Interconnection Feasibility Study Report
Request # GI-2008-14
Working Draft

400 MW Wind Powered Generation Interconnecting at Green Valley Substation

PSCo Transmission Planning
November 2009

A. Executive Summary

On September 23, 2008 Public Service Company of Colorado (PSCo) Transmission Planning received a generation interconnection request to determine the potential system impacts associated with interconnecting a 405-MW wind generation facility at the Green Valley Substation through a 165-mile transmission line. The 230-kV bus at Green Valley was considered to be the primary Point of Interconnection (POI). The 345 kV bus at Green Valley is also analyzed as an alternative Point of Interconnection. The customer requested a commercial operation date for the expansion of December 31, 2011, and a back-feed for site energization date of September 30, 2011. Based on this feasibility study, the interconnection at the 230 kV bus as requested by the Customer was not determined feasible; therefore, it is recommended that the Customer's POI ultimately be at the 345-kV bus at Green Valley. 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 short-circuit 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 2011. The main purpose of this study was to evaluate the potential impact of GI-2008-14 on the PSCo transmission infrastructure as well as that of neighboring entities, when injecting a total of 400 MW of wind turbine generation into Green Valley, and delivering the

[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.

additional generation to native PSCo loads. The costs to interconnect the project with the transmission system at the Green Valley Substation have been evaluated by PSCo Engineering. 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 2011 budget model with heavy summer load and moderately heavy stressed north-to-south (HSHN) flows.

Energy Resource (ER)

The results of this Feasibility Study indicate that firm transmission capacity for the 400 MW wind generation facility expansion is not available due to existing overloads and firm transmission commitments and is not possible without the construction of network reinforcements. Non-firm transmission capability may be available depending on marketing activities, dispatch patterns, generation levels, demand levels, import path levels (TOT3, etc.) and the operational status of transmission facilities.

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.

As a network request, a contingency analysis was performed to determine the network upgrades that would be required to deliver the entire output of the GI-2008-14 wind facility as provided at the POI to PSCo native load customers. Interconnection at the 230 kV bus was not determined feasible; therefore it is recommended that the Customer's POI ultimately be at the 345-kV bus at Green Valley. Under that condition, the estimated cost of the recommended system upgrades to accommodate the project is approximately **$**_____ and includes:

- ***$0 for PSCo-Owned, Customer-Funded Interconnection Facilities***
- ***$0 for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection***

- ***$0 for PSCo Network Upgrades for Delivery. This assumes that PSCo completes the network upgrade projects that have been identified and included in the PSCo Transmission Capital Budget.***

Based upon the steady-state analysis performed for the feasibility, the full 400-MW generation output of the GI-2008-14 project could be provided to PSCo after reinforcements to the PSCo transmission system have been completed. PSCo will complete these reinforcements through its capital budget process for transmission upgrades.

The feasibility study indicates that approximately 50 - 110 MVAR of reactors will likely be required for the Customer's wind generating plant to maintain a power factor within the range of 0.95 leading to 0.95 lagging near minimum generation levels, measured at the POI. This would be needed whenever the Customer facilities are off-line or generating at very low levels while the Customer is connected to the POI. In addition, about 70 - 400 MVAR of switched capacitors will be needed to meet the voltage criteria at the POI near maximum generation depending on the POI and transmission voltage selected. More detailed studies should be performed by the Customer to ensure that proposed wind generation facility will display acceptable performance during the commissioning testing. If the Customer advances the request to the system impact study phase, the results of the stability analysis may modify the nature of the reactive power support that may be required of the Customer for the project to meet relevant reliability criteria.

Interconnecting to the PSCo bulk transmission system requires the Customer to adhere to certain interconnection requirements. These requirements are contained in the Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater than 20 MW (Guidelines). The Guidelines make reference to interconnection requirements resulting 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. The Transmission Provider's System Impact Study is needed to demonstrate that such a power factor requirement is necessary to ensure safety or reliability.

2. The voltage at a POI shall be maintained in the ideal voltage range for the appropriate Colorado region and bus type (regulating[3] or non-regulating) as

[3] A regulating bus is defined in the Rocky Mountain Area Voltage Coordination Guidelines as any transmission or generation bus with controllable VAR's. This implies that the bus has a voltage schedule that is being regulated by a generating facility. Generating facilities include Static VAR Compensators (SVC's), synchronous generators, or synchronous condensers that can supply fast-acting reactive power (VAR) compensation to dynamically regulate voltage at a power system bus. Switchable capacitors, switchable reactors, load tap changing transformers, etc. are not defined as generating facilities as they do not provide controllable dynamic VARs'.

determined in the Rocky Mountain Area Voltage Coordination Guidelines[4]. The System Impact Study will investigate pertinent demand (on-peak or off-peak), season (summer or winter), 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 POI for a wind generating facility cannot be declared a regulating bus unless system studies demonstrate that the designation of the POI as a regulating bus is needed for system reliability or safety.

4. The impact of the wind generating facility on the reactive power schedules of nearby generating units may need to be mitigated by the Customer if system studies demonstrate that the proposed wind generating facility causes nearby generating units to generate or absorb reactive power for voltage control [5]. It is understood that sufficient reactive power reserve must be maintained on generating units to allow them to dynamically regulate voltage for extreme system conditions.

5. If a wind generating facility is interconnected to the bulk transmission system but is operating with its generation off-line and receiving power from the bulk transmission system for its station service requirements, that facility is acting as a load and will be required to maintain the power factor at the POI within 98% lagging or leading (when the station service load is greater than 85% of maximum) as per the Xcel Energy document titled Interconnection Guidelines For Transmission Interconnected Customer Loads.

6. 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.

7. It is the responsibility of the Customer to determine what type of equipment (DVAR, added switched capacitors, SVC, reactors, etc.), the ratings, and the

[4] The Voltage Coordination Guidelines Subcommittee (VCGS) of the Colorado Coordinated Planning Group developed the guidelines. The subcommittee consisted of representatives from major Colorado utilities including Colorado Springs Utilities, Platte River Power Authority, Tri-State Generation and Transmission, Public Service Company of Colorado, and Western Area Power Administration-Rocky Mountain Region. Other major utilities outside of Colorado were also involved in the development of these guidelines.

[5] The Rocky Mountain Area Voltage Coordination Guidelines (July 2006), page 8 of 34, Item 6, states that "Static VAR sources (switched shunt capacitors, reactors) should be operated to control the voltage profile before relying on LTC or generator VAR output, and should be used in such a manner to keep LTC transformers near their nominal tap range and to keep reactive margin on generating equipment. The rationale for this goal is that the generator is a dynamic reactive source that can provide high-speed reactive support to the transmission system after a disturbance that results in low voltages, or conversely are in a position to reduce voltages after a contingency that results in high voltages. Keeping transformers near their mid-tap range also allows for maximum response to either boost or reduce voltages following a disturbance".

locations of those facilities that may be needed for acceptable performance during the commissioning testing.

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 the line near the POI will need to be controlled according to the Interconnection Guidelines.

The Interconnection Agreement (IA) requires that certain conditions be met, as follows:

1. The conditions of the Large Generator Interconnection Guidelines[6] (LGIG) are met.

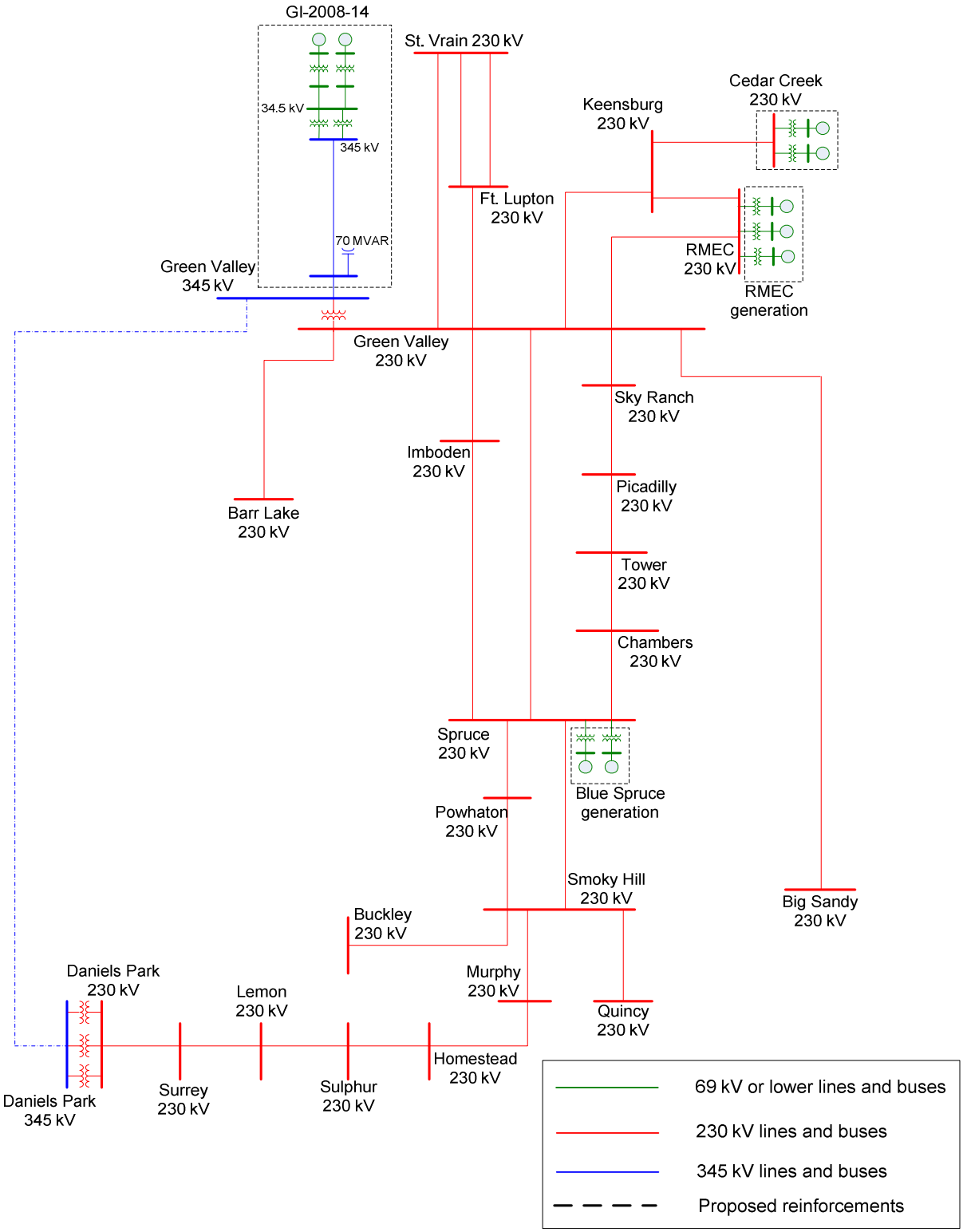
2. A single point of contact is given to Operations to manage the transmission system reliably for all wind projects using the transmission facilities associated with GI-2008-14 that deliver power to the Green Valley POI, as indicated in the Interconnection Guidelines.

3. PSCo will require testing of the full range of 0 MW to 400 MW of the wind project. These tests will include, but not be limited to, power factor (pf) control, and voltage control as measured at the Green Valley POI for various generation output levels (0 to 400 MW) of the overall wind generation facility.

4. The Customer must show that the power factor at the POI is within the required +/-0.95 power factor range at all levels of generation and that the voltage levels and changes are within reliability criteria as measured at the POI for the full range of testing (including generator off-line conditions).

[6] Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater than 20 MW, version 3.0, 12/31/06

Figure 1. Simple Diagram of the Green Valley Interconnection at 345-kV – 2011



Introduction

Public Service Company of Colorado (PSCo) received a large generator interconnection request (GI-2008-14) to interconnect 270 GE 1.5 MW wind turbines, with a total generator nameplate capacity of 405 MW, a commercial operation date of December 31, 2011, and a back-feed for site energization date of September 30, 2011. The proposed project would be located in Sedgewick County, Colorado. The GI-2008-14 project would be connected with a new 165-mile transmission line to the Green Valley Substation. As per the customer's request, the 230-kV bus at Green Valley was considered to be the primary Point of Interconnection (POI). A 345-kV POI at Green Valley was considered as an alternative. Interconnection at the 230 kV bus was not determined feasible, therefore it is recommended that the Customer's POI ultimately be at the 345-kV bus at Green Valley. This request is evaluated as a stand-alone project with no other higher queued projects modeled.

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

B. Study Scope and Analysis

This feasibility study evaluates the feasibility of providing 400 MW of energy from GI-2008-14 through the point of interconnection at Green Valley to PSCO native loads. This request was studied both as an Energy Resource (ER) as well as a Network Resource (NR). This feasibility study consisted of both steady state power flow analysis and short circuit analysis. The power flow analysis provides a preliminary identification of any thermal or voltage limit violations resulting from the interconnection, and for an NR request, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identifies any circuit breakers with 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.

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 intact conditions, transmission system bus voltages must be maintained between 0.95 and 1.05 per-unit of system nominal / normal conditions, and steady-state power flows must be maintained within 1.0 per-unit of all elements' thermal (continuous current or MVA) ratings.
- PSCO tries to maintain a transmission system voltage profile ranging from 1.02 per unit or higher at regulating buses, and 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 between

0.92 per-unit and 1.07 per-unit at load buses for PRPA), and power flows within 1.0 per-unit of the elements' continuous thermal ratings.

For this project, the potential affected party is Tri-State Generation and Transmission (TSG&T). PSCo will provide TSG&T with a copy of this feasibility study report and will work with TSGT during the system impact study phase.

C. Power Flow study Models

Western Electricity Coordinating Council (WECC) coordinates the preparation of regional power flow cases for transmission planning purposes. PSCo transmission developed a base case for the 2011 heavy summer peak load as a part of their annual five-year project identification process, from WECC approved models and modified for PSCo-approved projects and topology changes. In the 2011 case, the following generators in Area 70 (PSCo Transmission) were re-dispatched to simulate high north-to-south stressed system conditions.

- The generation at RMEC, Spruce, Ft. St. Vrain, Cherokee, Brighton and the thermal units at Ft. Lupton were increased to their maximum value.
- The generation at Cedar Creek was raised to its maximum capacity of 300 MW.
- The generation at Peetz Logan was decreased to 12% of its maximum capacity.
- To accommodate this increase in generation, the generation at Comanche as decreased and the Lamar DC tie was set to 0 MW.

Implementation of these changes resulted in the benchmark case used for this study. Comanche Unit 1 was designated as the Slack bus for Area 70.

Using the 2011 benchmark case as the starting point, two power flow models were developed to reflect the GI-2008-14 project with the two potential transmission line alternatives and POIs, at 230-kV and 345-kV. The proposed wind generation facility consists of 270 General Electric (GE) 1.5 MW wind turbines. The turbines have a terminal voltage of 575 volts. For this feasibility study, the turbines have been represented as two equivalent generators of 200 MW with a terminal voltage of 575 volts, which is stepped up to 34.5 kV.

The Customer has requested that the study consider a 230-kV interconnection at Green Valley. However, an alternate 345-kV POI at Green Valley was also considered. The wind generation facility would be connected to the Green Valley substation by a radial transmission line, 165 miles long, at either 230-kV or 345-kV bus. However, there is no 345-kV bus at Green Valley. Therefore, for the Customer's 345-kV transmission line alternative, a 560-MVA 345/230-kV transformer has been assumed to be added to the PSCo transmission system at Green Valley. For the 230-kV interconnection, the following has been added to the benchmark power flow case for 2011:

1. The GI-2008-14 generation and a simplistic 34.5-kV collector system

2. Two 200-MVA 34.5/230-kV transformers at the wind farm site
3. 165-mile transmission line built for and operated at 230-kV operation

In the 345-kV interconnection alternative, the 2011 benchmark power flow case was modified to include:

1. The GI-2008-14 generation and 34.5-kV collector system
2. Two 200-MVA 34.5/230-kV transformers at the wind farm site
3. 165-mile transmission line built for and operated at 345-kV operation
4. One 560-MVA 345/230-kV transformer at Green Valley

A bundled 1272-kcmil ACSR (Bittern) conductor was used for the radial line connecting the proposed facility to PSCo system. The line impedance parameters for the 165-mile line were calculated for each voltage level using the PSS®E program TMLC. The new generation from GI-2008-14 was accommodated by decreasing generation at Comanche unit 2 and unit 3.

D. Power Flow Study Process

Automated contingency power flow studies were completed on all power flow models using the PSS®MUST program, switching out single elements one at a time for all of the elements (lines and transformers) in control areas 70 (PSCo) and 73 (WAPA RM). Upon switching each element out, the program re-solves the power flow model with all transformer taps and switched shunt devices locked, and control area interchange adjustments disabled.

E. Power Flow Results

When GI-2008-14 delivers 400 MW at the 230-kV bus at Green Valley, the power flow case does not converge. The case converges only when a 180 MVAR capacitor is connected close to the POI and another one of the same size close to the generation facility. No attempt has been made to optimize other configurations. In addition, larger switched capacitors or other reactive power support will be required to meet reactive power requirements at the POI.

The results for the single line contingency analysis when 400 MW are connected to the Green Valley Substation are shown in Table 1. Connecting the new wind generation facility to the 230-kV bus at Green Valley without any reinforcements causes several lines in PSCo's system as well as in the TSG&T's system to overload. In comparing the results of the contingency analysis with the benchmark case for Area 70 (PSCo system), the 230-kV lines from Green Valley to Imboden, Imboden to Spruce, Spruce to Smoky Hill, Smoky Hill to Powhaton, Spruce to Powhaton and Washington to JL Green get overloaded under certain single line contingencies.

The 230-kV lines from Barr Lake to Green Valley, Cherokee to Lacombe and Ft. Lupton to JL Green are also overloaded. However, the thermal ratings of these lines have

been revised from 159 MVA, 517 MVA and 478 MVA to 518 MVA, 859 MVA and 571 MVA respectively as per the Substation/Transmission Facility Equipment Rating FAC-009 list. Therefore these lines would no longer be overloaded. The ratings of the 230-kV lines from green Valley to Imboden and Imboden to Spruce have also been revised from 479 MVA and 435 MVA respectively to 490 MVA. However, the loading on these lines is greater than the revised ratings and therefore they would still be overloaded.

Table 1. AC contingency analysis results for the 2011 case without reinforcements

** From bus ** ** To bus ** CKT	Branch Rating	Loading as % of branch rating			Contingency
		bench-mark	POI @ 230 kV	POI @ 345 kV	
70047 BARRLAKE 230 70048 GREENVAL 230 1	159.0	193.5	227.0	229.9	70192 FTLUPTON 230 70529 JLGREEN 230 1
70048 GREENVAL 230 70526 IMBODEN 230 1	479.0	101.2	120.7	122.4	70048 GREENVAL 230 70528 SPRUCE 230 1
70048 GREENVAL 230 70630 GEN CAP1 230 1	461.0	N/A	188.4		70625 GI_2008_14 230 70631 GEN CAP 2 230 1
70107 CHEROKEE 230 70324 LACOMBE 230 1	517.0	101.0	111.0	111.8	70266 LOOKOUT 230 70480 WESTPS 230 1
70192 FTLUPTON 230 70529 JLGREEN 230 1	478.0	99.3	103.7	104.1	70192 FTLUPTON 230 70605 HENRYLAK 230 1
70274 MALTA 230 73138 MT.ELBRT 230 1	159.0	N/A	129.5	128.6	70625 GI_2008_14 230 70631 GEN CAP 2 230 1
70396 SMOKYHIL 230 70528 SPRUCE 230 2	800.0	94.2	109.9	111.2	5177
70396 SMOKYHIL 230 70532 POWHATON 230 1	800.0	94.2	109.9	111.2	70396 SMOKYHIL 230 70528 SPRUCE 230 2
70526 IMBODEN 230 70528 SPRUCE 230 1	435.0	109.8	131.2	133.1	70048 GREENVAL 230 70528 SPRUCE 230 1
70528 SPRUCE 230 70532 POWHATON 230 1	800.0	94.2	109.9	111.2	70396 SMOKYHIL 230 70528 SPRUCE 230 2
70538 CHMBERS 115 70539 CHMBERS 230 1	280.0	91.3	100.7	101.5	70396 SMOKYHIL 230 70528 SPRUCE 230 2
70630 GEN CAP1 230 70631 GEN CAP 2 230 1	461.0	N/A	134.9		70625 GI_2008_14 230 70631 GEN CAP 2 230 1
70461 WASHINGT 230 70529 JLGREEN 230 1	488.0	95.5		100.2	70192 FTLUPTON 230 70605 HENRYLAK 230 1

5177 70528 SPRUCE 230 70532 POWHATON 230
70396 SMOKYHIL 230 70532 POWHATON 230

The loss of the radial line from the generating facility to the POI causes the power flow case to diverge. This is due to the large capacitors connected to support the radial line when the facility is at maximum output. For normal operation, the capacitor will be switched off for the loss of this line and this issue would not occur.

Since several lines would be overloaded under contingency conditions when the GI-2008-14 facility is connected to the Green Valley substation, network upgrades are necessary to accommodate the injection of 400 MW. The following network upgrades were considered for this study.

Option 1: 345kV line from Green Valley to Smoky Hill

Option 2: 230kV line from Green Valley to Barr Lake

Option 3: 230kV line from Green Valley to Cherokee

Option 4: 345kV line from Green valley to Daniels Park

The results of the AC contingency analysis with the proposed reinforcements were compared with the benchmark case, as shown in Table 2. In all these cases, a 345-kV bus at Green Valley was considered to be the POI.

As discussed previously, the ratings 230-kV lines from Barr Lake to Green Valley, Cherokee to Lacombe and Ft Lupton to JL Green have been revised as per FAC 009 and are no longer overloaded. In addition, the rating of the line from Buckley to Smoky Hill has also been revised from 479 MVA to 506 MVA. Therefore it would no longer be overloaded. Similarly the rating for the line from Denver Terminal to Lacombe has also been revised from 571 MVA to 817 MVA and it is no longer overloaded. The emergency line ratings for underground lines allow the Clark to Jordan line to operate for over 100 hours when overloaded 7%. However, in this case the line is overloaded up to 110% of its normal rating.

Table 2. AC contingency analysis for the 2011 case with reinforcements, POI is the 345kV bus at Green Valley

** From bus ** ** To bus ** CKT	Branch Rating	Loading as % of branch rating						Contingency
		bench-mark	no upgrade	Option 1	Option 2	Option 3	Option 4	
70047 BARRLAKE 230 70048 GREENVAL 230 1	159.0	193.5	229.9				188.4	70192 FTLUPTON 230 70529 JLGREEN 230 1
70048 GREENVAL 230 70526 IMBODEN 230 1	479.0	101.2	122.4		119.3	108.9		70048 GREENVAL 230 70528 SPRUCE 230 1
70107 CHEROKEE 230 70324 LACOMBE 230 1	517.0	101.0	111.8		115.3	127.3		70266 LOOKOUT 230 70480 WESTPS 230 1
70192 FTLUPTON 230 70529 JLGREEN 230 1	478.0	99.3	104.1		102.0			70192 FTLUPTON 230 70605 HENRYLAK 230 1
70274 MALTA 230 73138 MT.ELBRT 230 1	159.0	N/A	128.6	128.7	128.6	128.7	128.8	70048 GREENVAL 230 70636 GREENVAL 345 1
70396 SMOKYHIL 230 70528 SPRUCE 230 2	800.0	94.2	111.2		109.1	101.4		5177
70396 SMOKYHIL 230 70532 POWHATON 230 1	800.0	94.2	111.2		109.0	101.4		70396 SMOKYHIL 230 70528 SPRUCE 230 2
70461 WASHINGT 230 70529 JLGREEN 230 1	413.0	112.8	118.3					70192 FTLUPTON 230 70605 HENRYLAK 230 1
70526 IMBODEN 230 70528 SPRUCE 230 1	435.0	109.8	133.1		129.7	118.2		70048 GREENVAL 230 70528 SPRUCE 230 1
70528 SPRUCE 230 70532 POWHATON 230 1	800.0	94.2	111.2		109.0	101.4		70396 SMOKYHIL 230 70528 SPRUCE 230 2
70538 CHMBERS 115 70539 CHMBERS 230 1	280.0	91.3	101.5					70396 SMOKYHIL 230 70528 SPRUCE 230 2
70067 BUCKLY12 230 70396 SMOKYHIL 230 1	479.0	83.0		103.6				70283 MEADOWHL 230 70396 SMOKYHIL 230 1
70112 CLARK 230 70241 JORDAN 230 1	398.0	80.0		110.2				70067 BUCKLY12 230 70396 SMOKYHIL 230 1
70517 PARKERPS 115 70518 BAYOU 115 1	133.5	97.1		106.4				** Base Case **
70107 CHEROKEE 230 70609 SILVSADL 230 1	402.0	83.1			110.8			70192 FTLUPTON 230 70529 JLGREEN 230 1
70149 DENVTM 230 70324 LACOMBE 230 1	571.0	79.0				102.7		70266 LOOKOUT 230 70480 WESTPS 230 1

5177 70528 SPRUCE 230 70532 POWHATON 230
70396 SMOKYHIL 230 70532 POWHATON 230

Of all the options studied, it is seen that option 4 alleviates all the overloads in the system. Therefore this is the preferred network reinforcement.

Voltage Criteria Violations

Interconnecting to the PSCo bulk transmission system involves the Customer adhering to certain interconnection requirements. These requirements are contained in the Interconnection Guidelines for Transmission Interconnected Producer-Owned 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 230-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 230-kV/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 2011 benchmark case, the voltage at the 230-kV bus at Green Valley is 1.024 per unit. When GI-2008-14 is connected to the PSCo system at the 230-kV POI, the network solution does not converge. With a 200 MVAR capacitor close to the POI and another 200 MVAR capacitor close to the generation facility, the power flow case solves and voltage at the Point of interconnection is 1.02 per unit. A 250 MVAR capacitor connected close on the 165-mile line to the POI and a 200 MVAR capacitor connected near the generation facility bring the voltage at the POI up to 1.024 per unit. No reactive support is required to get the case to solve when the generation is connected to the 345-kV bus at Green Valley. However, the voltage at the 230-kV bus at Green Valley falls to 1.019 per unit, while it is 1.009 at the POI. A 70 MVAR capacitor connected on

the 165-mile line close to the POI restores the voltage at the 230-kV bus at Green Valley to benchmark levels.

During periods of minimal wind generation, line charging associated with the 165-mile 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 a customer 230-kV line, voltages on the wind farm rise above 1.10 per unit and with a 345-kV line they rise above 1.11 per unit. When GI-2008-14 is connected to Green Valley through a 230-kV line, a 30 MVAR reactor connected on the 165-kV line close to the POI and a 20 MVAR reactor connected close to the generation facility brings the voltages at the generation facility below 1.05 per unit and maintains the power factor at the POI between 0.95 leading to 0.95 lagging during periods of minimal wind generation. When it is connected to Green Valley through a 345-kV transmission line, a 60 MVAR capacitor connected close to the POI and a 50 MVAR reactor connected close to the generating facility keeps the voltage at the facility below 1.05 per unit and maintains power factor at the POI during minimal wind generation.

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-2008-14 facility. This should also be considered by the Customer in determining the final design equipment and parameters. If the Customer advances the request to the system impact study phase, the results of the stability analysis may modify the nature of the reactive power support that may be required of the Customer for the project to meet relevant reliability criteria. For the system impact study, especially for the stability analysis portion, technical details of the collector system, transformers and transmission line will be necessary to proceed.

Energy Resource (ER):

The ER portion of this study indicates that the Customer could provide 0 MW without the construction of new transmission lines from Green Valley. Once the interconnection is made, at the 230 kV or 345 kV POI, non-firm transmission capability may be available depending upon marketing activities, dispatch patterns, generation levels, demand levels, import path flow levels (TOT3, etc.), and the operational status of the transmission facilities.

Network Resource (NR):

The results of this study indicate that the 400 MW GI-2008-14 generation project delivered to the Green Valley POI could result in the overloading of facilities in the PSCo regional transmission system. Therefore, the 400 MW NR value requested will require interconnection and Transmission Network Upgrades. After these upgrades are complete, the 400 MW generating facility could be considered a network resource with firm transmission capability for the entire output of the plant to be delivered to load.

F. Short Circuit Analysis

A short circuit study was conducted to determine the fault currents (single line-to-ground or three-phase) at the Green Valley substation. The approximate fault currents at Green Valley with the addition of the GI-2008-14 400 MW wind facility are summarized in Table 3.

Insert Table 3 – the results of short circuit analysis along with appropriate comments

G. Costs Estimates and Assumptions

The estimated total cost for the required upgrades is approximately **$_____.**

The estimated costs shown are (+/-30%) estimates in 2008 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. 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 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 4 PSCo Owned; Customer Funded Interconnection Facilities

Element	*Description*	***Cost Est. Millions***
Green Valley Substation	*Miscellaneous work needed to interconnect the 400 MW expansion project:* • *Relaying and testing* • *SCADA/EMS modifications*	***$0.00***
Total	***Transmission Provider's Interconnection Facilities***	***$0.00***
Time Frame	*Substation and Transmission*	***0 Months***

Table 5 PSCo Owned; PSCo Funded Interconnection Facilities

Element	***Description***	***Cost Estimate (Millions)***
Green Valley Substation	***Circuit breaker*** ***Switches***	***$0.00***
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	***$0.00***
Time Frame	*Site, engineer, procure and construct*	***0 Months***

Table 6 PSCo Network Upgrades for Delivery

Element	***Description***	***Cost Est. (Millions)***
PSCo's Transmission Network	•	***0.00***
	Total Cost Estimate for PSCo Network Upgrades for Delivery	*N/A*
Time Frame	***Network Upgrades for Delivery – to be constructed via the PSCo Capital Budget Construction Process and are expected to require approximately __ to __ months to complete.***	*N/A*
	Total Cost of Project	***$0.00***

Assumptions

- *The cost estimates provided are "Scoping Estimates" with an accuracy of +/- 30%.*
- *Estimates have not been escalated. Estimates are based on 2008 dollars.*
- *There is no contingency added to the estimates. AFUDC is not included.*
- *PSCo (or its Contractor) crews will perform all construction and wiring associated with PSCo-owned and maintained facilities.*
- *No new substation land required. Substation work to be completed within existing property boundaries.*
- *A CPCN will be required for network upgrades for delivery.*