Interconnection System Impact Study Report
REQUEST # GI-2004-10

70 MW Wind Facility in Adams County, Colorado

Xcel Energy Transmission Planning
October 2005

Executive Summary

This Interconnection System Impact Study Report summarizes the analyses performed by the Transmission Planning group of Public Service Company of Colorado (PSCo) to interconnect 70 MW of wind powered generation located near the town of Byers, Colorado to the Pawnee – Daniels Park 230 kV line. The Customer proposed in-service date for commercial operation of the facility is December 31, 2005, with an assumed back-feed date of October 1, 2005. This date, as stated in the Feasibility Study, is not feasible. At the request of the Customer, the Project was evaluated as both an Energy Resource (ER) and as a Network Resource (NR) with the power going to PSCo customers. The request was studied primarily as a "stand-alone" project, but some sensitivity analyses were also performed to consider a higher project in the Rocky Mountain Area OASIS queue[1].

The estimated cost of the PSCo Network Upgrades for interconnection is **$4.28 million** and includes:

- $0.52 million for PSCo-Owned, Customer Funded Interconnection Facilities.
- $3.76 million for PSCo Network Upgrades for Interconnection.

Energy / Network Resource

This study determined that as a stand-alone project, the full **70 MW** of firm energy could be accommodated without any additional Network Upgrades for Delivery. Therefore, the Project could also be considered a Network Resource.

The time required to engineer, permit, and construct the facilities for interconnection is estimated to be at least 16 months. Therefore, it is not feasible to interconnect the project by the proposed in-service date. According to the interconnection request, the Customer is responsible for all facilities from the project to the point of interconnection at the new PSCo switching station.

Sensitivity studies evaluated the system performance considering the higher queued wind project GI-2003-1. If GI-2003-1 and its associated system upgrades are considered to be in place, studies still indicate that no additional Network Upgrades for Delivery would be required for this project.

[1] www.rmao.com

A simple diagram of the Network Upgrades for Interconnection and the regional transmission system for this request is shown in Figures 1 and 2.

Figure 1 – Regional Transmission System

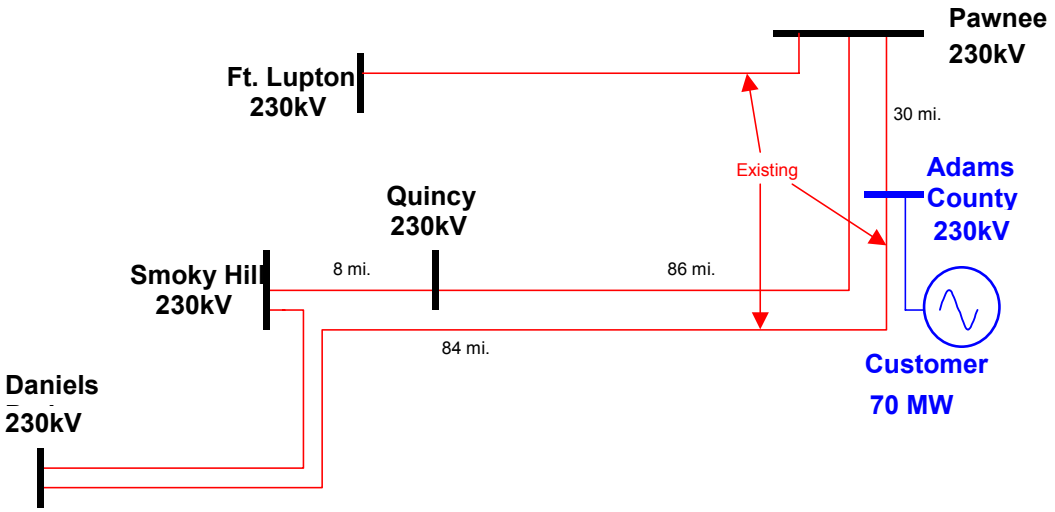
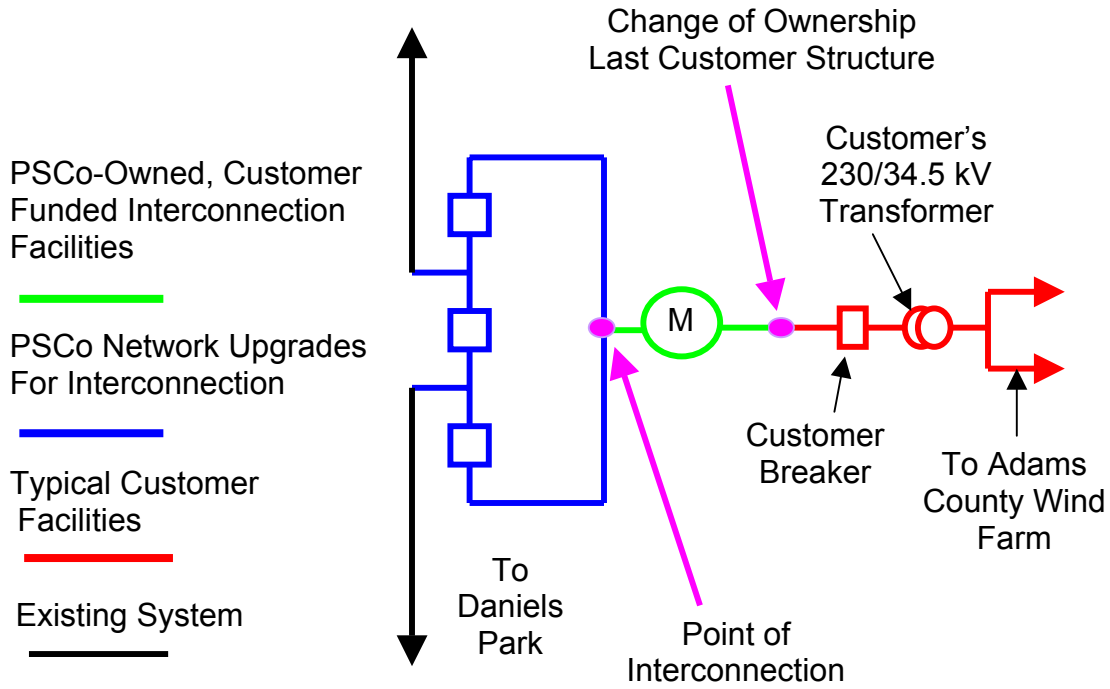


Figure 2 – Customer Wind Interconnection GI-2004-10



Study Scope and Analysis

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

The Study consisted of power flow, short circuit, and dynamic stability analyses. The power flow analysis looked for any thermal or voltage limit violations resulting from the interconnection. The short circuit analysis determined if any circuit breaker short circuit capability limits were exceeded as a result of the interconnection and delivery of the proposed generation to PSCo loads. The dynamic stability analysis evaluated the transient performance of the system for regional disturbances.

PSCo adheres to NERC / WECC Reliability Criteria, as well as internal Company criteria for planning studies. During system intact conditions, criteria are to maintain transmission system bus voltages between 0.95 and 1.05 per-unit of system normal conditions, and steady state power flows within 1.0 per-unit of all elements thermal (continuous current or MVA) ratings. Operationally, PSCo tries to maintain a transmission system voltage profile ranging from 1.02 per-unit or higher at generation buses, to 1.0 per-unit or higher at transmission load buses. Following a single contingency element outage, transmission system steady state bus voltages must remain within 0.90 per-unit to 1.10 per-unit, and power flows within 1.0 per-unit of the elements continuous thermal ratings.

Study Models

For this analysis, a power flow model was developed to reflect 2007 heavy summer loading conditions. Data representation in the area of study was reviewed and modified to accurately reflect the Rocky Mountain regional transmission system. The TOT 3 transfer path was increased to 92% of its 1569 MW 2005 Summer Rating.

The 70 MW wind farm was modeled as two 35 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, that the Customer has stated in their request to be GE 1.5 MW DFIG turbines. The project generation was scheduled to PSCo peaking units located in the Southern PSCo area.

The specified point of interconnection for the new generation is the new PSCo Adams switching station, near Pawnee Station. The proposed project was connected to the Pawnee – Daniels Park 230 kV line, and modeled as:

- Two 6-mile 34.5kV lines using conventional wood pole construction with a single 954 ACSR conductor per phase
- One 230-34.5 kV, 80 MVA transformer, modeled grounded wye-wye with a 10% impedance, located at the Customer's 230/34.5kV substation.

Study Results

Energy Resource (ER) Study Results:

The results of the ER study indicate that 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 the full **70 MW**.

Network Resource (NR) Study Results:

The NR study determined there are no network upgrades that will be required to accept the full 70 MW from the proposed wind project. Modeling the customer wind generation at 70 MW did not create local contingency overloads on the PSCo system or the neighboring systems.

Results indicate no impacts to neighboring utilities or for the TOT3 transmission path.

Sensitivity Results for Higher Queued Projects

The Project was also evaluated taking into consideration a project ahead in the queue, which was GI-2003-1. This is a 300 MW wind facility interconnected at Pawnee. The associated network upgrades for GI-2003-1 were also included in the studies. The details of the upgrades for that project can be seen in the associated studies on the RMAO web page www.rmao.com

With the addition of the GI-2004-10 generation at the full 70 MW, studies demonstrated that no additional Network Upgrades would be required.

Short Circuit Analysis

The short circuit analysis consisted of faulting and measuring the current at 230 kV buses in the region of study. Only three-phase faults were evaluated. Results indicated that there are not any major increases in fault currents and that current breaker ratings are sufficient to integrate this project into the PSCo system.

Table 1: Short Circuit Study Results

Configuration	Fault Current (Amps)			
	Daniels Park	Smoky Hill	Adams Wind	Pawnee
Benchmark Existing system 2007 system	26,412	27,286	NA	19,049
GI-2004-10 Add wind project at Pawnee-Daniels Park 230 kV line	26,429	27,383	7,473	19,165

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Dynamic Stability Analysis

Transient stability analyses were performed by modeling three-phase fault contingencies in the region of study. Dynamic models for the proposed project were prepared using Customer supplied data that assumed to use the GE 1.5 MW DFIG with low voltage ride through (LVRT) capability as low as 30% of nominal voltage. The analysis indicated the system is stable before, during, and after contingencies.

Even though the models used wind generators with LVRT as low as 30%, the models showed that the Adams Project would trip off-line (self protection) for faults at or near Pawnee. Additional Studies were conducted with LVRT at the 70% level revealing with that the wind farm turbines would still trip off for faults at or near Pawnee. The following tables show stability results before and after the project is added to the system.

Table 2: Transient Stability Results – Base Case without Network Upgrades (Adams Project Off)

	Fault Location	Action	Result
1	3PH at Pawnee 230 kV bus, 6 cycles	Trip Pawnee-Daniels Park 230 kV line	System Stable
2	3PH at Daniels Park 230 kV bus, 6 cycles	Trip Pawnee -Daniels Park 230 kV line	System Stable
3	3PH at Pawnee 230 kV bus, 6 cycles	Trip Pawnee - Story 230 kV line	System Stable
4	3PH at Story 230 kV bus, 6 cycles	Trip Pawnee – Story 230 kV line	System Stable
5	3PH at Pawnee 230 kV bus, 6 cycles	Trip Pawnee – Quincy-Smoky Hill 230 kV line	System Stable
6	3PH at Smoky Hill 230 kV bus, 6 cycles	Trip Pawnee – Quincy-Smoky Hill 230 kV line	System Stable
7	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee – Ft. Lupton 230 kV line	System Stable
8	3PH at Ft. Lupton 230 kV bus; 6 cycles	Trip Pawnee – Ft. Lupton 230 kV line	System Stable
9	3PH at LRS 345 kV bus; 4 cycles	Trip LRS – Story 345 kV line	System Stable
10	3PH at LRS 345 kV bus; 4 cycles	Trip LRS – Ault 345 kV line	System Stable

Table 3: Transient Stability Results – Case with 70 MW Adams Wind Project and without Network Upgrades

#	Fault Location	Action	Result
1	3PH at Pawnee 230 kV bus, 6 cycles	Trip Pawnee - Adams 230 kV line	System Stable Adams Gen Trips
2	3PH at Adams 230 kV bus, 6 cycles	Trip Pawnee - Adams 230 kV line	System Stable Adams Gen Trips
3	3PH at Pawnee 230 kV bus, 6 cycles	Trip Pawnee - Story 230 kV line	System Stable Adams Gen Trips
4	3PH at Story	Trip Pawnee - Story	System Stable

#	Fault Location	Action	Result
	230 kV bus, 6 cycles	230 kV line	
5	3PH at Pawnee 230 kV bus, 6 cycles	Trip Pawnee – Quincy-Smoky Hill 230 kV line	System Stable Adams Gen Trips
6	3PH at Smoky Hill 230 kV bus, 6 cycles	Trip Pawnee – Quincy-Smoky Hill 230 kV line	System Stable
7	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee – Ft. Lupton 230 kV line	System Stable Adams Gen Trips
8	3PH at Ft. Lupton 230 kV bus; 6 cycles	Trip Pawnee – Ft. Lupton 230 kV line	System Stable
9	3PH at Corner Point 230 kV bus; 6 cycles	Trip Corner Point - Adams 230 kV line	System Stable Adams Gen Trips
10	3PH at Corner Point 230 kV bus; 6 cycles	Trip Daniels Park - Corner Point 230 kV line	System Stable Adams Gen Trips
11	3PH at Daniels Park 230 kV bus; 6 cycles	Trip Daniels Park - Corner Point 230 kV line	System Stable
12	3PH at Adams 230 kV bus; 6 cycles	Trip Adams – Corner Point 230 kV line	System Stable Adams Gen Trips
13	3PH at LRS 345 kV bus; 4 cycles	Trip LRS – Ault 345 kV line	System Stable
14	3PH at LRS 345 kV bus; 4 cycles	Trip LRS – Story 345 kV line	System Stable

The results from Table 3 show that the transient stability of the region is not affected by proposed project. The system is stable and will continue to be stable with the 70 MW wind project.

If the Customer chooses to move forward with this project, detailed generator models will need to be submitted to PSCo for further evaluation and studies. Once the collector system is designed, the Customer is also expected to provide studies showing that all PSCo Interconnection Requirements are met and that the models can be validated during commissioning tests as per Xcel Energy Interconnection Guidelines[2].

Cost Estimates and Assumptions

The estimated total cost for the required upgrades is $4.28 million.

The estimated costs shown are “indicative” (+/-30%) preliminary budgetary costs in 2005 dollars and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the engineering, design, and construction of these new PSCo facilities. The estimates do not include any costs for any Customer-owned, supplied, and installed equipment and associated design and engineering. This estimate also does not include any costs that may, or may not be required for other entities’ systems. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines.

[2] **“Interconnection Guidelines For Transmission Interconnected, Producer-Owned Generation Greater Than 20 MW “**can be found at www.xcelenergy.com.

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

PSCo Network Upgrades for Interconnection

Tables 4 and 5 describe the costs associated with providing an interconnection and network upgrades to PSCo's system for interconnection.

Table 4: PSCo-Owned, Customer Funded Interconnection Facilities

Element	Description	Cost ($ Millions)
New PSCo Customer Tap Switchyard	Interconnect 230 kV line from Customer's facility to a new 230 kV switchyard. The new equipment required includes: • 230 kV bi-directional revenue metering • Required steel supporting structures • Associated metering control and relaying	**$0.44**
	Transmission line tap structure & tap	**$0.08**
Time Frame		**9 months**
Total	**Customer Interconnection Facilities**	**$0.52**

Table 5: PSCo Network Upgrades for Interconnection

Element	Description	Cost ($ Millions)
New PSCo Switching Station	Construct a new three-breaker ring bus substation that will interconnect the Customer's 230 kV line to the Project. The equipment required includes: • Site development and land • Control building • Three (3) 230 kV 3000 amp 40 kA circuit breakers	**$3.55**
	Siting & Land Rights	**$0.21**
Total Cost	**Estimated Costs for Network Upgrades for Interconnection**	**$3.76**
Time Frame		**16 months**

Assumptions

- Estimate costs and time frames are updated from the GI-2004-10 Feasibility study.
- **The estimate above is for reference only and is subject to change with a more detailed system study.**
- The estimated costs provided are "Scoping Estimates" with an accuracy of ± 30%.

- Estimates are based on 2005 dollars. Estimates are fully loaded with appropriate overheads. PSCo paid estimates include AFUDC. Customer estimates do not include AFUDC.
- Estimates include the time and cost to engineer, permit, procure materials, construct, and commission the facilities.
- PSCo (or its contractor) crews will perform all construction and wiring associated with PSCo-owned and maintained equipment.
- Customer Interconnection Transmission Line estimated built to PSCo design with PSCo construction costs.
- Customer Interconnection Transmission Line estimate does not include customer facility's substation or termination cost. Estimated line terminates on customer's dead-end structure.
- Timeline and cost estimates assume permits, substation land, and right-of-way, as needed, will be available within typical costs and time frames.