Interconnection Feasibility Study Report
Request # GI-2008-24

Comanche 345 kV 400 MW Wind Project

PSCo Transmission Planning
July 22, 2010

A. Executive Summary

The purpose of the Interconnection Feasibility Study is to provide a preliminary evaluation of the feasibility to connect a large generation project to the bulk transmission system and the cost of interconnecting the Generating Facility to the Transmission Provider's Transmission System, the scope of which is described in the Standard Large Generator Interconnection Procedures (LGIP).

Public Service Company of Colorado (PSCo) received a generation interconnection request to determine the possible impacts of interconnecting a proposed new 400 MW wind powered generation plant, located in the Walsenburg area in southern Colorado, to the Comanche 345 kV Bus. The Customer's project facility is to consist of 267 GE 1.5-MW SLE wind turbine generators, with an associated collector system to step up the voltage from 34.5 kV to 345 kV at the Generation Provider wind site. The study was conducted assuming the wind farm would connect into the PSCo 345 kV transmission system via a Generation Provider-owned and constructed 40-mile, 345 kV transmission line (see Figure 1 and Appendix A). The Commercial Operation Date[1] requested by the Generation Provider is October 31, 2012 and the Back-Feed In-Service Date[2] is April 30, 2012.

The Generation Provider requested the primary Point of Interconnection (POI) be the 345 kV bus at the Comanche Substation with the proposed Calumet Substation as possible alternative. Interconnection to the Calumet substation was not determined feasible; therefore, it was not studied as a POI.

The investigation included steady-state power flow and short circuit studies but did not include transient dynamic stability studies. The request was studied as a stand-alone project only, with no evaluations made of other new generation requests that

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[1] **Commercial Operation Date** of a unit shall mean the date on which the Generating Facility commences Commercial Operation as agreed to by the Parties pursuant to Appendix E to the Standard Large Generator Interconnection Agreement

[2] **In-Service Date** shall mean the date upon which the Interconnection Generation Provider reasonably expects it will be ready to begin use of the Transmission Provider's Interconnection Facilities to obtain back-feed power.

may exist in the LGIP queue other than the generation projects that are already approved and planned to be in service by the summer of 2012. This study does not include the recent modifications to the output of the Comanche generation levels, the potential for new generation by Black Hills scheduled for 2012 or the addition of potential wind generation. These new implications will be included in the System Impact Study.

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-2008-24 wind facility as provided at the POI to PSCo native load customers. **Interconnection at the 345 kV bus was determined feasible.** Under that condition, the estimated cost of the recommended system upgrades to accommodate the project is approximately **$5,370,000** and includes:

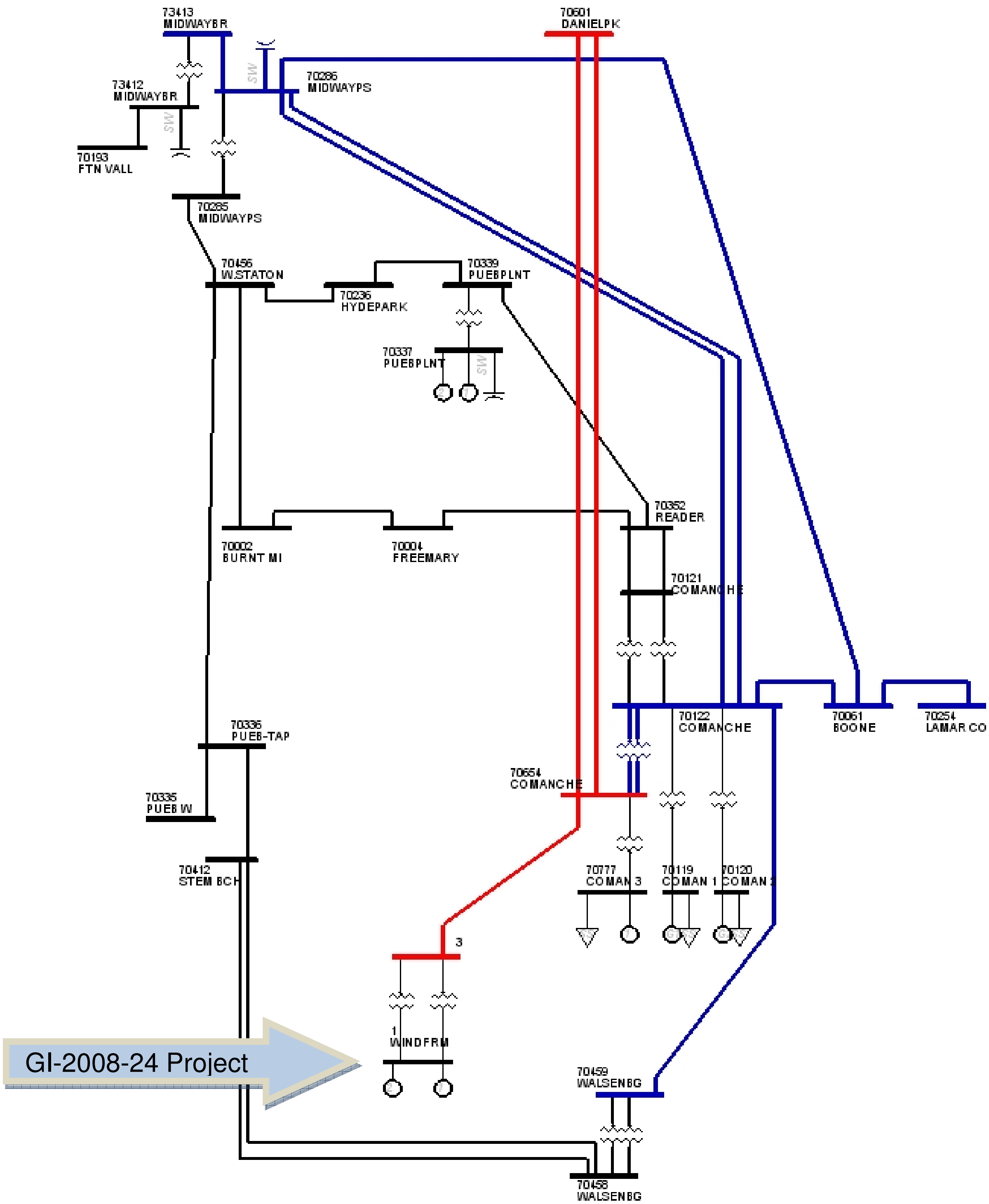
- ***$1,751,000 for PSCo-Owned, Customer-Funded Interconnection Facilities***
- ***$3,616,000 for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection***
- ***$0 for PSCo Network Upgrades for Delivery. This assumes that PSCo completes the network upgrade projects that have been identified and included in the PSCo Transmission Capital Budget.***

Additional network upgrades required on Tri-State Generation and Transmission (TSGT) and Black Hills systems are listed and described in Section G. These network upgrades have not been addressed in this study, nor have their costs been added in. They will be addressed with the affected utilities in the System Impact Study phase.

Engineering evaluation determined that from the time of the Authorization to Proceed until the In-Service Date for back-feed would be approximately 20 months.

Xcel Energy

Figure 1: Transmission System Overview in Project Region



B. Introduction

The Interconnection Feasibility Study evaluated the transmission impacts associated with the proposed interconnection of 400 MW of new Generation Provider generation into the PSCo Transmission System at the Comanche Substation 345 kV bus. The Generation Provider's proposed new 400 MW wind project would be located just east of Walsenburg, Colorado. The study assumed that the Generation Provider's new interconnecting 345 kV transmission line would be constructed for approximately 40 miles in a typical horizontal configuration on lattice-type structures using bundled Drake (2-795 ASCR) conductor per phase. The Comanche 345 kV Point of Interconnection (POI) was the only interconnection point studied.

C. Study Scope and Analysis

PSCo studied this request as both a Network Resource (NR)[3], and as an Energy Resource (ER)[4].

This study consisted of steady-state power flow analysis and short circuit analysis. The power flow analysis provided a preliminary identification of any thermal or voltage violations resulting from the interconnection of the wind facility; and for a NR request, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo loads. 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 nominal/normal conditions, and steady state power flows no greater than 1.0 per-unit of all elements' thermal (continuous current or MVA) ratings. Operationally, PSCo maintains 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 no greater than 1.0 per-unit of the elements' continuous thermal ratings.

Interconnecting to the PSCo bulk transmission system involves the Generation Provider adhering to certain interconnection requirements. These requirements are

[3] **Network Resource Interconnection Service** shall mean an Interconnection Service that allows the Interconnection Generation Provider 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 generation facilities to serve native load Generation Providers; 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.

[4] **Energy Resource Interconnection Service** (ER Interconnection Service) shall mean an Interconnection Service that allows the Interconnection Generation Provider 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.

contained in the Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater than 20 MW (Guidelines). The guidelines refer to interconnection requirements from FERC Order 661A, which 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 Generation Provider's facilities. Some of the requirements that the Generation Provider 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 Study shows that such a requirement is necessary to ensure safety or reliability.
2. The Feasibility 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. Reactive Power Control at the POI is the responsibility of the Generation Provider. Additional Generation Provider studies should be conducted by the Generation Provider to ensure that the facilities can meet the power factor control test and the voltage controller test when the facility is undergoing commission testing.
4. PSCo System Operations will require the Generation Provider to perform operational tests prior to commercial operation that would verify that the equipment installed by the Generation Provider meets operational requirements.
5. The Generation Provider is responsible for engineering, permitting, and financing their transmission facilities up to the POI to PSCo.

The wind farm site would be located in the San Isabel Electric Association service territory and not in the PSCo retail service territory. San Isabel Electric Association is a rural electric cooperative and a Tri-State Generation &Transmission member. If the Generation Provider chooses to obtain the house power requirements for the site from San Isabel Electric Association, the Generation Provider will need to coordinate this with San Isabel Electric Association.

For this project, potential affected parties include Black Hills Power (service territory formerly the responsibility of Aquila, Inc.), Tri-State Generation &Transmision, and Colorado Springs Utilities (CSU). These parties will be contacted for involvement in the transmission overloads identified in this study, and possible new projects that may be required as a result of this interconnection.

D. **Stand-Alone Study Results**

The stand-alone results are based upon comparative studies with the new Generation Provider wind generation project interconnecting at the Comanche Substation 345 kV bus, with the Generation Provider generation modeled in the power flow case either at a full output of approximately 400 MW or offline at 0 MW output. The remaining PSCo Balancing Authority (Area 70) generation and loads in the power flow model reflect a 2012 heavy summer load with heavy south-to-north flows. This study does not include the recent modifications to the output of the Comanche generation levels, the potential for new generation by Black Hills scheduled for 2012 or the addition of potential wind generation. These new implications will be included in the System Impact Study. For further details, refer to the Power Flow Study Models section below.

1. Network Resource (NR)

The Feasibility Study determined 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. The network upgrades required have been identified and are being addressed through the PSCo Capital Construction Budget.

2. Energy Resource (ER)

The study has determined that the Customer may interconnect as a Network Resource after the required Network Upgrades for Delivery are completed. Interconnection as an Energy Resource will require the same Network Upgrades to deliver the requested generation level on a firm basis. Some non-firm transmission capability may be available depending upon generation dispatch levels, demand levels, import path levels, and the operational status of transmission facilities.

3. Reactive Power Capability

A wind generating plant needs to 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 demonstrates that such a power factor requirement is necessary to ensure safety or reliability. The voltage at the Comanche 345kV POI needs to be maintained in the ideal voltage range for the appropriate Region 4 – Southeast

Colorado Region and bus type (regulating[5] or non-regulating) as determined in the Rocky Mountain Area Voltage Coordination Guidelines[6].
The voltage coordination guidelines for Region 4 have not defined the limits for 345kV buses; therefore, there are no high voltage and no low voltage limits for 345kV buses. The ideal voltage range for a 230kV regulating bus is between 1.02 p.u. and 1.03 p.u. while the acceptable voltage range for 230kV regulating buses is between 0.96 p.u. and 1.05 p.u. Since an ideal voltage range has not been established for 345kV buses in Region 4, the study allowed some latitude in the bus voltages tolerated at the POI. The study found that voltage at the POI ranged from 1.03 p.u. to 1.05 p.u. across the operating range of the proposed wind generation facility, and this range is within the acceptable voltage range for 230kV regulating buses.

A unity power factor at the 345kV POI with full output of the plant (400 MW) was achieved by the wind farm generating 58 MVAR. To achieve this reactive power generation level, the wind farm 34.5kV bus voltage had to increase to 1.08 p.u. Since the 34.5-345kV transformer no load taps were set at nominal for the study, it is understood that +/- 2.5% and +/- 5.0% no load taps will likely be available to boost the voltage at the customer site and reduce the wind farm reactive power generation and reduce the 34.5kV bus from 1.08 p.u. The Comanche 1, 2 and 3 generators increased their combined reactive power output by 58 MVAR to maintain the Comanche 345kV and 230kV bus voltages and accommodate the 400 MW power schedule and unity power factor at the 345kV POI. Sufficient reactive power reserve must be maintained on the Comanche generating units to allow them to dynamically regulate voltage for extreme system conditions. Increasing the reactive power generation of the wind farm units to reduce the Comanche generator reactive power contribution will increase the 34.5kV collector bus voltage above 1.08 p.u. Increasing the wind power reactive power generation to 132 MVAR (the maximum reactive power generation capability of the wind farm), results in a reduction in the Comanche total generation by approximately 12 MVAR; unfortunately, the 34.5kV collector bus voltage increases to 1.12 p.u. in order to reduce the Comanche

[5] A "regulating bus" is defined in the Rocky Mountain Area Voltage Coordination Guidelines as any transmission or generation bus with controllable VAR's. For Continuously-Controllable reactive power (VAR's), this implies that the bus has a voltage schedule that is being regulated by a generating facility. Generating facilities include synchronous generators, synchronous condensers or Static VAR Compensators (SVC's),that can supply continuous, fast-acting reactive power (VAR) compensation to dynamically regulate voltage at a power system bus. For Step-Controllable reactive power (VAR's), this implies that the bus has a voltage schedule that is being regulated by a device that provides reactive power in discrete steps or increments such as switchable capacitors, switchable reactors, and load tap changing transformers.

[6] 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.

generator contribution. Therefore, some type of reactive power source closer to the POI could be needed. A more detailed study with more detailed information will be conducted for the System Impact Study. Because of the long 40-mile 345kV line, the line and transformer reactive power losses (less the reactive power generation due to the line capacitance) are considerable.

When the 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 required to maintain the power factor at the POI within 0.98 lagging or leading. With the generation off-line and the transmission line energized, 26 MVAR is introduced into the bulk transmission system at the POI. To operate at ±0.98 power factor while off-line, a reactor must be installed to reduce the reactive power at the POI to 0 MVAR.

This model did not include any of the Generation Provider's wind farm 34.5 kV collector feeders and cables, so the capacitive contribution of this 34.5 kV network has not been determined in this study. A more detailed investigation will be conducted in the System Impact Study. It is the responsibility of the Generation Provider to determine what type of equipment is required (CVAR, switched capacitors, SVC, reactors, etc.), the final ratings (MVAR, voltage), and the location (project substation or Comanche POI) that will be necessary to meet the reactive power controllability requirements.

4. Interconnection Agreement (IA)

The Generation Provider's interconnection facilities costs are to be determined by the Generation Provider. These include all facilities and equipment, as identified in the Standard Large Generator Interconnection Agreement, which are located between the Generating Facility and the Point of Change of Ownership, including any modifications, additions, or upgrades to such facilities and equipment necessary to physically and electrically interconnect the Generating Facility to the Transmission Provider's Transmission System. The Generation Provider's Interconnection Facilities are sole use facilities.

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

1. The conditions of the Large Generator Interconnection Guidelines (LGIG) must be met.

2. PSCo will require testing of the full range of 0 MW to 400 MW operational capability of the facility. These tests will include, but not be limited to, power factor control, and VAR control as measured at the Comanche 345 kV bus POI for the full range of generation output levels of the Generation Provider's wind generation facility.

3. A single point of contact needs to be provided to PSCo Operations to manage the transmission system reliably for all wind projects on the proposed line.

E. Power Flow Study Models

The study cases provide a representation of the transmission system as projected by the utilities in the study area for the year, season, and demand condition selected. PSCo has studied the future upgrade of the MidwayPS-Daniels Park 230 kV line to a MidwayPS-Waterton 345 kV line along with the addition of a 560 MVA 345-230 kV transformer at the MidwayPS Substation and the addition of a 560 MVA 345-230 kV transformer at the Waterton Substation. The In-Service Date for this project is June 2011. The study included cases with and without the MidwayPS-Waterton 345 kV line and transformers.

The generation in the PSCo Balancing Authority (Area 70) was dispatched for heavy south-to-north stressing, with the PSCo swing bus moved to Cherokee #3 and generation levels in the south increased to maximum levels. Generation in the north was correspondingly decreased, and Western-RMR Balancing Authority (Area 73) to PSCo interchange was held constant. The power flow studies used PSCo's 2012 heavy summer budget case, which is based off the WECC 2012 heavy summer approved operating case.

The PSCo case was modified to include some corrections and additions that were not already included in the case model. The cases were modeled with and without the Midway-Waterton 345 kV line in service. In addition, CSU loads, switched shunts, and branch impedances were modified to create a more accurate model of the CSU system. A generator named "Planning" near Craig, CO was removed and nearby generators (Craig and Hayden) were increased to make up for this reduction in generation. Future projects that were not modeled include Pawnee-Smoky Hills 345 kV and the new generation at Lamar Energy Center as well as the associated 500 kV system. Furthermore, PSCo and Tri-State Generation &Transmission transmission planning groups are still in the preliminary study phase for the Calumet Substation; therefore, PSCo did not consider Calumet as an alternative POI with this request. Finally, the Comanche-Daniels Park 345 kV line was included which is currently in service. In association with this line, 40 MVAR reactors were modeled at Comanche and Daniels Park.

F. Power Flow Study Process

Two main power flow generation dispatch scenarios were evaluated. A reference dispatch model was established without the Generation Provider 400 MW generation ("Base Case"), and a second model with the new 400 MW of generation included ("Gen Case"). Additional power flow cases were analyzed with and without the Midway-Waterton 345 kV line, which is scheduled to be in service in 2011. A second set of cases for 2012 light winter (LW) were also studied to determine VAR requirements at the POI.

The Generation Provider's generation was dispatched in the Gen case by lowering other PSCo generation by 400 MW in the north and imports from Western-RMR (Area 73) were held constant. Reductions were made at locations that would maintain or maximize the south-to-north stressing in the case. The generation schedules of the Base Case and Gen Case are shown in Table 1.

Table 1: Case Generation Schedules

Station / Interface	Base Case (MW)	Gen Case (MW)
Pawnee	505	360
Manchief	65	65
Brush	0	0
Ft. Lupton	265	265
Ft. St. Vrain	450	450
Comanche	1475	1475
Ftn. Valley	240	240
Lamar DC (E-W)	210	210
Twin Buttes	9.4	9.4
CO Green	20	20
Peetz-Logan	50	50
Sidney DC (E-W)	120	120
Stegall DC (E-W)	80	80
Laramie River (MBPP)	1135	1160
Valmont	200	200
Spruce	240	140
RMEC	240	155
WY - CO (TOT3)	1305	1317

The Generation Provider's facility was modeled as two 200.25 MW lumped-equivalent generators with two 34.5-345 kV GSU transformers. The Generation Provider did not provide any specific data for the step up transformers; therefore, the transformers were modeled with a 220 MVA rating each, which is enough to carry the full output of the wind farm when both transformers are in service. However, if one transformer is out of service the output of the wind farm would have to be reduced, or larger transformers should be selected. It is the Generation Provider's responsibility to decide the actual characteristics of the transformers.

The wind farm will consist of 267 GE SLE 1.5-MW wind turbine generators with an associated collector system to bring power back to the project substation where it will be stepped up to 345 kV. The wind farm was modeled as connecting into the PSCo 345 kV transmission system via a Generation Provider-owned and constructed 40-mile, 345 kV transmission line. Since the data provided by the Generation Provider was for a 230 kV transmission line, typical data for a horizontal configuration on lattice-type structures using bundled Drake (2-795 kcmil ASCR) conductors per phase was used to model the 345 kV interconnect line. It is the Generation Provider's responsibility to select the appropriate 345 kV line parameters to the POI.

The two equivalent generators were each modeled with a maximum capacity of 200.25 MW (Pmax) / 66 MVAR (Qmax), or effectively 0.95 power factor at the Generation Provider 34.5 kV bus, with reactive power generation in the model adjusted to regulate the voltage on the 34.5 kV bus.

G. Power Flow Study Results and Conclusions

Automated single contingency power flow studies were completed on the case models using Siemens PTI's PSS/E program, switching out individual elements one at a time for all of the elements (lines and transformers) in Area 70 and Area 73. Upon switching each element out, the program re-solves with all voltage taps and switched shunt devices locked, and control area interchange adjustments disabled. Automated contingency studies were performed for both the Base Case and the Gen Case models, and the resulting lists of overloaded elements (load flows in excess of their continuous rating) are listed in Table 2. The table lists overloaded elements that are caused by the addition of the Project, or made worse by greater than 5%. The transmission facilities highlighted in Table 2 are on Black Hills Power's system. The percent loading is calculated in terms of the model rating, not the FAC-9[7] rating.

[7] "FAC-9" is the Substation/Transmission Facility Equipment Ratings FAC-9 Listing that PSCo maintains for its transmission facilities.

Table 2: Summary Listing of Differentially Overloaded Elements

Branch		Case Rating	FAC-9	Base Case (%)*	Gen Case (%)*	Diff.	Contingency
From	To		Rating				
70122 COMANCHE 230	70459 WALSENBG 230	159.0	239.0	128.5%	136.1%	7.6%	None
70004 FREEMARY 115	70352 READER 115	100.0		96.6%	111.8%	15.2%	Hydepark 115 - Pueblo Plant 115
70121 COMANCHE 115	70122 COMANCHE 230 A1	176.0	176.0	119.6%	134.7%	15.1%	Comanche 115 - Comanche 230 A1
70121 COMANCHE 115	70122 COMANCHE 230 A2	184.0	185.0	114.7%	129.2%	14.5%	Comanche 115 - Comanche 230 A2
70121 COMANCHE 115	70352 READER 115 1	239.0	218.0	101.1%	114.8%	13.7%	Comanche 115 - Reader 115 CKT 2
70121 COMANCHE 115	70352 READER 115 2	239.0	218.0	101.1%	114.8%	13.7%	Comanche 115 - Reader 115 CKT 1
70122 COMANCHE 230	70459 WALSENBG 230	159.0	239.0	176.9%	183.1%	6.2%	Pueblo Tap 115 – W. Station 115
70212 GREENWD 230	70323 PRAIRIE2 230	275.0	478.0	130.5%	168.2%	37.7%	Daniels Park 230 - Prairie 230
70212 GREENWD 230	70331 PRAIRIE 230.00	275.0	478.0	94.5%	131.3%	36.8%	Daniels Park 230 - Prairie2 230
70236 HYDEPARK 115	70339 PUEBPLNT 115	105.0		141.0%	158.1%	17.1%	Comanche 230 - Walsenburg 230
70236 HYDEPARK 115	70456 W.STATON 115	105.0		125.2%	142.3%	17.1%	Comanche 230 - Walsenburg 230
70330 PORTLAND 115	70456 W.STATON 115	80.0		95.6%	109.5%	13.9%	Midwaybr 230 - W Canon 230 CKT 1
70336 PUEB-TAP 115	70412 STEM BCH 115	77.0		258.5%	267.1%	8.6%	Comanche 230 - Walsenburg 230
70336 PUEB-TAP 115	70456 W.STATON 115	95.0		263.6%	270.9%	7.3%	Comanche 230 - Walsenburg 230
70463 WATERTON 115	70464 WATERTON 230 T2	100.0	100.0	120.0%	128.1%	8.1%	Waterton 115 - Waterton 230 CKT 2
70463 WATERTON 115	70464 WATERTON 230 T3	100.0	100.0	121.1%	129.3%	8.2%	Waterton 115 - Waterton 230 CKT 1
70002 BURNT MI 115	70456 W.STATON 115	100.0		87.3%	102.5%	15.2%	Hydepark 115 - Pueblo Plant 115
70339 PUEBPLNT 115	70352 READER 115	159.0		92.7%	104.0%	11.3%	Comanche 230 - Walsenburg 230
Note 1: All results in the above table come from cases with the Midway – Waterton 345 kV line in service.							
Note 2: Items highlighted are on Tri-State Generation & Transmission or Black Hills Power's system.							
Note 3: All percentage overloads are based off of the Case Rating							

The studies indicated that the additional 400 MW of Generation Provider injection into the Comanche 345 kV bus POI could cause new and/or additional flows in excess of present or planned element ratings. There were also new voltage violations as a result of added generation. The following is a list of overloaded transmission facilities and under-voltage violations that are due to or made worse by the proposed 400 MW generating facility.

- Comanche 115 - 230 kV autotransformers: During the loss of one of the two 115 - 230 kV autotransformers at Comanche, the other transformer becomes overloaded. These overloads occur in the Base Case but are worsened by 15% in the Gen Case. This issue can be resolved by completion of planned upgrades of the autotransformers to units with 280 MVA ratings. The upgrades are planned to be completed in summer 2010 (July 1, 2010).

- Prairie - Greenwood 230 kV: For N-1 conditions, during the loss of one of the two Daniels Park - Prairie lines, the Prairie – Greenwood 230 kV line overloads. This contingency overload occurs in the Base Case but is worsened by 37% in the Gen Case. The issue is resolved with updated ratings in FAC-9 to 478 MVA.

- Comanche - Reader 115 kV: For N-1 conditions, during the loss of Comanche - Walsenburg 230 kV, both Comanche - Reader 115 kV lines overloaded. The overload increases from 101% in the Base Case to 115% in the Gen Case. This issue is resolved with the updated line ratings of 398 MVA.

- Waterton 115 -230 kV Transformers: During the loss of one of the two 115 - 230 kV autotransformers at Waterton, the other transformer becomes overloaded. These overloads occur in the Base Case but are worsened by 8% in the Gen Case. This issue is resolved with the upgrade of the transformers to 280 MVA, which is scheduled to be completed in May 2011.

The transmission facility enhancements listed above will be completed through the PSCo Capital Budget Construction Process. The replacement of the MidwayPS-Daniels Park 230 kV line with the MidwayPS-Waterton 345 kV line has an expected In-Service Date of June 2011. Replacing the Comanche 230-115 kV transformers should be complete by December of 2010. The addition of the Comanche-Reader115 kV #2 transmission line should be complete by May 31, 2010. The Waterton 230-115kV transformer replacement should be complete by May 2011.

The following lines on the Black Hills Power and Tri-State Generation & Transmission systems show overloads and voltage criteria violations in N-1 contingency conditions in both the Base Case and the Gen case with more than 5% additional overload in the Gen Case:

- Comanche - Walsenburg 230 kV: During system-intact conditions, the Comanche-Walsenburg 230 kV line is overloaded. The Base Case loading is 129% and increases to 136% in the Gen Case. For N-1 conditions, during the loss of Pueblo Tap – West Station 115 kV, the loading in the Base Case is 177% and 183% for the Gen Case. The issue is resolved by upgrading the terminals at both Comanche and Walsenburg substations. The rating of the Comanche - Walsenburg line then increases to the thermal limit of 489.6 MVA.

- 70068 Burro Canyon: For N-1 conditions during the loss of Comanche – Walsenburg 230 kV line, Burro Canyon bus drops below the minimum allowable voltage level. The Base Case drops to 0.902 p.u. and the Gen Case drops to 0.888 p.u.

- 70335 Pueblo West: For N-1 conditions during the loss of Pueblo Tap – West Station 115 kV, Pueblo West bus drops below the minimum allowable voltage level. The Base Case drops to 0.902 p.u. and the Gen Case drops to 0.896 p.u.

- Pueblo Tap – Stem Beach 115 kV (11% additional overload)
- Pueblo Tap – West Station 115 kV (7% additional overload)
- Hyde Park - Pueblo 115 kV (17% additional overload)
- Hyde Park - West Station 115 kV (17% additional overload)
- Burnt Mill - West Station 115 kV (15% additional overload)
- Freemary - Reader 115 kV (15% additional overload)
- Pueblo Tap - Plant 115 kV (11% additional overload)
- Portland – West Station 115 kV (14% additional overload)

Future plans on the Black Hills Power and Tri-State Generation & Transmission systems are yet to be determined, so it is possible that planned future upgrades will resolve these overloads. It is also possible that additional upgrades will be necessary. Burnt Mill – West Station 115 kV does not overload in the Gen case with the Midway – Waterton 345 kV line out of service. These overloads will be addressed in conjunction with Black Hills Power and Tri-State Generation &Transmission in more detail in the System Impact Study.

Construction work required to interconnect the Generation Provider's Generation Facility at the Comanche 345 kV yard for back-feed would consist of the following:

- Construct an additional line position in the Comanche 345 kV bus. (PSCo-funded costs)
- Install revenue-metering equipment including CT/VT metering instrument and line termination equipment at the Comanche transformers, meters, and recorder. (Generation Provider-funded costs)
- Modify the substation associated with the Generation Provider's 345 kV transmission line to Comanche. (Generation Provider-funded costs)

The project costs to install the transmission interconnection facilities (ER & NR) and transmission system infrastructure (NR) upgrades necessary to accommodate the added Generation Provider generation have been evaluated by Engineering.

The estimated project cost is: $ 5.37 million

The costs for the transmission interconnection required for back-feed are scoping level cost estimates (+/- 30%) in 2009 dollars (no escalation applied) and are based upon typical construction costs for previously performed similar construction.

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 study has determined that the Customer may interconnect as a Network Resource after the required Network Upgrades for Delivery are completed. Interconnection as an Energy Resource will require the same Network Upgrades to deliver the requested generation level on a firm basis. Some non-firm transmission capability may be available depending upon generation dispatch levels, demand levels, import path levels, and the operational status of transmission facilities.

Network Resource (NR)

The contingency tables in the report list the lines and auto-transformers that either incur new single-contingency (N-1) overloading or that become significantly overloaded as a result of adding 400 MW of generation at the Comanche 345 kV bus POI. These results are for a power flow model for heavy summer 2012 system conditions, with the case re-dispatched for the maximum generation at Comanche and heavy south-to-north flows. Branch ratings that are expected to change as listed in the FAC-9 Facility Equipment Ratings (Rev. 8) are listed in the table. The study determined that the proposed wind generation facility may be considered a 400 MW network resource to PSCo as soon as the network upgrades associated with the project as identified in the Feasibility Study have been completed.

H. Voltage Control at the Point of Interconnection

A power flow model was used to determine the Generation Provider's reactive power generation requirements necessary to maintain a power factor within the range of 0.95 leading to 0.95 lagging at the POI allow the wind farm to ensure the reliability and safely of the system. PSCo studied the impact of the proposed wind generation facility on the reactive power (MVAR) requirements at the Comanche 345 kV POI. A simplified power flow model was used for the Generation Provider's wind farm model. A detailed model of the Generation Provider's 34.5 kV collector and feeder systems and their associated reactive and capacitive characteristics have not been developed at this stage. In addition, the 34.5-345kV transformer at the Generation Provider's site was set on the nominal tap. It is assumed that +/- 2.5% and +/- 5.0% no load taps would be available to boost the voltage at the Generation Provider's site. The Generation Provider will need to provide more detailed data for further/future studies (e.g. dynamic System Impact Study, detailed Facilities Study) in order to ascertain the specific dynamic VAR capacitive and inductive equipment (DVAR, CVAR, SVC, reactors, etc.) that would be required to meet the VAR requirements.

Heavy Load Case

Several generation scenarios were studied to identify the reactive power and voltage regulation capabilities of the Project. The existing Comanche generators were set to regulate voltage at 1.04 p.u. at the Comanche 230 kV bus. Next, the wind farm model was adjusted to provide power factors at the POI of 0.95 lead, 0.95 lag, and unity. Reactive power flows and voltages at the POI, Comanche generators, and the regulated buses were recorded. The results of this analysis are presented in Tables 3, 4 and 5.

Table 3: 2012 HS Reactive Power Effects on Comanche Generators (Unity PF)

	Base Case				Unity Power Factor at POI			
Bus Name	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)
Comanche 345 kV (POI)				1.04				1.04
Comanche 230 kV (Vreg)				1.04				1.04
WF Net @ POI	0.0	0.0			393.0	0.0	73.1/-226.2	1.04
Wind farm Gen 34.5 kV	0.0	0.0			400.5	58.4	132/-132	1.08
Comanche 1 24 kV	360.0	92.1	260/-50	1.03	360.0	106.6	260/-50	1.03
Comanche 2 24 kV	365.0	92.1	260/-50	1.03	365.0	106.6	260/-50	1.04
Comanche 3 24 kV	750.0	184.3	395/-280	1.06	750.0	213.2	395/-280	1.07
Total Comanche Generation	1475.0	368.5			1475.0	426.4		

Table 4: 2012 HS Reactive Power Effects on Comanche Generators (Lag PF)

	Base Case				0.95 Lagging at POI (Absorbing VARs)			
Bus Name	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)
Comanche 345 kV (POI)				1.04				1.04
Comanche 230 kV (Vreg)				1.04				1.04
WF Net @ POI	0.0	0.0			391.9	-128.8	73.1/-226.2	1.03
Wind farm Gen 34.5 kV	0.0	0.0			400.5	-57.0	132/-132	1.00
Comanche 1 24 kV	360.0	92.1	260/-50	1.03	360.0	138.0	260/-50	1.04
Comanche 2 24 kV	365.0	92.1	260/-50	1.03	365.0	138.0	260/-50	1.04
Comanche 3 24 kV	750.0	184.3	395/-280	1.06	750.0	276.0	395/-280	1.08
Total Comanche Generation	1475.0	368.5			1475.0	552.0		

Table 5: 2012 HS Reactive Power Effects on Comanche Generators (Lead PF)

Bus Name	Base Case				0.983 Leading at POI (Generating VARs)			
	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)
Comanche 345 kV (POI)				1.04				1.05
Comanche 230 kV (Vreg)				1.04				1.04
WF Net @ POI	0.0	0.0			392.8	73.3	73.1/-226.2	1.05
Wind farm Gen 34.5 kV	0.0	0.0			400.5	132.0	132/-132	1.12
Comanche 1 24 kV	360.0	92.1	260/-50	1.03	360.0	89.1	260/-50	1.03
Comanche 2 24 kV	365.0	92.1	260/-50	1.03	365.0	89.1	260/-50	1.03
Comanche 3 24 kV	750.0	184.3	395/-280	1.06	750.0	178.2	395/-280	1.06
Total Comanche Generation	1475.0	368.5			1475.0	356.4		

Tables 3 through 5 show how reactive power from the 400 MW wind farm affects the Comanche generators. The wind farm has a significant effect on the reactive power outputs of all three Comanche generators. The wind generators could not produce enough reactive power to create a 0.95 leading power factor at the POI, so the generator was set to produce its maximum reactive power (132 MVAR). At its maximum output, the wind farm was only able to create a 0.983 leading pf at the POI. The Comanche 3 generator bus voltage is 1.06 p.u. or higher, which is above the limit of 1.05 p.u. for regulating buses, according to the Xcel Energy document titled Rocky Mountain Area Voltage Coordination Guidelines. This is resolved by having the Comanche 3 generator regulate itself or the Comanche 345 kV bus instead of the Comanche 230 kV bus.

The impact of the wind generating facility on the reactive power schedules of nearby generating units may need to be mitigated by the Generation Provider if system studies demonstrate that the proposed wind generating facility causes nearby generating units to generate or absorb reactive power for voltage control. Sufficient reactive power reserve must be maintained on generating units to allow them to dynamically regulate voltage for extreme system conditions. PSCo will accommodate up to 10 MVAR of reactive power at the POI for a wind generating facility. Any additional VAR requirements are the responsibility of the wind generating facility. In order to operate within ± 10 MVAR at the POI, the generators would have to operate between 0.986 and 0.992 lagging (delivering) pf. These models did not include any of the Generation Provider's wind farm 34.5 kV collector feeders and cables; therefore, the capacitive contribution of this 34.5 kV network has not been determined in this study.

The reactive power study also analyzed the model with the wind farm generation at 0 MW output and the project substation to Comanche 345 kV line energized. This model was used to determine the approximate MVAR flow from the project substation to the POI at Comanche due to line capacitance. PSCo requires that, if a wind generating facility is acting as a load (operating with its generation off-line) it will be required to maintain the power factor at the POI within 0.98 lagging or leading pf per the Xcel Energy document titled Interconnection Guidelines for Transmission Interconnected Generation Provider Loads. This requirement helps ensure that the PSCo transmission system would not be burdened with absorbing unwanted reactive flows and potentially high voltages caused by this reactive power under typically light system loading conditions. The studies performed with a typical 40-mile, 345 kV line indicate that the reactive flow into the POI is approximately 26 MVAR with the project generation at 0 MW and the bus voltage near 1.04 per-unit at the Comanche 345 kV bus POI. Therefore, it appears likely that shunt reactors or generator CVAR lagging power factor operation will be needed to operate within the ±0.98 pf range requirement[8]. As previously stated, these models did not include any of the Generation Provider's wind farm 34.5 kV collector feeders and cables, so the potential capacitive contribution of this 34.5 kV network has not been determined in this study. The reactive charging of the actual 345 kV line configuration used should also be taken into account in more detailed future studies.

Light Load Case

A light load case was studied to determine how the wind farm would affect the VAR output of the surrounding Comanche generators. The WECC 2011 light winter case was modified to more closely match the 2012 heavy summer case. These modifications include the changes to the CSU system, removal of Pawnee – Smoky Hills 345 kV line, removal of Stem Beach 230 kV, removal of Walsenburg – San Louis Valley 230 kV line, and modification of generation schedules to create a heavy south to north flow. After the modifications, the wind farm generation was added and generation in the north reduced. Again, the existing Comanche generators were set to regulate voltage at 1.04 p.u. at the Comanche 230 kV bus and the wind farm model was adjusted to provide power factors at the POI of 0.95 lead, 0.95 lag, and unity. Reactive power flow and voltages at the POI, Comanche generators, and the regulated bus were recorded. The results of this analysis are presented in Tables 6, 7 and 8.

[8] NOTE – It is the responsibility of the Generation Provider to determine what type of equipment is required (CVAR, added switched capacitors, SVC, reactors, etc.) and what final ratings (MVAR, voltage 34.5 kV, 345 kV) and location (project substation or Comanche POI) will be necessary to meet the reactive power controllability requirements. Furthermore, the actual voltage tap ratios used for the Generation Provider's main 34.5 – 345 kV transformers will directly impact the operating voltages and related reactive capabilities for the project facility. The Generation Provider should review these studies in determining the final design requirements for this equipment (CVAR, transformer voltage tap ratios and MVA, etc.).

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Table 6: 2012 LW Reactive Power Effects on Comanche Generators (Unity PF)

Bus Name	Base Case				Unity Power Factor at POI			
	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)
Comanche 345 kV (POI)				1.04				1.04
Comanche 230 kV (Vreg)				1.04				1.04
WF Net @ POI	0.0	0.0			393.0	0.0	73.1/-226.2	1.04
Wind farm Gen 34.5 kV	0.0	0.0			400.5	58.8	132/-132	1.07
Comanche 1 24 kV	360.0	86.9	260/-50	1.03	360.0	101.4	260/-50	1.03
Comanche 2 24 kV	365.0	86.9	260/-50	1.03	365.0	101.4	260/-50	1.03
Comanche 3 24 kV	750.0	173.9	395/-280	1.06	750.0	202.8	395/-280	1.07
Total Comanche Generation	1475.0	347.7			1475.0	405.6		

Table 7: 2012 LW Reactive Power Effects on Comanche Generators (Lagging PF)

Bus Name	Base Case				0.95 Lagging at POI (Absorbing VARs)			
	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)
Comanche 345 kV (POI)				1.04				1.04
Comanche 230 kV (Vreg)				1.04				1.04
WF Net @ POI	0.0	0.0			391.9	-128.8	73.1/-226.2	1.03
Wind farm Gen 34.5 kV	0.0	0.0			400.5	-56.6	132/-132	1.00
Comanche 1 24 kV	360.0	86.9	260/-50	1.03	360.0	132.7	260/-50	1.04
Comanche 2 24 kV	365.0	86.9	260/-50	1.03	365.0	132.7	260/-50	1.04
Comanche 3 24 kV	750.0	173.9	395/-280	1.06	750.0	265.4	395/-280	1.08
Total Comanche Generation	1475.0	347.7			1475.0	530.8		

Table 8: 2012 LW Reactive Power Effects on Comanche Generators (Leading PF)

Bus Name	Base Case				0.983 Leading at POI (Generating VARs)			
	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)	P (MW)	Q (MVAR)	Max/Min (MVAR)	V (pu)
Comanche 345 kV (POI)				1.04				1.04
Comanche 230 kV (Vreg)				1.04				1.04
WF Net @ POI	0.0	0.0			392.8	73.0	73.1/-226.2	1.04
Wind farm Gen 34.5 kV	0.0	0.0			400.5	132.0	132/-132	1.12
Comanche 1 24 kV	360.0	86.9	260/-50	1.03	360.0	84.0	260/-50	1.03
Comanche 2 24 kV	365.0	86.9	260/-50	1.03	365.0	84.0	260/-50	1.03
Comanche 3 24 kV	750.0	173.9	395/-280	1.06	750.0	168.0	395/-280	1.06
Total ComancheGeneration	1475.0	347.7			1475.0	336.0		

Table 7 shows the effect of the wind farm on the existing Comanche generators during the light load case. The results for the light load case are very similar to the heavy summer load case. The voltages and power factors are very close to the heavy load values and the Comanche generators produce approximately 20 MVAR less than the heavy load case. Again, the Comanche 3 bus is operating at 1.06 p.u. or higher, which is above the limit of 1.05 p.u. for regulating buses. This is resolved by having the Comanche 3 generator regulate itself or the Comanche 345 kV bus. The wind farm would still need to operate between 0.986 and 0.992 lagging (delivering) pf to be within ±10 MVAR of unity pf at the POI. These models did not include any of the Generation Provider's wind farm 34.5 kV collector feeders and cables, so the capacitive contribution of this 34.5 kV network has not been determined in this study.

I. Short Circuit Study Results

A short circuit study was conducted to determine the fault currents (single–line–to ground or three–phase) at the Comanche Substation 345 kV bus. The study was conducted without the addition of the proposed 400–MW wind farm, as it is not expected to significantly increase the fault currents at the Comanche Substation. Table 9 below summarizes the potential fault currents at the Comanche 345 kV Bus without the addition of the GI–2008–24 facility.

Table 9: Short–Circuit Study Results Without the Proposed 400 MW Wind Farm

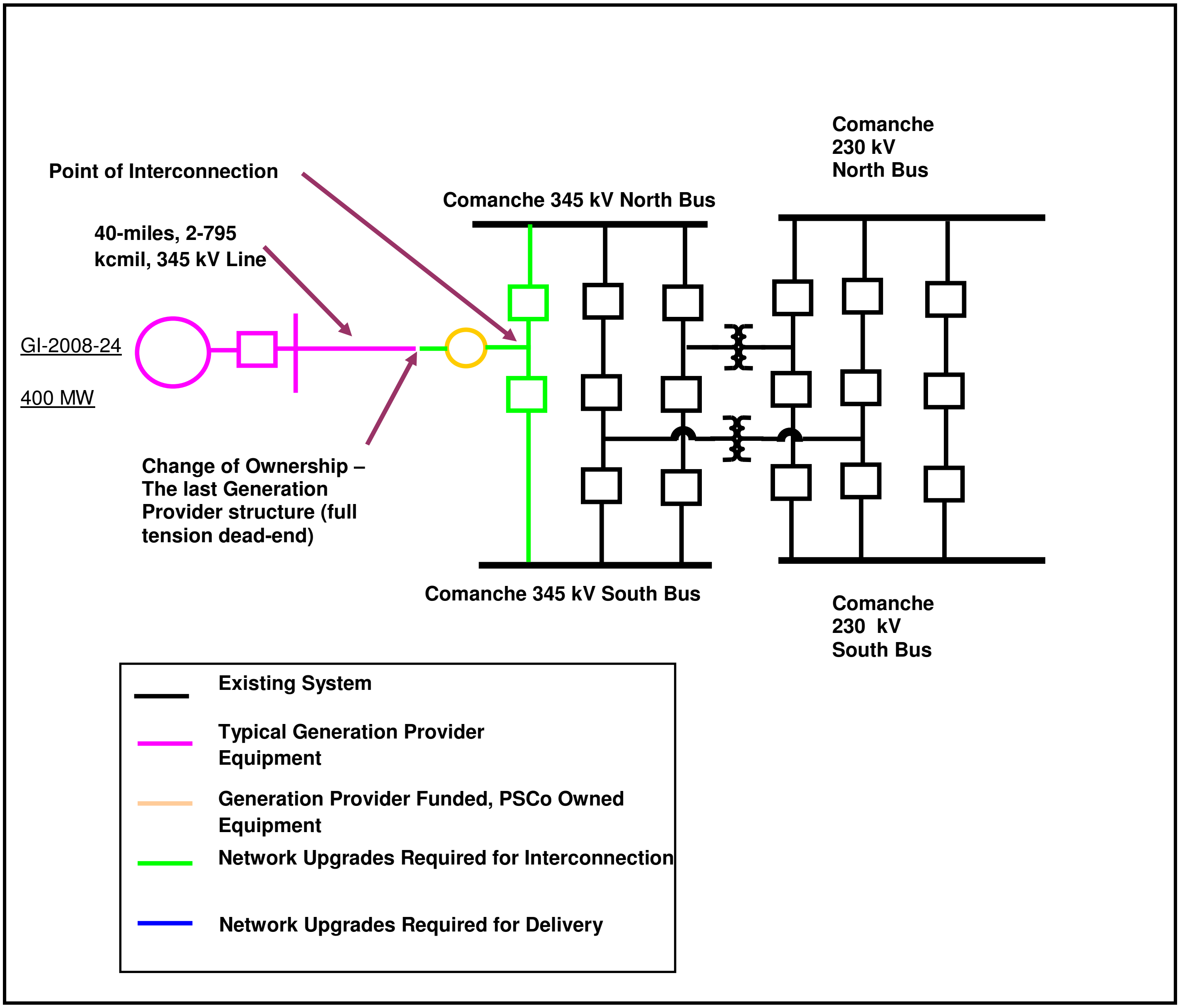
System Condition	Three-phase (amps)	Thevenin System Equivalent Impedance (R,X) in ohms	Single-line-to-ground (amps)	Thevenin System Equivalent Impedance (R,X) in ohms
System Intact	I_1=15063.2 I_2=I_0=0.0 I_A=I_B=I_C=15063.2	Z_1(pos)= 0.65620,13.2071 Z_2(neg)= 0.66313,13.2287 Z_0(zero)= 0.48046,8.25350	I_1=I_2=5734.3 $3I_0$=17202.9 I_A=17202.9 I_B=I_C=0.0	Z_1(pos)= 0.65620,13.2071 Z_2(neg)= 0.66313,13.2287 Z_0(zero)= 0.48046,8.25350

The addition of the 400 MW wind farm is not expected to necessitate the replacement of circuit breakers, switches or other substation equipment due to the increased fault current levels at the Comanche Substation.

J. Costs Estimates and Assumptions

Cost estimates of the PSCo-owned/Generation Provider-funded interconnection facilities, the PSCo-owned/PSCo-funded interconnection facilities, and the PSCo network upgrades for delivery were evaluated to determine the approximate cost of these facilities. The results of these evaluations are included below. A conceptual project one-line is included in Figure 2 below for reference.

Figure 2: Conceptual Project One-Line



The following tables list the improvements required to accommodate the interconnection and the delivery of the Project generation output. 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 10: PSCo Owned; Generation Provider Funded Interconnection Facilities

Element	Description	Cost Est. Millions
PSCo's Comanche 345 kV Substation	Interconnect Generation Provider at Xcel's Comanche 345 kV Substation. The new equipment includes revenue metering and associated equipment and material.	$0.389
	Transmission tie line into substation.	$1.342
	Generation Provider LF/ACG and Generator Witness Testing.	$0.010
	Siting and Land Rights for required easements, reports, permits and licenses.	$0.010
	Total Cost Estimate for PSCo-Owned, Generation Provider-Funded Interconnection Facilities	$1.751
Time Frame		20 Months

Table 11: PSCo Owned; PSCo Funded Interconnection Facilities

Element	Description	Cost
PSCo's Comanche 345 kV Substation	Interconnect Generation Provider at Xcel's Comanche 345 kV Substation. New 345 kV line termination requiring the following equipment: • Three 345 kV breakers • Seven 345 kV gang switches • Electrical bus work • Required steel and foundations • Minor site work (station wiring, grounding) • X- double circuit T-Line structures	
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	$3.616
Time Frame		20 Months

Table 12: PSCo Network Upgrades for Delivery

Element	Description	Cost Est. Millions
PSCo's Transmission Network	Upgrade the two Comanche 230-115 kV transformers to 280 MVA each.	PSCo-funded costs
	Add a Comanche-Reader 115 kV Line #2	PSCo-funded costs
	Uprate the Daniels Park-Prairie 230 kV line	PSCo-funded costs
	Uprate the Prairie-Greenwood 230 kV line	PSCo-funded costs
	Replace the MidwayPS-Daniels Park 230 kV line with the MidwayPS-Waterton 345 kV line. Install a 560 MVA 345-230 kV transformer at the MidwayPS Substation and a 560 MVA 345-230 kV transformer at the Waterton Substation.	PSCo-funded costs
	Total Cost Estimate for PSCo Network Upgrades for Delivery	-----------
Time Frame	Network Upgrades for Delivery – to be constructed via the PSCo Capital Budget Construction Process.	These projects will not be in-service by the Generation Provider's requested ISD.

Element	Description	Cost Est. Millions
	Total Cost of Project	**$5.370**

Assumptions for Alternatives

- The estimates provided are "scoping estimates" with an accuracy of +/- 30%.
- Estimated dollars include typical escalations for time frame required for design and construction (assumed Fall 2009 to Summer 2011).
- AFUDC is excluded.
- Labor is estimated for straight time only – no overtime included.
- PSCo (or it's Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- The cost estimates for the PSCo network upgrades for delivery are not included as they are part of PSCo's Capital Budget Construction process.
- No additional land will be required at the Comanche Substation.
- A 230 kV interconnection was deemed not feasible, so those estimates are not included.
- This estimate and schedule is dependent on other projects at Comanche. If other projects at Comanche at the same time, that could slow down the schedule.
- Lead times for materials were considered for the schedule.
- The transmission line will be required to exit Comanche to the North and will then turn West to exit the Comanche site.
- The Generation Provider transmission line is assumed to be fully compensated per interconnection requirements. Line compensation such as capacitors or line reactors and associated equipment are not included in this estimate and are the responsibility of the Generation Provider.
- The addition of Generation Provider generation will not increase the fault current above the current ratings of existing equipment.