Interconnection System Impact Study Report
Request # GI-2008-8
(Preliminary)

400 MW Wind Powered Generation Interconnecting at Pawnee Substation

PSCo Transmission Planning
July 12, 2011

A. Executive Summary

On September 25, 2009, Public Service Company of Colorado (PSCo) Transmission Planning received a generation interconnection request, GI-2008-8, to determine the potential system impacts associated with interconnecting a 400.5 MW wind generation facility at the Pawnee Substation through a 90-mile 345 kV transmission line. The 345 kV bus at Pawnee was considered as the POI. The customer requested a commercial operation date for the facility of not before May 30, 2013 to coincide with the completion of a new 345 kV transmission line between Pawnee and Smoky Hill 345 kV substations, and a back-feed date for site energization of November 30, 2012. The study request indicated that the generation would be delivered for PSCo native load.

This request was studied as both an Energy Resource (ER)[1] and as a Network Resource (NR)[2]. These investigations included steady-state power flow and dynamic studies. The request was studied as a stand-alone project only, with no evaluations made of other potential new generation requests that may exist in the Large Generator Interconnection Request (LGIR) queue, other than the generation projects that are already approved and planned to be in service by the summer of 2013. The main purpose of this study was to evaluate the potential impact of GI-2008-8 on the PSCo transmission infrastructure as well as that of neighboring entities, when injecting a total of 400 MW of wind turbine generation at Pawnee, and delivering the additional generation to native PSCo loads. The costs to interconnect the project with the transmission system at Pawnee Substation have been evaluated by PSCo Engineering.

[1] **Energy Resource Interconnection Service (ER Interconnection Service)** shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an as available basis. Energy Resource Interconnection Service in and of itself does not convey transmission service.

[2] **Network Resource Interconnection Service** shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission System (1) in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an RTO or ISO with market based congestion management, in the same manner as all other Network Resources. Network Resource Interconnection Service in and of itself does not convey transmission service.

This study considered facilities that are part of the PSCo transmission system as well as monitoring other nearby entities' regional transmission systems.

Stand Alone Results

The stand-alone analysis consisted of a comparative study of the system behavior with the addition of the Customer's 400-MW project to the PSCo system compared with that associated with the existing PSCo system. The power flow model used in this study is a 2013 budget model with heavy summer load and moderately heavy stressed north-to-south (HSHN) flows.

Energy Resource (ER)

Energy Resource Interconnection Service (ER) is an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an as available basis. Energy Resource Interconnection Service in and of itself does not convey transmission service.

The initial study analysis indicated that the firm ER injection capability is 0 MW. No firm capacity is available for any plant output due to overloads under contingency analysis and firm transmission commitments without the construction of network reinforcements. Non-firm transmission capability may be available at a higher MW value depending on marketing activities, dispatch patterns, generation levels, demand levels, import path levels (TOT3, etc.) and the operational status of transmission facilities.

Therefore, as it pertains to this Study, the ER capability is as follows:

Energy Resource (ER):

ER Injection Capability Estimate: 0 MW

As a result of adding 400 MW of new generation at the Pawnee 345 kV bus POI, there are facilities that either incur new single contingency (N-1) overloads, or that become significantly overloaded. These overloaded facilities, listed in Table 1, are for a power flow model with heavy summer 2013 system conditions with the re-dispatched case for the maximum wind power generation at Peetz Logan (575 MW), new generation (250 MW) at Cedar Point and new generation (200 MW) connected to Missile Site 345 kV. Any N-1 contingencies causing new facility overloads or existing overloads to increase by 3% or more between the case with the new GI-2008-8 generation at 400 MW and the benchmark case without the GI-2008-8 project at Pawnee 345 kV are listed. The line ratings and limiting elements identified in Table 1 are based upon the base case ratings along with new project upgrades or additions that are already planned and budgeted for in the 2013 time frame.

Table 1 shows that with the GI-2008-8 wind facility at 400 MW, the worst contingency overloads are the Smoky Hill 345/230 kV transformers at 142.5% of the 560 MVA rating with the loss of the parallel transformer. The second worst contingency overload is the Brick Center 230/115 kV transformer, at 108.4% of its 200 MVA rating. The third worst contingency is the overload of either of the Beaver Creek 115 kV transmission line at 107.3% of the 200 MVA rating; this line is located in the system operated by Tri-State Generation and Transmission (Tri-State G&T).

Network Resource (NR)

Network Resource Interconnection Service is an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission System in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers. A Network Resource is any designated generating resource owned, purchased, or leased by a Network Customer under the Network Integration Transmission Service Tariff. Network Resources do not include any resource, or any portion thereof, that is committed for sale to third parties or otherwise cannot be called upon to meet the Network Customer's Network Load on a non-interruptible basis. Network Resource Interconnection Service in and of itself does not convey transmission service.

Network Resource (NR):

NR Injection Capability Estimate: 400 MW

Table 1 lists the lines and autotransformers that either incur new single contingency (N-1) overloads or that become significantly overloaded as a result of adding 400 MW of new generation at the Pawnee 345 kV POI bus. These results are for a power flow model for heavy summer 2013 system conditions, with the re-dispatched case for the maximum wind power generation at Peetz-Logan (575 MW), new generation (250 MW) at Cedar Point and new generation (200 MW) connect to Missile Site 345 kV. Overloaded facilities that have a 3% or more differential loading between the case with the new GI-2008-8 generation at 400 MW and the benchmark case with 0 MW injection at Pawnee 345 kV are listed. The line ratings and limiting elements identified in Table 1 are based upon the base case ratings along with new project upgrades or additions that are already planned and budgeted for in the 2013 time frame.

With the GI-2008-8 wind facility at 400 MW, a contingency overload of the Brick Center 230/115 kV transformer occurs at 108.4% of the 200 MVA rating. There is also a contingency overload of the Smoky Hill 345/230 kV transformer, at 142.5% of the 560 MVA rating, associated with the outage of the parallel transformer. In the system operated by Tri-State G&T, there is also a contingency overload of the Beaver Creek 115 kV transmission line, at 107.3% of the 200 MVA rating.

The System Impact Study indicated that the NR Injection capability is 400 MW after network upgrades are completed. Network upgrades are additions, modifications, and upgrades to the Transmission Provider's Transmission System required at or beyond the point at which the Interconnection Facilities connect to the Transmission Provider's Transmission System to accommodate the interconnection of the Large Generating Facility to the Transmission Provider's Transmission System.

Voltage Criteria

Interconnecting to the PSCo bulk transmission system involves the Customer adhering to certain interconnection requirements as described in FERC Order 661A which is a order of interconnection requirements for wind generation plants. This order states requirements for power factor and voltage regulation at the POI to protect the reliability of the existing system.

From the 2013 benchmark case, the voltage at the 345 kV bus at Pawnee is reduced from 1.024 per unit to 1.016 per unit when the new GI-2008-8 generation facility is connected to PSCo system with the Customer's 345 kV transmission line and operating at full output (400 MW). In order to not allow the GI-2008-8 generation facility to affect the Pawnee bus voltages and existing generation capability, about 150 MVAR of switched capacitors, or other reactive power source, would need to be added. Table 3 shows that about 150 MVAR is needed when measured at Pawnee 345 kV (POI).

During periods when the wind generation is at minimal levels, line charging associated with the 345 kV lightly-loaded Customer transmission line results in the power factor at the POI to be outside the allowable range additionally voltages on the wind farm will tend to rise above acceptable levels. To restore the power factor at the POI to near unity and minimize the potential of high voltage on the wind farm, about 77 MVAR of switched reactors would likely be needed as indicated in Table 3.

Dynamic Analysis

Stability analysis was performed to determine the transmission response to disturbances such as faults, tripping of generators, or tripping of transmission lines. Generator monitoring, bus voltages, and power flows are all monitored before, during and after disturbances to determine if the system would remain stable.

Several faults and system outages were evaluated in the stability analysis for the area that could be impacted by adding the GI-2008-8 400 MW generating facility. This stability analysis has demonstrated that all the wind turbine generating units should remain on-line during the selected disturbances. Also, the oscillations for all the monitored units were positively damped and frequency and voltage levels were within criteria.

Figure 1 Simple Diagram of the Pawnee Interconnection at 345 kV – 2013

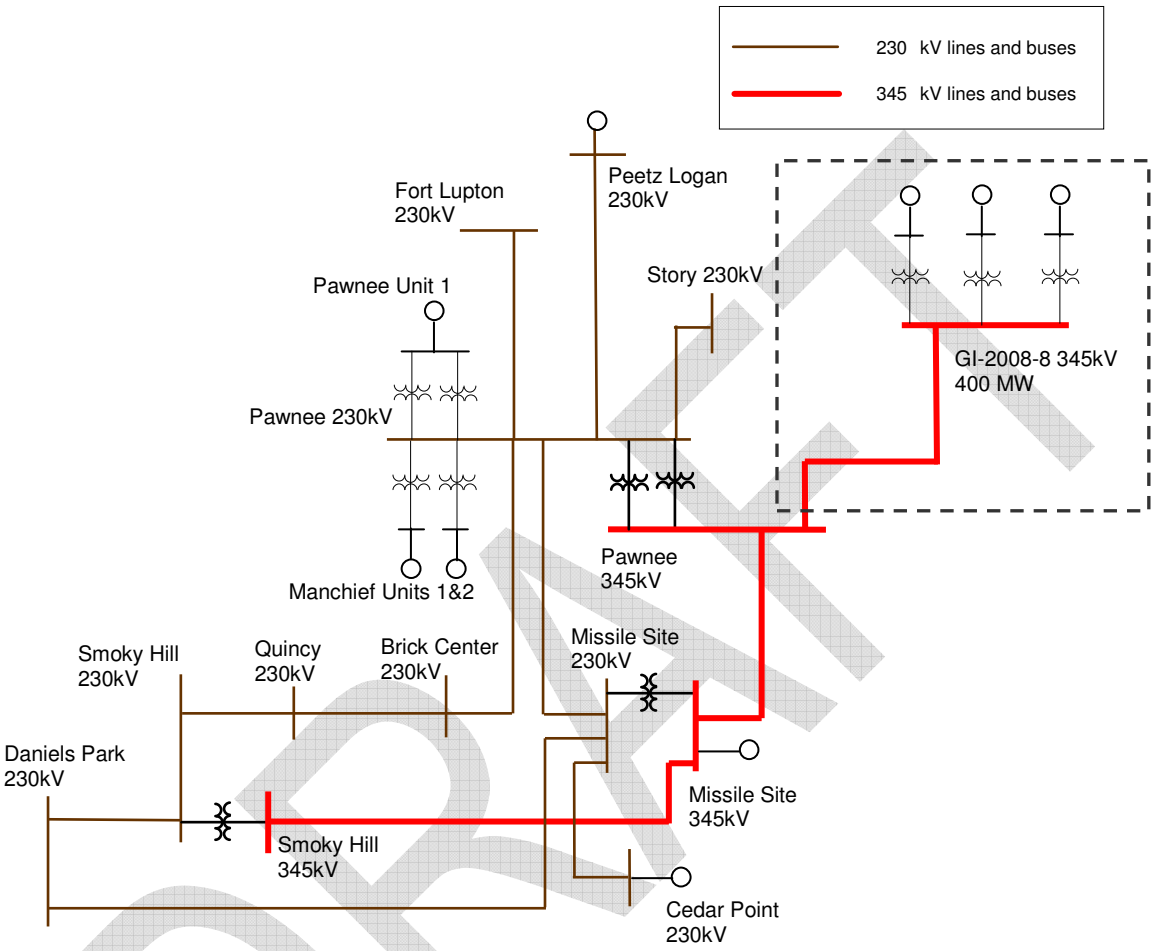
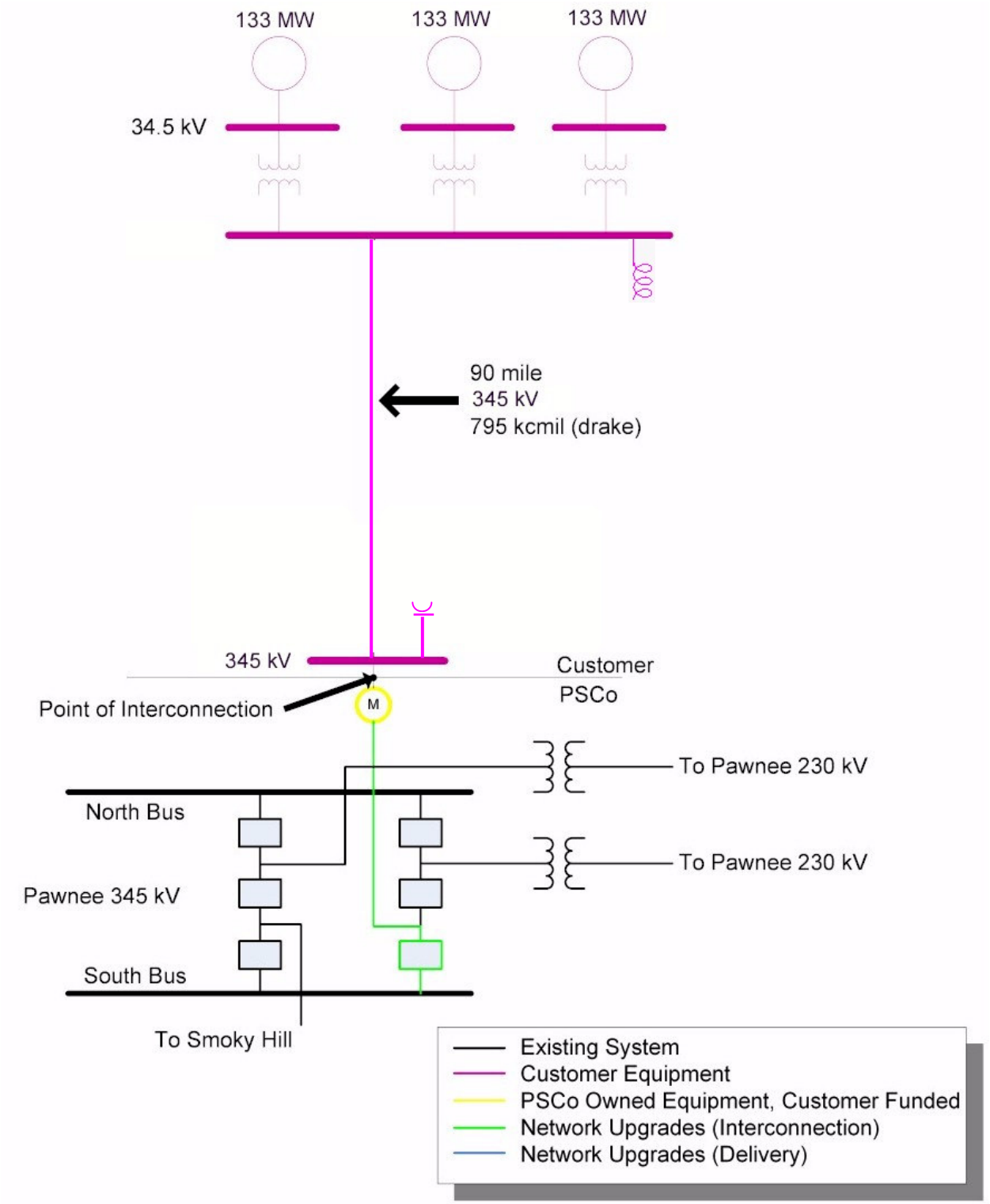


Figure 2 Preliminary One-Line of the Proposed 400 MW Generating Facility



Introduction

Public Service Company of Colorado (PSCo) received a large generator interconnection request (GI-2008-8) to interconnect 267 GE 1.5 MW wind turbines, with a total generator nameplate capacity of 400.5 MW, a commercial operation date of not before May 30, 2013 to coincide with the completion of the new 345 kV transmission line between Pawnee and Smoky Hill 345 kV substations, and a back-feed for site energization date of November 30, 2012. The proposed project would be located in Sedgewick County, Colorado. The GI-2008-8 project would be connected with a new 90-mile 345 kV transmission line to the Pawnee Substation. As per the customer's request, the 345 kV bus at Pawnee was considered to be the Point of Interconnection (POI). This request is evaluated as a stand-alone project with no other higher queued projects modeled.

The analytical efforts for this request were performed for a generation capacity of 400 MW facility consisting of 267 GE 1.5-MW wind turbines for the steady state, and stability analysis.

The Customer has requested that this project be evaluated as a Network Resource (NR) and an Energy Resource (ER), with the energy delivered to PSCo customers.

Study Scope and Analysis

The generation system impact study evaluated the transmission impacts associated with the proposed interconnection of 400 MW of energy from the point of interconnection to native PSCo loads. This study involves both steady state power flow analysis, and stability analysis.

The power flow analysis provides an identification of any thermal or voltage limit violations resulting from the interconnection, and, for a NR request, an indication of network upgrades required to deliver the proposed generation to PSCo loads.

PSCo adheres to NERC / WECC criteria as well as internal company criteria for planning studies. The following criteria were used for this study:

- For system impact study, the transmission system bus voltage must be maintained between 0.95 and 1.05 per unit, and the transmission line power flows must be maintained within 1.0 per unit of the line thermal rating.
- PSCo tries to maintain a transmission system voltage profile ranging from 1.02 per unit or higher at regulated buses, and 1.0 per unit or higher at non-regulated buses.
- Following a single element outage, the transmission system bus voltages must be maintained between 0.9 per unit to 1.10 per unit, and transmission line flows must be maintained within 1.0 per unit of the transmission line thermal ratings.

- The ideal voltage range for the buses at the Pawnee substation is between 1.03 per unit to 1.04 per unit.

For this project, potential affected parties include Intermountain REA and Tri-State G&T. PSCo has forwarded a copy of the feasibility study report to the affected utilities.

Power Flow Study Models

The proposed project is scheduled to be in service by May 30, 2013. For this study, it was evaluated for the 2013 time frame with the Point of Interconnection (POI) as the Pawnee 345 kV bus. Western Electric Coordinating Council (WECC) creates future power flow cases for transmission planning purposes. The power flow studies were based on a PSCo-developed 2013 heavy summer base case that originated from the study model developed in early 2010 as part of PSCo's normal annual Five Year Transmission Capital Budget project identification process. This budget case model was developed from Western Electricity Coordinating Council (WECC) approved models, modified as appropriate for PSCo planned and approved projects and associated topology. Load levels reflect expected 2013 heavy summer peak system conditions. Since the POI is located at Pawnee, generation schedules for the major sources of generation in this area were reviewed. All the significant resource were dispatched at maximum capacity; these resources include both Missile Site wind projects, a 200 MW facility connected to the Missile Site substation 345 kV bus, the Cedar Creek 250 MW facility connected to the Missile Site 230 kV bus, and the Peetz Logan (575-MW) wind farm. At Pawnee, the Pawnee unit 1 is dispatched at 505 MW and the Manchief units 1 and 2 are each dispatched at 130.5 MW. For the purpose of this study, the generation in area 70 (PSCo Transmission System) was re-dispatched to simulate north-to-south stress on the system. The TOT3 north-to-south flow was adjusted to 1280 MW. The Cedar Point 230 kV and the Peetz Logan wind farms were modeled in detail. The Cherokee Unit 3 was designated as the slack bus for Area 70. This constitutes the benchmark case.

The proposed wind generation facility, as modeled, consists of 267 GE 1.5-MW wind turbines. The turbines have a terminal voltage of 690 volts and are connected to the 34.5 kV collector system through individual step-up transformers. The current layout indicates a total of eighteen 34.5 kV feeder circuits for the entire wind farm. The facility has three 34.5 kV substation buses, with six feeder circuits connected to each bus. The 34.5 kV buses are connected to the 345 kV buses through identical 34.5/345 kV transformers.

For the purpose of this study, each of the turbines was represented as an individual generator, with a +/- 0.95 power factor, and a terminal voltage of 690 volts. The collector system for each circuit was modeled in detail, using the feeder impedances provided by the customer. The generation facility was connected to Xcel's 345 kV transmission system by a 90-mile 345 kV radial line. The power flow case, containing

the proposed generation facility delivering 400 MW, was modeled with the 345 kV interconnection point at Pawnee.

The new generation was assumed to displace generation in the southern part of PSCo system, in particular, the generation at Comanche units 2 and 3. The PSCo control area (Area 70) wind generation facilities, other than GI-2008-8, both Cedar Point wind stations and Peetz Logan, were dispatched to approximately 12% of facility ratings, consistent with other similar planning studies.

Power Flow Study Process

Automated contingency power flow studies were completed on all case models using the PSS®MUST program. This process was undertaken to determine if interconnecting the new facility would result in thermal overloads or voltage violations for the power flow case with the proposed generation facility compared with system behavior without GI-2008-8. The studies included all single line contingencies in Area 70 (PSCo) and Area 73 (WAPA RM). In the analysis, after switching each element out, the program re-solves the power flow case with all voltage taps and switched shunt devices locked, and control area interchange adjustments disabled and identifies facilities that do not meet relevant criteria.

Stand Alone Power Flow Results

AC Contingency analysis was performed to determine if interconnecting the wind generation facility results in thermal overloads or voltage violations. The stand-alone analysis reflected the new generation interconnecting at the Pawnee 345 kV bus in the power flow case at full output, or approximately 400 MW, with the rest of the generation and loads in the power flow model reflecting heavy summer load 2013 case. The contingency studies were performed for both the “with GI-2008-8” generation model and the benchmark model without the proposed wind farm.

The results for the AC contingency analysis for the Pawnee 345 kV POI were compared with those from the benchmark case. For the 2013 case with the proposed generation addition of 400 MW and without any transmission system reinforcements, there are facilities that are adversely impacted by the new generation. Those facilities that were observed to be adversely impacted are listed in Table 1.

Table 1. Preliminary AC Contingency Analysis for the 2013 Case Without Reinforcements

Monitored Element	Branch Rating	Loading as % of Branch Rating		Contingency
		Bench-mark Case	With GI-2008-8	
70396 SMOKYHIL 230 70599 SMOKYHIL 345 T4	560.0	122.4	142.5	70396 SMOKYHIL 230 70599 SMOKYHIL 345 T5
70396 SMOKYHIL 230 70599 SMOKYHIL 345 T5	560.0	122.4	142.5	70396 SMOKYHIL 230 70599 SMOKYHIL 345 T4
70545 BRICKCTR 230 70546 BRICKCTR 115 T1	200.0	95.9	108.4	70343 QUINCY 230 70545 BRICKCTR 230 1
73015 B.CK TRI 115 73020 BEAVERCK 115 1	200.0	97.0	107.3	70397 B.CRK_PS 115 73020 BEAVERCK 115 1
70107 CHEROKEE 230 70609 SILVSADL 230 1	401.0	101.5	105.5	5275_5270_5277
70112 CLARK 230 70212 GREENWD 230 1	438.0	88.2	108.3	5167_5285
70112 CLARK 230 70241 JORDAN 230 1	438.0	112.5	132.6	5167_5285
70241 JORDAN 230 70313 ORCHARD 230 1	442.0	117.9	137.9	5167_5285
70283 MEADOWHL 230 70313 ORCHARD 230 1	442.0	129.1	149.0	5167_5285

Since several lines would be overloaded under contingency conditions when the GI-2008-8 facility is connected to the Pawnee substation, network upgrades are necessary to accommodate the injection of 400 MW at Pawnee. A 345 kV line from Pawnee to Smoky Hill is included in the benchmark case as a network upgrade in the PSCo capital budget, as PSCo has received the CPCN necessary construct this transmission line. It is expected that the 345 kV line along with the necessary 345/230 kV transformers will be operational by the May 2013 timeframe.

Table 1 shows that, for the full output of GI-2008-8, there is a contingency overload of the Smoky Hill 345/230 kV transformers at 142.5% of it's 560 MVA rating with the outage of the parallel unit. The next limiting elements would be the Brick Center 230/115 kV transformer, at 108.4% of its 200 MVA rating. In the system operated by Tri-State G&T, there is also a contingency overload of the Beaver Creek 115 kV transmission line at 107.4% of the 200 MVA rating

Included in Table 1 are two common-mode contingencies, 5275_5270_5277 and 5167-5285. These common-mode contingencies are described in Table 2. The contingent loading of the Cherokee to Silver Saddle 230 kV line increases due to the addition of GI-2008-8, but the increase is within a 5% accommodation level. The contingency loading on the Clark to Smoky Hill 230 kV line also increases due to the addition of GI-2008-8. For this contingency loading, the increase is approximately 19%. Also, due to the common mode contingency, the outage of circuits 5167 and 5285, an overload of the Clark to Greenwood 230kV transmission line at 108.3% of it's 438 MVA rating exists due to the addition of GI-2008-8.

Table 2. Common-Mode Contingency Descriptions

Contingency Name 5167_5285
SMOKYHIL to BUCKLY34 345 kV
BUCKLY34 to TOLGATE 345 kV
TOLGATE to JEWELL2 345 kV
JEWELL2 to LEETSDAL 345 kV
SMOKYHIL to BUCKLY12 345 kV
BUCKLY12 to JEWELL1 345 kV
JEWELL1 to SULLIVN 345 kV

Contingency Name 5275_5270_5277
GREENVAL to SKYRANCH 345 kV
GREENVAL to SPRUCE 345 kV
GREENVAL to IMBODEN 345 kV
IMBODEN to SPRUCE 345 kV

Possible network reinforcements to address the single contingency overloads would be to add a second 230/115 kV transformer at Brick Center and a third 345/230 kV transformer at Smoky Hill. These network upgrades were modeled and the contingency analysis was performed to identify any new violations resulted from these network upgrades. The results of this analysis with these system upgrades indicated that the overloads were resolved, and showed no new violations under single contingency conditions. While there were some small changes in results seen under the common-mode outages, the loading tended to be slightly lower in the case with the reinforcements added. The Beaver Creek 115 kV transmission line, operated by Tri-State G&T, remains a contingency overload, but loadings are approximately 1% lower after network upgrades were modeled. The results after the network upgrades were modeled are shown in Table 3.

Table 3. Preliminary AC Contingency Analysis for the 2013 Case <u>With</u> Reinforcements

Monitored Element	Branch Rating	Loading as % of Branch Rating		Contingency
		Bench-mark Case	With GI-2008-8	
73015 B.CK TRI 115 73020 BEAVERCK 115 1	200.0	96.1	106.2	70397 B.CRK_PS 115 73020 BEAVERCK 115 1
70107 CHEROKEE 230 70609 SILVSADL 230 1	401.0	101.3	104.8	5275_5270_5277
70112 CLARK 230 70212 GREENWD 230 1	438.0	89.2	110.2	5167_5285
70112 CLARK 230 70241 JORDAN 230 1	438.0	113.5	134.6	5167_5285
70241 JORDAN 230 70313 ORCHARD 230 1	442.0	118.9	139.8	5167_5285
70283 MEADOWHL 230 70313 ORCHARD 230 1	442.0	130.0	150.9	5167_5285
70283 MEADOWHL 230 70396 SMOKYHIL 230 1	557.0	113.1	129.6	5167_5285

<u>Voltage Criteria Violations</u>

Interconnecting to the PSCo bulk transmission system involves the Customer adhering to certain interconnection requirements. These requirements are contained in the <u>Interconnection Guidelines for Transmission Interconnected Producer-Owned</u>

Generation Greater than 20 MW (Guidelines). The Guidelines make reference to interconnection requirements from FERC Order 661A. FERC Order 661A describes the interconnection requirements for wind generation plants. In addition, PSCo System Operations conducts commissioning tests prior to the commercial in-service date for a Customer's facilities. Some of the requirements that the Customer must complete include the following:

1. A wind generating plant shall maintain a power factor within the range of 0.95 leading to 0.95 lagging, measured at the POI, if the Transmission Provider's System Impact Study shows that such a requirement is necessary to ensure safety or reliability.
2. The System Impact Study will investigate pertinent demand, dispatch, and outage scenarios based on the defined study area that includes the proposed POI. The study will conform to the NERC Transmission System Planning Performance Requirements (TPL standards).
3. The results of the System Impact Study (mentioned in Item 1 and 2 above) do not absolve the Customer from its responsibility to demonstrate to the satisfaction of PSCo System Operations prior to the commercial in-service date that it can safely operate within the required power factor and voltage ranges.
4. Reactive Power Control at the POI is the responsibility of the Customer. Additional Customer studies should be conducted by Customer to ensure that the facilities can meet the power factor control test and the voltage controller test when the facility is undergoing commissioning testing.
5. PSCo System Operations will require the Customer to perform operational tests prior to commercial operation that would verify that the equipment installed by the Customer meets operational requirements.
6. It is the responsibility of the Customer to determine what type of equipment (DVAR, added switched capacitors, SVC, reactors, etc.), the ratings (MVAR, voltage--34.5 kV or 345 kV), and the locations of those facilities that may be needed for acceptable performance during the commissioning testing.
7. PSCo requires the Customer to provide a single point of contact to coordinate compliance with the power factor and voltage regulation at the POI. The reactive flow at the end of 345 kV line near the POI will need to be controlled according to the Interconnection Guidelines

According to WECC/NERC criteria, it is necessary to maintain voltages at all buses in the system between 0.95 per unit to 1.05 per unit under operating conditions. In the Rocky Mountain Voltage Coordination Guidelines that were developed by the Voltage Coordination Guideline Subcommittee of the Colorado Coordinated Planning Group, the ideal voltage range for the 345 kV bus voltage at Pawnee is 1.03 – 1.04 per unit.

In the 2013 benchmark case, the voltage at the 230 kV bus at Pawnee is 1.024 per unit, with Peetz Logan generation at 575 MW. The voltage at this bus decreases in the 2013 analysis to 1.016 per unit when the new GI-2008-8 generation facility is connected to PSCo system with the Customer's 345 kV transmission line and operating at full output

(400 MW). In order to restore the Pawnee bus voltages to the benchmark levels, a significant amount of switched capacitors, or other reactive power source, would need to be added. Table 3 shows that about 150 MVAR is needed when installed near the Pawnee 345 kV (POI) bus. In this study, the capacitor was modeled at a 345kV bus 5% away from Pawnee on the Pawnee to GI-2008-8 project 345kV transmission line.

During periods of minimal wind generation, line charging associated with the 90-mile 345 kV lightly-loaded Customer transmission line results in the power factor at the POI to be outside the range of 0.95 leading to 0.95 lagging. In addition, with that 345 kV line, voltages on the wind farm will rise above 1.05 pu when the wind farm is generating near zero MW. In this study the maximum bus voltage when generating zero MW and no reactors installed was 1.053 pu at the wind farm. To restore the power factor at the POI to near unity and minimize the potential of high voltage on the wind farm, 77 MVAR of switched reactors would likely be needed by the customer's facility; for this study these were assumed to be added at the customer's 345/34.5 kV substation on the 345 kV bus. The reactor sizing was established by setting MVAR flow at Pawnee 345kV (POI) to zero. With this reactor modeled, the maximum bus voltage at the wind farm was 1.006 pu, measured at the wind turbine generator bus, when generating zero MW.

Table 4. Preliminary Reactive Power Requirements

	2013 Base Case		
	Without GI-2008-8	**With GI-2008-8 (No Capacitor Support)**	**With GI-2008-8 and 150 MVAR Developer Capacitor**
Voltage at the Pawnee 230 kV (p.u.)	1.024	1.016	1.024
Reactive power drawn at 345 kV Pawnee bus at maximum GI-2008-8 generation (MVAR)	-	66.2	-92.6
Manchief Unit 1 & 2 MVAR generation (MVAR each)	56.1	65	56.1
Pawnee unit 1 MVAR generation in benchmark case without GI-2008-8 (MVAR)	113.4	168.8	113.4
Switched shunt capacitor size to maintain voltage at POI at full generation (MVAR)	-	150	150
Reactor size to maintain VAR neutrality at POI at 0 MW GI-2008-8 generation (MVAR)	-	77	77

The results of the steady state contingency analysis do not indicate high or low voltage violations or any voltage deviation criteria violations as a result of the studied contingencies.

It is the responsibility of the Customer to determine what type of equipment (CVAR, added switched capacitors, STATCOM, SVC, reactors, etc.), at what overall ratings (MVAR, voltage-34.5 kV, 230 kV, 345 kV), and at what locations (at the wind farm, near the POI) will be added to meet these reactive power control requirements. The voltage-tap settings on the main power transformers that connect the 34.5 kV system to the Customer's transmission line will impact the operating voltages and related reactive

power capabilities and requirements for the GI-2008-8 facility. This should also be considered by the Customer in determining the final design equipment and parameters.

Dynamic Analysis

Stability studies determine the response of the transmission system to system disturbances such as the occurrence of faults, tripping of generators, tripping of transmission lines, or tripping of loads in the study area. Typical results that are monitored in these studies include generator frequency, generator rotor angles, bus voltages and power flows before, during and after a disturbance to determine if the system would remain stable after the disturbance. In addition, FERC Order 661A requires wind generating plants to remain on-line during voltage disturbances up to the time periods and associated voltage levels set for in the Low Voltage Ride-Through (LVRT) capability standard.

Stability analyses were performed for a number of three-phase faults near the Pawnee POI, including by Cedar Point, Missile Site and Story. Normal fault clearing times of 5 cycles for 345 kV and 230 kV facilities were used in this study; delayed clearing cases were not considered in this study. The 575 MW of wind generation at Peetz Logan was modeled in detail, reflecting the various wind turbines and the feeder impedances. The GI-2008-8 wind generating facility was modeled at the 690 volt level, with each turbine connected through a generator step-up transformer (GSU) to 34.5 kV. The 34.5 kV collector system at GI-2008-8 consists of 18 circuits. These circuits were modeled in complete detail with the turbines represented by individual generators connected to feeders with detailed impedance for each circuit as provided by the customer.

Most of the system disturbances simulated were three-phase faults by the indicated location shown in Table 4. For each of those contingencies, a three-phase fault was applied at a bus for 5 cycles and appropriate action is taken to clear the fault. This procedure was done for both cases with and without generation at GI-2008-8. For three contingencies, sudden loss of equipment without a fault was studied.

The results indicate that the system remains stable during and after each contingency studied. All system oscillations were damped quickly and all expected generation remained online. For contingencies where generating units were suddenly lost or would become isolated due to fault clearing activities, all remaining generation remained on line and the system exhibited stable operation. All wind turbines at GI-2008-8 remained on-line for all system disturbances that did not disconnect the proposed project. The voltage recovery at Pawnee, Peetz Logan, Missile Site and Brick Center buses was observed to be within criteria as it was in benchmark case.

Table 5. Preliminary Transient Stability Analysis Results

Cont	Fault Location	Action	Benchmark Case	With GI-2008-8 Generation
1	Pawnee 230 kV	Trip Pawnee to Story 230 kV	Stable	Stable
2	Story 230 kV	Trip Pawnee to Story 230 kV	Stable	Stable
3	Pawnee 345 kV	Trip Pawnee to Missile Site 345 kV	Stable	Stable
4	Missile Site 345 kV	Trip Pawnee to Missile Site 345 kV	Stable	Stable
5	Pawnee 345 kV	Trip Pawnee 345/230 kV Transformer	Stable	Stable
6	Pawnee 230 kV	Trip Pawnee 345/230 kV Transformer	Stable	Stable
7	Pawnee 230 kV	Trip Pawnee to Peetz Logan 230 kV	Stable, generation disconnected	Stable, generation disconnected
8	Pawnee 230 kV	Trip Pawnee 230/22 kV Step-up Transformer	Stable, generation disconnected	Stable, generation disconnected
9	Pawnee 230 kV	Trip Pawnee to Fort Lupton 230 kV	Stable	Stable
10	Pawnee 230 kV	Trip Pawnee to Brick Center 230 kV	Stable	Stable
11	Missile Site 230 kV	Trip Missile Site to Smoky Hill 230 kV	Stable	Stable
12	-	Trip Missile Site to Smoky Hill 230 kV	Stable	Stable
13	-	Trip Pawnee to Missile Site 230 kV	Stable	Stable
14	Story 230 kV	Trip North Yuma to Story 230 kV	Stable	Stable
15	-	Trip Pawnee Generator	Stable, generation disconnected	Stable, generation disconnected

Costs Estimates and Assumptions

The estimated total cost for the required upgrades is approximately **$1,542,000.**

The estimated costs shown are (+/-30%) estimates in 2011 dollars. No escalation was applied. The costs 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. This estimate did not include the cost for any other Customer owned equipment and associated design and engineering.

This estimate does not include any network reinforcements that may be required to meet the interconnection guidelines as required by PSCo in the Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater than 20 MW (Guidelines). Other projects, including the required Pawnee – Smoky Hill 345 kV line, are included in the PSCo Capital Budget process and are assumed to be in-service by the commercial in-service date of the 400 MW project.

The following tables lists 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.

Table 6 PSCo Owned; Customer Funded Interconnection Facilities

Element	Description	Cost Est. Millions
PSCo's Pawnee 345kV Substation	Interconnect Customer at PSCo's Pawnee Substation. The new equipment includes a 345kV 2000A gang switch, bi-directional metering, control area boundary metering, relaying and associated equipment and material.	**$0.695**
	Transmission tie line into substation.	**$0.232**
	Customer Generator Communication to Lookout.	**$0.010**
	Customer LF/AGC and Generator Witness Testing.	**$0.140**
	Siting and Land Rights for required easements, reports, permits and licenses.	**$0.010**
	Total Cost Estimate for Customer Interconnection Facilities	**$1.087**
Time Frame		**12 Months**

Table 7 PSCo Owned; PSCo Funded Interconnection Facilities

Element	Description	Cost
PSCo's Pawnee 345kV Substation	Interconnect Customer at PSCo's Pawnee 345kV Substation. New 345kV line termination requiring the following equipment: • one 345kV 40 kA, dead tank circuit breaker • one 345kV, 3000 amp gang switch • electrical bus work • required steel and foundations • minor site work (station wiring, grounding)	**$0.455**
Time Frame		**4 Months**

Table 8 Total Project Cost

	Total Cost of Project	**$1.542**
Time Frame		**12 Months**

Assumptions

- The cost estimates provided are "scoping estimates" with an accuracy of +/- 30%.
- Estimates are based on 2011 dollars (no escalation applied) for the customer responsibility costs and on 2011 dollars for the PSCo responsibility costs.
- There is no contingency added to the estimates.
- AFUDC is included for network upgrades, excluded in delivery upgrades.
- Labor is estimated for straight time only – no overtime included.

- PSCo (or its Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- Project feasibility and ISD is contingent upon the completion of the Pawnee – Smoky Hill 345 kV Project: A 345 kV transmission line that will be installed between Pawnee Substation and Smoky Hill Substation, proposed in accordance to SB-07-100, with an approximate in service date of May 2013.
- Due to customer's transmission line length, dual power line carrier will be installed for relay communications.
- Addition of generation does not require any breakers to be replaced due to fault interruption rating.
- The Wind Site is not in PSCo's service territory. The local utility will provide station service power to the generator.
- The estimated time for design and construction of PSCo network upgrades for interconnection is at least 12 months and is completely independent of other queued projects and their respective ISD's.
- This is a preliminary study only and the results have not been verified.