Interconnection System Impact Study Report
Request # GI-2004-6

250 MW Wind Facility, near Akron, Colorado

Xcel Energy Transmission Planning
September 2005

Executive Summary

PSCo Transmission received a generation request to determine the feasibility of interconnecting 250 MW of new Customer wind turbine generation into the PSCo transmission system at the Pawnee Station 230 kV 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 a higher queued project.

The ER portion of this study determined that the Customer could not provide any firm energy without the construction of network reinforcements. This determination is based on existing limitations due to the TOT3 transfer path. Non-firm transmission capability may be available depending on marketing activities, dispatch patterns, demand levels and the status of transmission facilities.

As an NR request, PSCo evaluated the network to determine the upgrades required to deliver the full 250 MW of the wind facility to PSCo native load customers. The total estimated cost of the recommended system upgrades to accommodate the project is approximately **$53.06** million and includes:

- $0.35 million for PSCo-Owned, Customer Funded Interconnection Facilities
- $0.53 million for PSCo Network Upgrades for Interconnection
- $52.18 million for PSCo Network Upgrades for Delivery

As a stand-alone project, the basic upgrades would consist of:

- Uprate the 94 mile PSCo 230 kV line from Pawnee Station to Quincy and Smoky Hill Substations from 500 MVA to 800 MVA.
- Upgrade the PSCo 64 mile 230 kV line from Pawnee Station to Ft. Lupton Station to a 230 kV double circuit, 800 MVA per circuit rated transmission line.
- Uprate the 9 miles of the Spruce to Smoky Hill 230 kV circuits #1 and #2 from 627 MVA to 800 MVA.

The regional transmission system is shown in Figure 1 along with the recommended upgrades. A partial one-line of Pawnee Station is shown in Figure 2.

[1] www.rmao.com

Figure 1- Regional Transmission Network with Recommended Upgrades

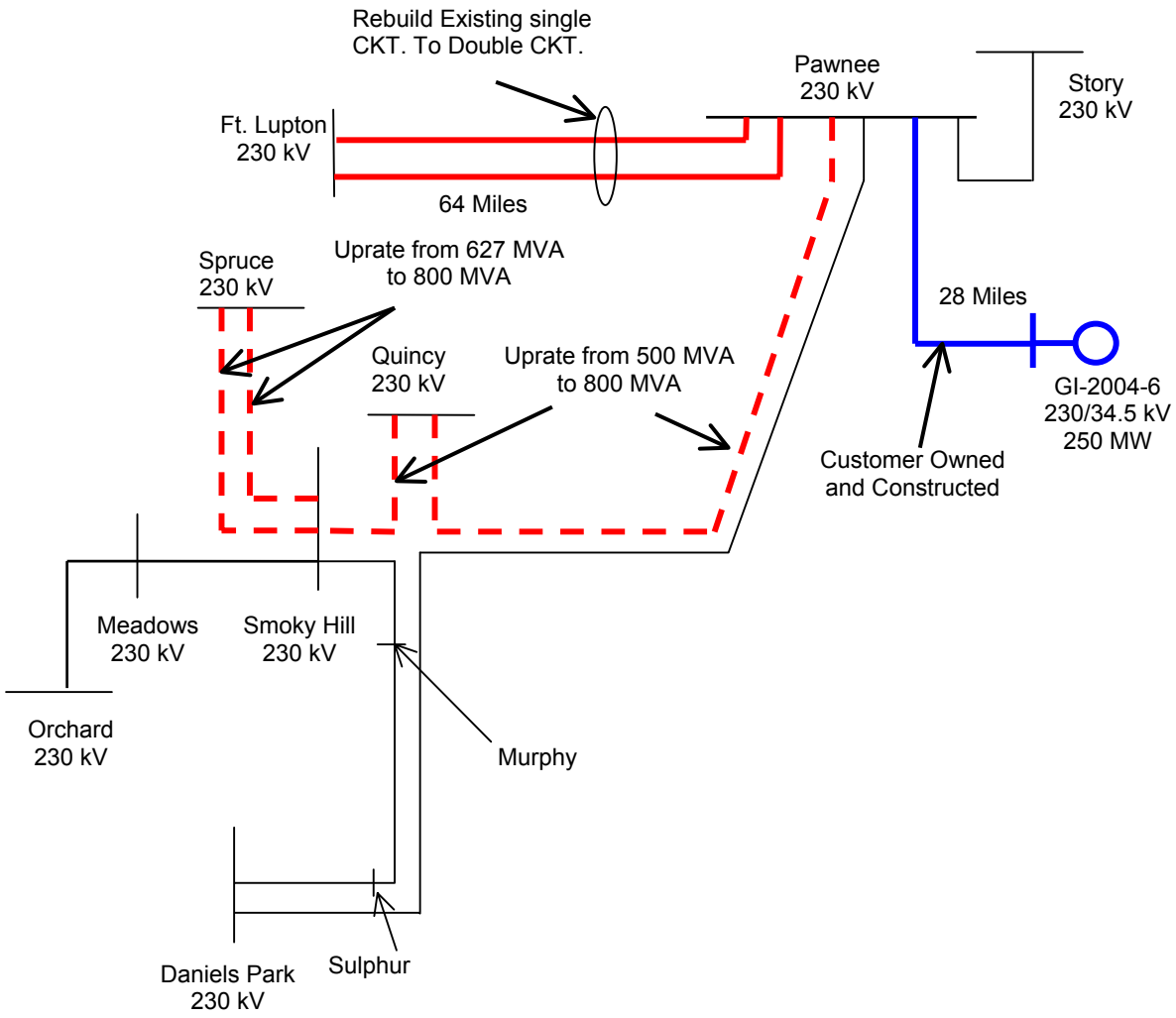

Figure 2: Pawnee Station One-line with GI-2004-6

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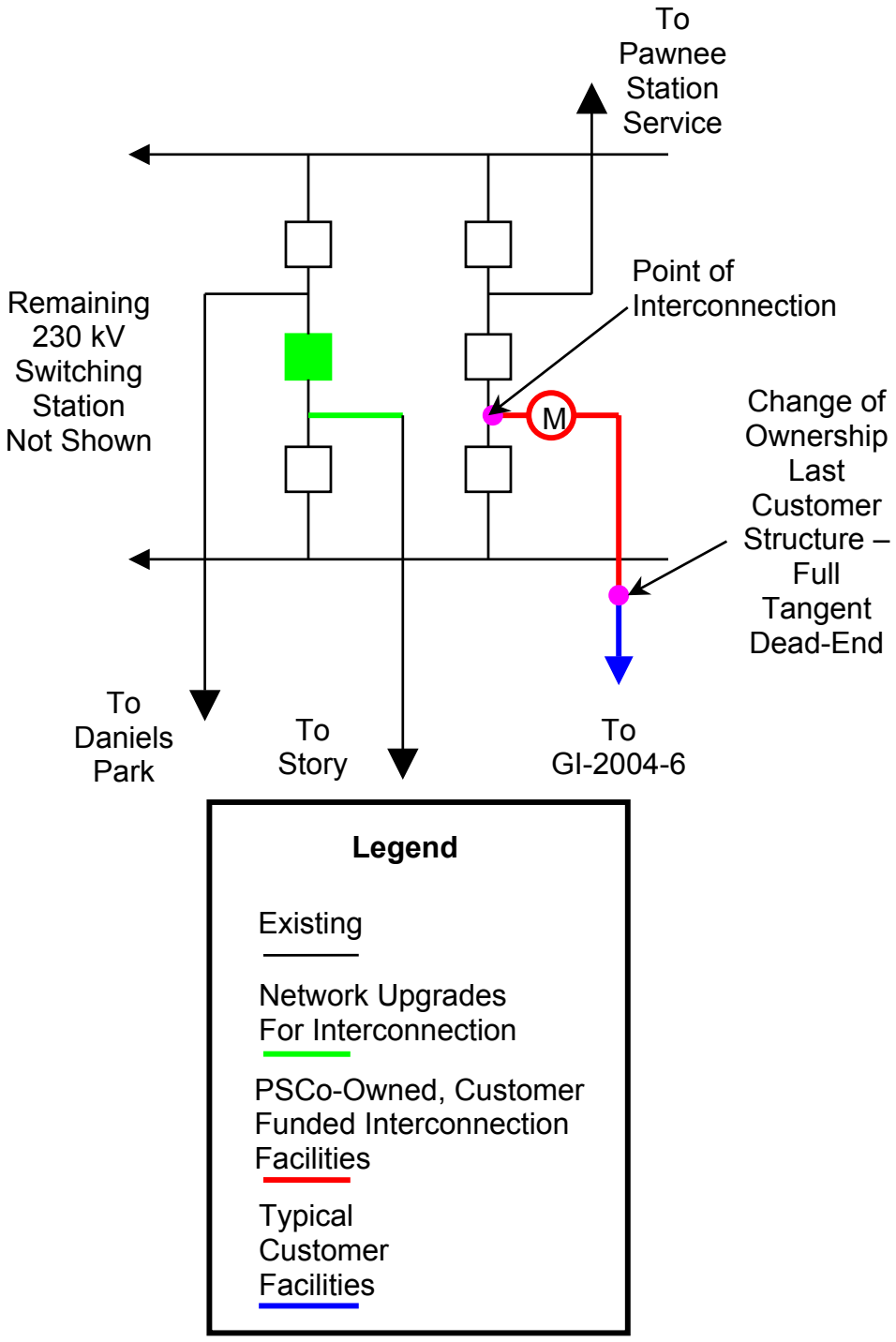

The estimated time required to engineer, permit, and construct all the required PSCo facilities for interconnection is estimated to be at least 9 months. The estimated time required to engineer, permit, and construct the Network Upgrade facilities for delivery is at least 38 months; therefore, it is not feasible to construct the Network Upgrades for Firm Delivery of this project before the required in-service date. According to the interconnection request, the Customer will engineer, permit, construct, and finance the 28-mile 230 kV transmission line to the proposed tap station.

Additional details of the studies can be found under the Power Flow and Stability Study sections.

Study Scope and Analysis

The Interconnection Feasibility Study evaluated the transmission requirements associated with the proposed interconnection to the PSCo Transmission System. It consisted of power flow, short circuit, and dynamic stability analyses. The power flow analysis provided a preliminary identification of any thermal or voltage limit violations resulting for the interconnection, and for a NR request, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified any circuit breaker short circuit capability limits exceeded as a result of the Interconnection and for a NR request, the delivery of the proposed generation to PSCo loads. The dynamic stability analysis identified any limitations due to angular instability 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 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.

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 the General Electric (GE) PSLF program. The 250 MW wind farm was modeled as two 125 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 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 28-mile transmission line meets the Pawnee Substation bus. The 28-mile line was modeled per the Customer provided information:

- A single-circuit 28-mile, 230 kV line using conventional 230 kV "H-frame" wood pole construction with a single 954 ACSR conductor per phase, with a 281 MVA rating.
- One 230-34.5 kV, 225/300 MVA Customer GSU transformer, located at the Customer collector site.

To evaluate the capabilities and system requirements for firm transfer levels, the power flow model was modified to simulate high TOT3 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. For the conditions studied, TOT 3 was at 88% of its 1569 MW 2005 Summer Rating.

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 TOT3, there is no available capacity at Pawnee Station; therefore the ER is zero MW. Non-firm transmission capability 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 250 MW from the proposed wind farm for the conditions studied. At 250 MW of generation from the Customer, there were a number of contingency overloads. Table 1 shows the most significant contingencies and the associated overloads along with results from the benchmark case and with the Network Upgrades

Table 1: Contingency Comparison Table for GI-2004-6

Contingency From Bus # Name KV To Bus # Name KV CKT #	Overloaded Element From Bus # Name KV To Bus # Name KV CKT #0	RATING (MVA)	Bench Mark Case	GI-2004-6 without Upgrades	GI-2004-6 with Upgrades
70311 PAWNEE 230 To 70343 QUINCY 230 CKT 1	70192 FTLUPTON 230 TO 70311PAWNEE 230 CKT 1	413	102%	120%	<100%
70311 PAWNEE 230 to 70343 DANIELPK 230 CKT 1	70192 FTLUPTON 230 TO 70311 PAWNEE 230 CKT 1	413	95%	113%	<100%
70311 PAWNEE 230 to 70343 DANIELPK 230 CKT 1	70311 PAWNEE 230 to 70343 QUINCY 230 CKT 1	500	97%	112%	<100%
70192 FTLUPTON 230 TO 70311 PAWNEE 230 CKT 1	70311 PAWNEE 230 to 70343 QUINCY 230 CKT 1	500	97%	112%	<100%
70528 SPRUCE 230 TO 70396 SMOKYHIL 230 CKT 2	70528 SPRUCE 230 TO 70396 SMOKYHIL 230 CKT 1	627	109%	112%	<100%
70528 SPRUCE 230 TO 70396 SMOKYHIL 230 CKT 1	70528 SPRUCE 230 TO 70396 SMOKYHIL 230 CKT 2	627	109%	112%	<100%

The Customer's interconnection request is similar to previously studied interconnection requests at Pawnee Substation. The upgrades were determined to be comparable with the network upgrades identified for GI-2003-1. The basic recommended network upgrades to alleviate the overloads and accommodate the generation include the following:

- Between Pawnee Station and Smoky Hill Substation, uprate the existing 230 kV line from 500 MVA to 800 MVA by using phase raisers to raise 15 transmission structures.
- From Pawnee Station to Ft. Lupton Station rebuild the existing 64 mile 230 kV 413 MVA rated line to a double circuit 230 kV, 800 MVA per circuit configuration.
- Uprate the Spruce to Smoky Hill 230 kV circuits #1 and #2 from 627 MVA to 800 MVA by installing and upgrading dead-end phases on tangent structures to obtain 123 degree C operation.

Studies indicated that if the proposed Network Upgrades for Delivery are implemented for this project, there are no significant impacts to the neighboring utilities or to the TOT3 transmission path.

Sensitivity Results for Higher Queued Projects

The Project was also evaluated taking into consideration one relevant 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 the queued project 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. With the addition of the Customer's generation at the full 250 MW, no contingency overloads were observed, thus not requiring additional Network Upgrades.

Short Circuit Study Results

For this study, it was assumed the wind contributes no fault current. The fault currents at the Pawnee 230kV bus are approximately 24kA for SLG faults and 21kA for 3-phase faults. These values are within the circuit breaker interrupting ratings.

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 once network upgrades were implemented.

Even though the models used wind generators with LVRT as low as 30%, the models showed that the Akron Project would trip off-line (self protection) for faults at

or near Pawnee and Story. 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 and Story. The following tables show stability results before and after the project is added to the system.

Table 2: Transient Stability Results – Bench Mark Case before GI-2004-6

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

Table 3: Transient Stability Results – Case with GI-2004-6 and Network Upgrades for Delivery

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

The results from Table 3 show that the transient stability of the region is not affected by proposed 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].

Costs Estimates and Assumptions

The estimated total cost for the required upgrades is **$53,060,000.**

The estimated costs shown are "indicative", or "scoping" (+/-30%) estimates 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 list the improvements required to accommodate the interconnection and the delivery of the Project. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to change upon more detailed analysis.

The estimated costs for interconnection are detailed in Table 4 and Table 5. The customer is responsible for the construction of the 28-mile transmission line from the wind project location to the point of interconnection at Pawnee Station. PSCo has not estimated this cost. Table 6 shows the detailed costs for Network Upgrades required for Firm Delivery.

Table 4 – Customer Interconnection Facilities

Element	Description	Cost Est. Millions
Pawnee Station	Interconnect Customer to tap PSCo's 230kV bus. The new equipment includes 230kV bi-directional transformer metering, relaying and associated equipment and material.	$0.285
	Transmission tie line into Pawnee Station.	$0.045
	Siting and Land Rights for required easements, reports, permits and licenses.	$0.020
	Total Cost Estimate for Customer Interconnection Facilities	**$0.350**

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

Table 5 – PSCo Network Upgrades for Interconnection

Element	Description	Cost Est. Millions
Pawnee Station	Interconnect Customer's 230 kV line, which will require the relocation of the existing Pawnee to Story 230 kV line to one bay west to allow the new Customer owned line to terminate in this position. The new equipment required includes: • a new 230 kV 3000 A, 50 kA circuit breaker • two 230 kV switches • transmission line relay testing • required steel supporting structures and foundations	$0.525
	Total Cost Estimate for PSCo Network Upgrades for Interconnection	**$0.525**
Time Frame		**9 Months**

Table 6 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. Millions
Pawnee Station	New 230 kV Line terminal to Ft. Lupton requiring the following equipment: • one new 230 kV breaker and half bay on the west side of the 230 kV switch yard • (2) 3000 Amp, 50 kA circuit breakers • (4) 230 kV switches • associated steel and foundations • electrical bus work • associated metering, control, relaying and testing Uprate the Pawnee to Smoky Hill 230 kV line requires the following: • replace six (6) 1600 Amp switches with 3000 Amp switches • replace 1200 Amp Line trap with 2000 Amp Line Trap	$1.78
Ft. Lupton Station	New 230 kV 2000 Amp Line Terminal to Pawnee which will require rearranging of the existing line terminations for the Henry Lake and Green Valley lines. The following equipment will be required: • a new 230 kV breaker and a half bay on the east side of the station • three (3) 230 kV 3000 Amp 50 kA circuit breakers that includes replacing one 1600 Amp breaker • ten (10) 230 kV switches that includes four (4) new and six (6) replacements from 1600 Amp to 3000 Amp • misc. supporting steel and foundations • electrical bus work • associated metering control , relaying and testing	$1.955
Smoky Hill Substation	Upgrade existing facilities on the Pawnee 230 kV line terminal which includes the following: • replace two (2) underrated 230 kV 1600 Amp circuit breakers with new 3000 Amp 50 kA circuit breakers • replace four (4) 1600 Amp switches with 3000 Amp switches	$2.40

Element	Description	Cost Est. Millions
	• replace 1200 Amp Line trap with 2000 Amp Line Trap • replace existing east and west main 1272 kCMIL strain buses with 5" aluminum tube bus • associated metering, control, relaying and testing Upgrade existing facilities to support the Spruce-Smoky Hill line uprate which includes the following: • five (5) 230 kV 3000 Amp 50 kA gas circuit breakers • twelve (12) 230 kV 3000 Amp switches • misc. supporting steel and foundations • electrical bus work • associated metering control, relaying and testing	
Quincy Substation	Replace existing 1200 Amp line-rupters with 2000 Amp line-rupters	$0.34
Spruce Substation	No upgrades or modifications required.	$0
Transmission	Rebuild existing 413 MVA 230 kV line from Pawnee to Ft. Lupton with new double circuit 230 kV 834 MVA transmission utilizing existing ROW as much as possible	$44.48
	Uprate the existing Pawnee to Quincy/Smoky Hill 230kV Line to 800 MVA from 500 MVA by installing approximately 15 phase raisers.	$0.25
	Uprate the Spruce to Smoky Hill 230 kV circuits #1 and #2 from 627 MVA to 800 MVA by installing and upgrading dead-end phases on tangent structures to obtain 123 degree C operation.	$0.20
Siting and Permitting	Obtain necessary siting, permits, and ROW as required	$0.790
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$52.18**
	Total Cost of Project	**$53.06**
Time Frame		**38 Months**

Assumptions

- The cost estimates provided are "scoping estimates" with an accuracy of +/- 30%.
- Estimates are based on 2006 dollars.
- PSCo (or it's Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- The estimated time for design and construction of PSCo network upgrades for interconnection at the Pawnee Station is at least 9 months, and is completely independent of other queued projects and their respective ISD's.
- It is anticipated that in order to construct the PSCo network upgrades for delivery, a Certificate of Public Convenience and Necessity (CPCN) will be required by the Colorado Public Utilities Commission (CPUC). The application for a CPCN will not be submitted until the Interconnection Agreement is fully executed. The estimated time frame for the CPCN process, siting, permitting, easement and right-of-way acquisition, design and construction for the PSCo network upgrades

is at least 38 months from the time the Interconnection Agreement is fully executed. This time frame is also based on other identified assumptions for Siting and Land Rights, Substation Engineering and Transmission Engineering as listed below.

- Implementation of the recommended infrastructure for delivery will require that existing facilities be taken out of service for sustained periods. In most cases, these outages cannot be taken during peak load periods due to operational constraints. As a result, the estimated time frame for implementation could be increased by 3-6 months.
- The Customer will be responsible for funding and constructing approximately 28 miles of transmission line from the wind farm to the point of interconnection (Pawnee Station).
- The last span into Pawnee Station from the Customer owned 230 kV 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 tangent structure.
- A siting study will not be required if network upgrades for delivery (transmission line construction) is in existing right-of-way. Extensive public involvement is anticipated. Permit applications and possible minor right-of-way acquisition will be required. Land use permits will be required from multiple local jurisdictions.