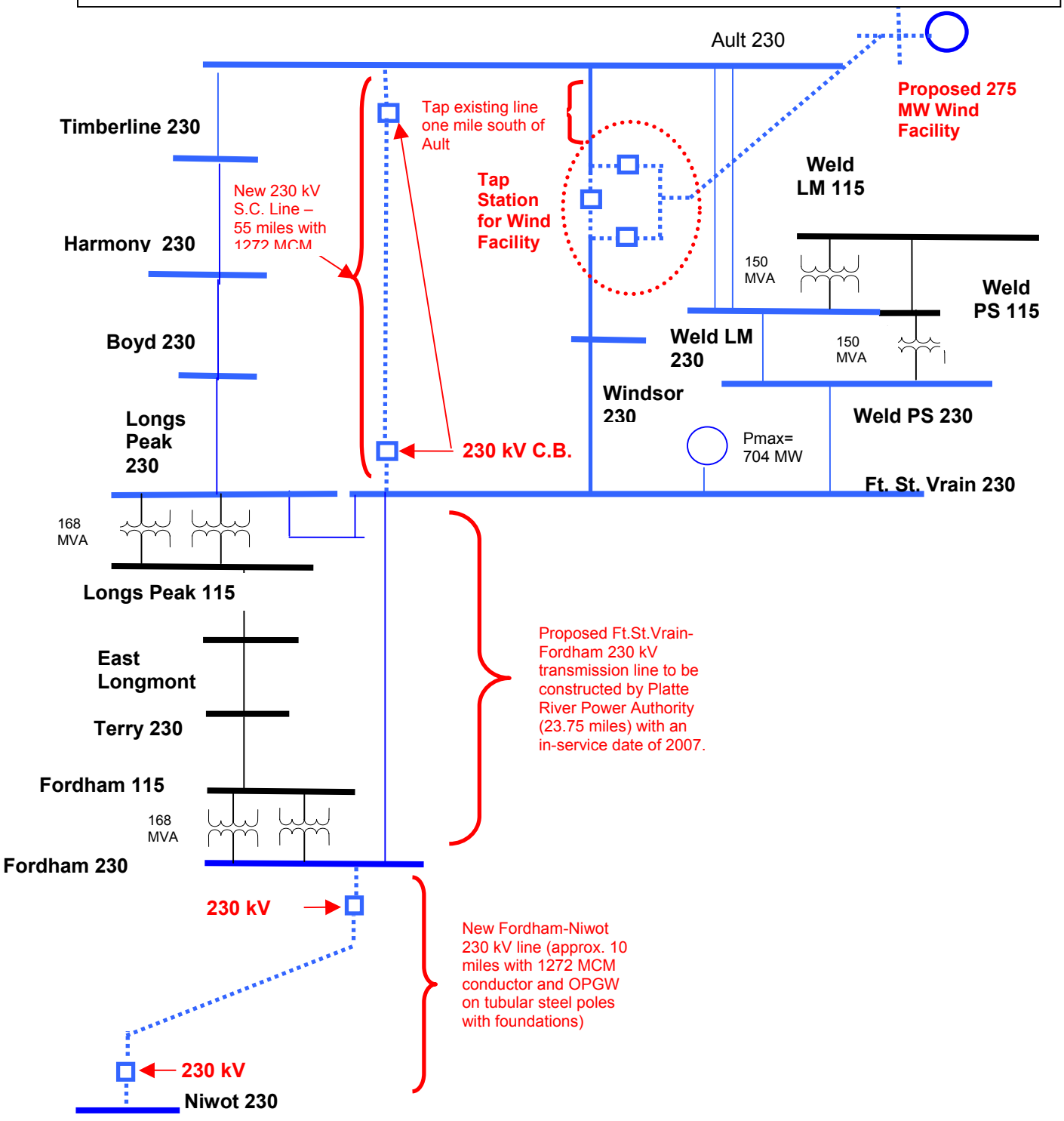
Study Scope and Analysis

This Interconnection Feasibility Study preliminarily evaluated the feasibility of the proposed interconnection to the PSCo Transmission System. It consisted of power flow and short circuit analyses. The power flow analysis identified thermal and voltage criteria violations resulting from the interconnection and also identified network upgrades required to deliver the full amount of proposed generation to PSCo loads. 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 fully 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 and neighboring utilities will be identified. For this project, it is expected that Western Area Power Administration (WAPA) and Platte River Power Authority (PRPA) may have an interest in participating in future studies. A TOT7 sensitivity study may be conducted to ascertain the impact of the preferred alternative on the TOT7 transfer path.

Figure 1 – Regional Transmission Network with Recommended Upgrades



Power Flow Study Models:

The power flow studies were based on a Western Electricity Coordinating Council (WECC) 2007 heavy summer base model. The studies were performed using PTI's PSS/E program. The 275 MW wind generation was modeled as four (4) 68.8 MW conventional generators 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 project generation was scheduled to the southern PSCo system by reducing generation in that area.
The Point of Interconnection (POI) between the Customer and PSCo is assumed to be the point at which the 30-mile transmission line meets the new switching station on the Ault-Windsor 230 kV line. The 30-mile line was modeled per Customer provided information:

- A single-circuit 30-mile, 230 kV line using conventional 230 kV "H-frame" wood pole construction with a single 954 ACSR conductor per phase, with a 413 MVA rating.
- Two 230-34.5 kV, 96/120/160 MVA Customer GSU transformers, located at the Customer collector site.

To evaluate the capabilities and system requirements for firm transfer levels, the powerflow model was modified to simulate high TOT7 and TOT 3 path flows. Efforts were made to include in the models all transmission projects expected to be in-service for the 2007 heavy summer season. The studies assumed 2007 peak summer demand conditions in the PSCo system and in other utility systems. The TOT7 flow in the case was 708 MW and the TOT3 flow in the case was 1468 MW.

Power Flow Study Results and Conclusions

Energy Resource (ER) Study Results:

The results of the ER study indicate that with the existing system and with existing firm reservations across TOT7, there is no available capacity across TOT7; therefore the ER is zero MW. Non-firm transmission capability across TOT7 may be available depending on marketing activities, dispatch patterns, demand levels and the status of transmission facilities.

Network Resource (NR) Study Results:

The NR study determined the network upgrades that would be required to accept the full 275 MW from the proposed generation for the conditions studied. For the study, the project generation was scheduled to the southern PSCo system by reducing generation in that area. At 275 MW of generation, there were numerous contingency overloads.

The basic recommended Network upgrades to alleviate the overloads and accommodate the generation include the following:

- A new Ault-Ft. St. Vrain 230 kV line consisting of approximately 55 miles of 230 kV structures with 1272 MCM "Bittern" conductor with OPGW on tubular steel poles.

- A new Fordham-Niwot 230 kV line consisting of approximately 10 miles of 230 kV structures with 1272 MCM conductor with OPGW on tubular steel poles.

A system one-line diagram showing this infrastructure is shown in Figure No. 1. The preferred alternative for network upgrades was determined after studying various transmission alternatives at the highest TOT7 and TOT3 path flows expected for the on-peak demand conditions, generation dispatch, and scheduled interchange expected for the 2007 summer season. It should be recognized that hourly, daily, weekly and monthly conditions vary considerably during the year and that this study did not attempt to determine the ER or the NR for any other set of conditions.

The preferred alternative for the network upgrades assumes a connection into WAPA's Ault Substation. Also, the alternative assumes that a Ft. St. Vrain-Fordham 230 kV line will be constructed by PRPA and placed in-serve in 2007. Since the proposed Network Upgrades for delivery either directly affect or depend on the implementation of facilities by PRPA and WAPA, coordination will be required with those entities in subsequent studies.

Alternatives:
As an alternative to the Fordham – Niwot 230kV line, some preliminary analysis explored a new 230kV transmission line from Ft. St. Vrain to Ft. Lupton to Cherokee. However, the contingency performance was lower and the estimated cost was higher than the recommended alternative. There were also some siting issues associated with the alternative.

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 Ft. St. Vrain, Ault, and other busses with three-phase and phase-to-ground faults. 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 (or lack thereof) will need to be addressed in later studies, such as the Interconnection System Impact Study (SIS), or following Interconnection Facilities Study. For all of the fault cases studied, the wind turbines for Ault 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 using CAPE.

The table shows how the fault currents change with the addition of the Ault Wind project and the network upgrades. Of particular interest is the noticeable increase in fault current with the infrastructure upgrades in service and the wind generation offline (producing 0 MW). The addition of the Ault Wind Project and the associated infrastructure upgrades pushes the available fault current well beyond the interrupting capability of ten 230kV circuit breakers at Ft. St. Vrain. Therefore the estimate to replace the ten breakers is included as part of the estimated project cost.

Table 1 Short Circuit Study Results

	Wind Gen[2] (MW)	Fault Location[3]	Fault Type[4]	Fault Current[5] (A)
Existing	0	Ft. St. Vrain	3 phase	32,776
Existing	0	Ft. St. Vrain	SLG	33,992
Interconnect	0	Ault Wind Tap	3 phase	20,509
Interconnect	0	Ault Wind Tap	SLG	18,659
Interconnect	0	Ft. St. Vrain	3 phase	33,877
Interconnect	0	Ft. St. Vrain	SLG	34,771
Delivery	0	Ault Wind Tap	3 phase	22,210
Delivery	0	Ault Wind Tap	SLG	20,020
Delivery	0	Ft. St. Vrain	3 phase	36,067
Delivery	0	Ft. St. Vrain	SLG	36,965
Delivery	275	Ault Wind Tap	3 phase	24,648
Delivery	275	Ault Wind Tap	SLG	20,895
Delivery	275	Ft. St. Vrain	3 phase	37,092
Delivery	275	Ft. St. Vrain	SLG	37,464

Costs Estimates and Assumptions:

To provide an interconnection and delivery for the Customer requested generation at the new tap station south of the Ault Substation; network upgrades must be made on the PSCo transmission system. The estimated indicative total cost for the upgrades is **$32,366,000**

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 cost to complete the section of the project from the point of interconnection to Ft. St. Vrain Substation is approximately $27.2 million and the cost to complete the section from Fordham to Niwot is approximately $4.8 million.

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.

[2] Initial cases were studied with the wind generators offline. Wind generation only introduced after infrastructure upgrades in service.
[3] Ault Wind Tap is the location where the wind generation from the customer ties into the Xcel Energy system (see one-lines). In addition the Ault Wind tap sectionalizes a 230kV transmission line between WAPA's Ault substation and Xcel Energy's Ft. St. Vrain 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).

Table 2 **Customer Interconnection Facilities**

Element	Description	Cost ($millions
New Ault 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	**$0.335**
Total Estimated Cost for Customer Interconnection Facilities		**$0.335**

Table 3 **Network Upgrades for Interconnection (ER & NR)**

Element	Description	Cost ($millions)
New Switching Station	Construct a three-breaker ring substation that will sectionalize the Ault – Windsor 230kV line one mile south of Ault, and interconnect the Customer's 230kV line to the Project. The equipment required includes: • Site development • Control building • Three (3) 230kV 3000 amp 50kA circuit breakers • Eight (8) 230kV disconnect switches • Dead-end structures, associated bus and connectors • High voltage metering with associated revenue metering equipment • Bus voltage transformers and line synchronizing transformers	**$2.896**
	Transmission line tap structure & tap	**$0.186**
	Siting & Land Rights	**$0.243**
TOTAL	**Total Cost**	**$3.325**
Time Frame		**20 months**

Table 4 Network Upgrades required to deliver 275 MW

	Description	Cost
WAPA's Ault Substation	New 230kV line termination for new trans line to the Ft. St. Vrain Substation. The following equipment will be required: • two (2) 230kV 3000 amp 50kA circuit breakers • four (4) 230kV switches • misc. supporting steel • electrical bus work • associated metering control and relaying	$1,010k
Ft. St. Vrain Substation	New 230kV line termination for new trans line from WAPA's Ault Substation. The following equipment will be required: • one (1) 230kV 3000 amp 50kA circuit breaker • one (1) 230kV switch • misc. supporting steel • electrical bus work • associated control and relaying	$658k
Ft. St. Vrain Substation	Replace ten (10) 230kV circuit breakers due to the fault duty rating being exceeded with infrastructure upgrades. Three (3) CCVT's will also be added and the RTU will be expanded to accommodate additional breaker alarm points.	$2,015k
PRPA's Fordham Substation (future)	New 230kV line termination for new trans line to the Niwot 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
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
New Trans Line from WAPA's Ault Substation to Ft. St Vrain Substation	New single circuit 230kV transmission line from WAPA's Ault Substation to Ft. St Vrain Substation (approx. 55 miles). 1272 kcmil "Bittern" conductor with OPGW on tubular steel poles with foundations.	$15,762k
New Trans Line from PRPA's Fordham Substation to the Niwot Substation	New single circuit 230kV transmission line from PRPA's Fordham Substation to the Niwot Substation (approx. 10 miles). 1272 kcmil conductor with OPGW on tubular steel poles with foundations.	$2,650k

	Description	Cost
Siting, Permitting and Acquisition	Siting and Land Rights activities including siting study, acquisition & permitting.	$5,295k
	Total Estimated Cost for Network Upgrades for Delivery	$28,706k
	TOTAL NETWORK UPGRADES	$32,031k
	TOTAL COST OF PROJECT	$32,366k

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 (switchyard only) is at least 20 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. Permitting is expected to be difficult and potentially controversial. Land use permits will be required from multiple local jurisdictions.
- The estimated time for siting, permitting, acquisition, design and construction for the PSCo network upgrades required for delivery is at least 42 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 Ault-Ft. St. Vrain 230kV transmission line.
- There is adequate space available at WAPA's Ault Substation for the new 230kV line termination, and WAPA will agree to allow this new installation.
- 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 Forham Substation and the Niwot Substation are adequate.
- The last span into the new 230kV Ault 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 four-acre site in fee for the new Ault Wind Farm Switchyard.