Interconnection Feasibility Study Report
Request # GI-2008-30

200 MW Wind Generation Interconnection at Ault Substation

PSCo Transmission Planning
January 13, 2011

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 Generationg Facility to the Transmission Provider's Transmission System, the scope of which is described in the Standard Large Generator Interconnection Procedures (LGIP).

On December 17, 2008, Public Service Company of Colorado (PSCo) received a generation interconnection request to determine the potential system impacts and costs associated with interconnecting a proposed new 200 MW wind generation facility, located approximately two miles west of the Rawhide Station, at Western Area Power Administration's (Western) Ault 230 kV Substation. The Customer's project facility is to consist of 133 GE 1.5 MW SLE wind turbine generators, with an associated collector system used to step up the voltage from 34.5 kV to 230 kV at the Customer's wind site. The study was conducted assuming the wind farm would connect into Western's 230 kV Bus via a Customer owned and constructed 35-mile, 230 kV transmission line. The Commercial Operation Date[1] requested by the Customer is December 31, 2010 and the Back-Feed In-Service Date[2] is June 30, 2010.

The Customer requested the primary Point of Interconnection (POI) be the 230 kV Bus at Ault Substation with an alternate POI at a location south of the Ault Substation on PSCo's Ault-Windsor-Ft.St.Vrain 230 kV transmission line.

The investigation included a steady-state power flow and short circuit studies, but did not include transient dynamic stability studies, as these will be conducted during the System Impact Study if the customer chooses to proceed. The request was studied as a stand-alone project only, with no evaluations made of the other new generation requests that may exist in the LGIP queue other than the generation projects that are

[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.

already approved and planned to be in service by the summer of 2013. This study does not include the recent modifications to the output of the Comanche generation levels. This new generation will be included in the System Impact Study.

The results of the feasibility study indicate that the firm ER Injection capability is 0 MW for the 200 MW wind generation facility expansion. Firm capacity is not available due to existing overloads and firm transmission commitments and is not possible without the construction of network reinforcements.

Based upon the steady-state analysis performed for the feasibility study, the full 200 MW generation output of the GI-2008-30 project could be provided to PSCo after reinforcements to the PSCo transmission system have been completed. PSCo will complete some of these reinforcements through its capital budget process for transmission upgrades, whereas others will be required as network upgrades. The required Network Upgrades for Delivery include the following:

- Construct a new 88-mile 230 kV transmission (345 kV construction) line using a two-conductor bundle of 954 kcmil "Cardinal" conductor per phase from the Ault Substation to Cherokee Substation. The line will consist of a single 59-mile line from Ault to just outside of Ft. Lupton. From this point the line will become a 29-mile double circuit 230 kV line by rebuilding the existing 115 kV line from Ft. Lupton to Cherokee on 230 kV structures with one side operated at 115 kV for the Tri-State Generation and Transmission (TSGT) load-serving substations, and the other side operated at 230 kV completing the circuit from Ault to Cherokee. The portion of the circuit from Ft. Lupton to Cherokee could be constructed for future 345 kV operation as there is sufficient existing right-of-way; however, adding a 345 kV yard at the Cherokee Substation may not be feasible.

The feasibility study indicates that approximately 15 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. No switched capacitors will be needed to meet the voltage criteria at the POI near maximum generation.

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-2008-30 wind facility as provided at the POI to PSCo native load customers. While interconnection at the Ault 230 kV bus was determined feasible, **based on projected equipment lead-times and other transmission project in-service dates, interconnection by the Customer proposed commercial operation date and back-feed date was not determined feasible.** The earliest date the wind generation facility could become a network resource for PSCo would be after the completion of the Ault - Cherokee 230 kV Line that is anticipated to be completed in 2016 – 2017. Under that condition, the

estimated cost of the recommended network upgrades to accommodate the project is approximately **$67,350,000** and includes:

- $0.890 million for PSCo Owned, Generation Provider Funded Interconnection Facilities. This includes a 230kV gang switch, 230kV lightning arrestors, CT/PT's, revenue metering and enclosure, foundations, structures, communications, relaying, testing, etc.
- $1.200 million for Western Owned, PSCo Funded network upgrades for interconnection. This includes and includes substation upgrades required at Western's Ault Substation (relaying and testing).
- $65.260 million for PSCo Network Upgrades for Delivery.

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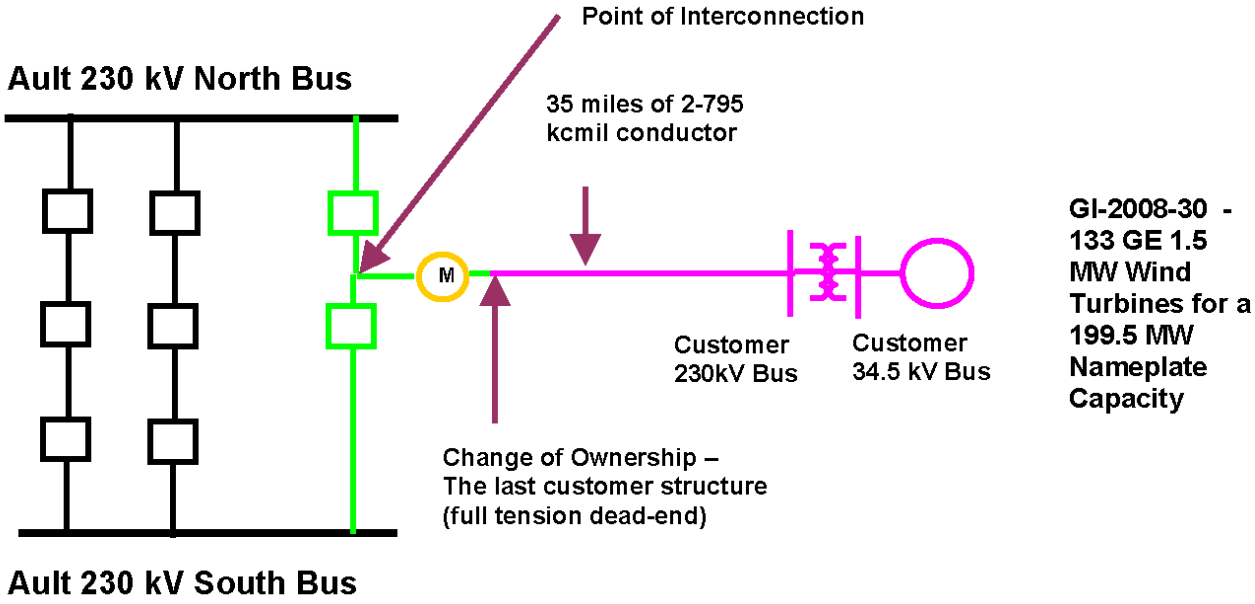
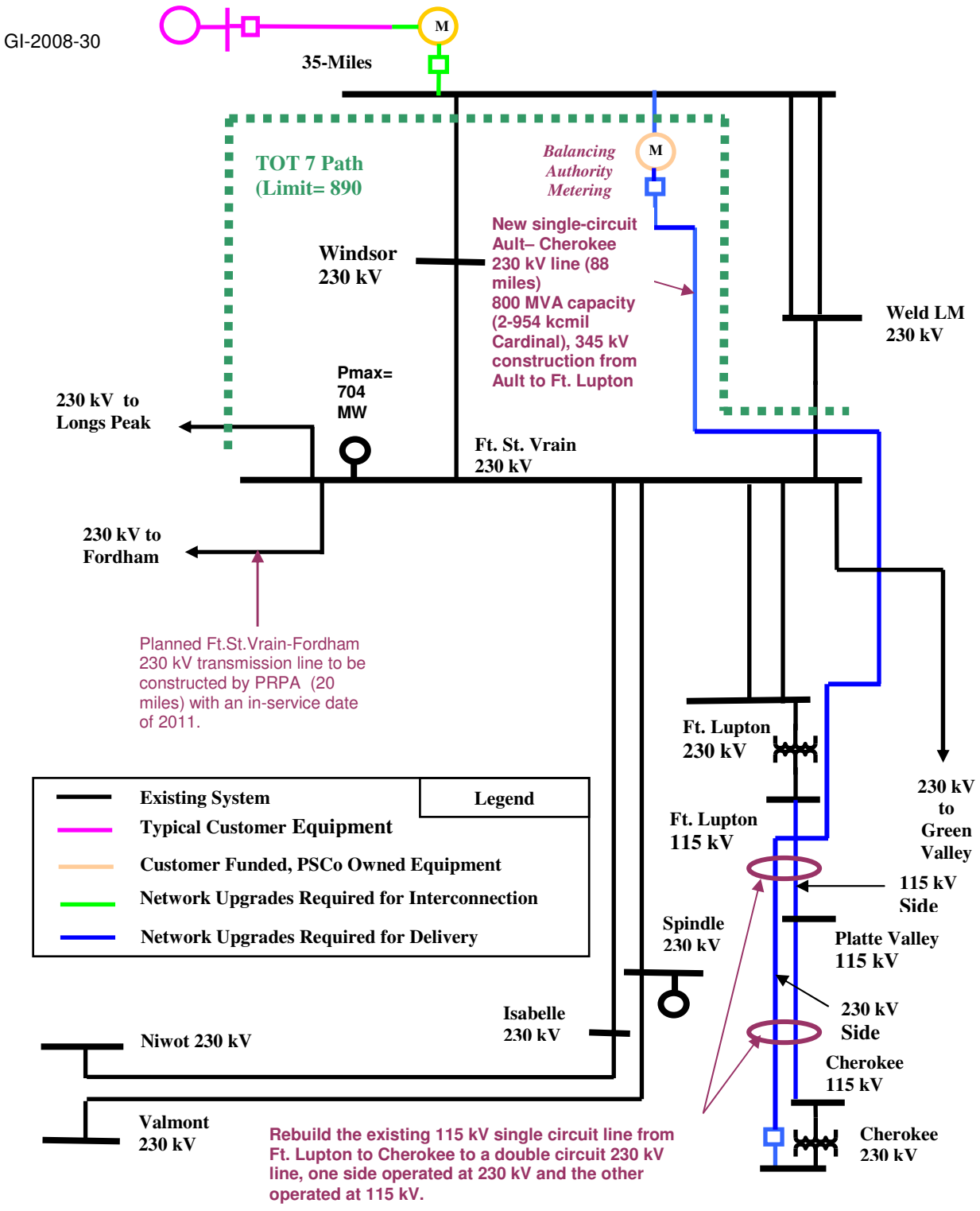
Figure 1: Preliminary One-Line of the Proposed GI-2008-30



Xcel Energy

Figure 2: Diagram of the GI-2008-30 Interconnection at Ault 230 kV



Introduction

Public Service Company of Colorado (PSCo) received a large generator interconnection request (GI-2008-30) to determine the feasibility and impacts associated with interconnecting a 200 MW wind-powered generation facility, located approximately two miles west of the Rawhide Station, at the 230 kV bus at Western's Ault Substation. The Customer requested the 230 kV Bus at Ault Substation to be the primary Point of Interconnection (POI), with an alternate POI located south of the Ault Substation on PSCo's Ault-Windsor-Ft.St.Vrain 230 kV transmission line. The Customer's project facility would consist of 133 GE 1.5 MW wind turbine generators with a total generator nameplate capacity of 199.5 MW, and an associated collector system located at the Customer's wind site used to step up the generator voltage from 34.5 kV to 230 kV. The study was conducted assuming the wind generation facility would interconnect to the 230 kV bus at the Ault Substation via a Customer-owned 35-mile, 2 conductor bundled 795 kcmil ACSR "Drake," radial 230 kV transmission line.

Study Scope and Analysis

The main purpose of this study was to evaluate the potential impact of GI-2008-30 on the PSCo transmission infrastructure as well as that of neighboring entities, when injecting a total of 200 MW of wind turbine generation into Ault, and delivering the additional generation to PSCo native loads. The costs to interconnect the project with the transmission system at the Ault 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.

PSCo studied this request as both an Energy Resource (ER)[3] and as a Network Resource (NR),[4] with power delivered to PSCo native load customers.

These investigations 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. The short circuit analysis identifies any circuit

[3] **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.

[4] **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.

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:

- During system intact (ATC) conditions, transmission system bus voltages must be between 0.95 and 1.05 per-unit of 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.
- Operationally, PSCo tries to maintain a transmission system voltage profile ranging from 1.02 per-unit or higher at generation buses to 1.0 per-unit or higher at transmission load buses.
- The ideal voltage range for the buses at the Ault substation is between 1.00 per unit and 1.025 per unit.
- Following a single-contingency element outage, transmission system state bus voltages must remain within 0.90 per-unit to 1.10 per-unit and power flows within 1.0 per-unit of the elements' continuous thermal ratings.

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.

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[5] or non-regulating) as

[5] 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

determined in the Rocky Mountain Area Voltage Coordination Guidelines[6]. 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[7]. The total MVAR output of all nearby generators must not be greater than 10 MVAR more than the total output of those generators before connecting the customer's system. 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) per the Xcel Energy document titled Interconnection Guidelines For Transmission Interconnected Customer Loads.

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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'.

[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.

[7] 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".

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 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[8] (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-2008-30 that deliver power to the Ault 230 kV POI, as indicated in the Interconnection Guidelines.

3. PSCo will require testing of the full range of 0 MW to 200 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 POI for various generation output levels (0 to 200 MW) of the overall wind generation facility.

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).

Three utilities could be affected by this project. These include: Platte River Power Authority (PRPA), Tri-State Generation & Transmission (TSGT) and Western Area Power Administration – Rocky Mountain Regional Office (Western). PSCo will notify and provide these parties with a copy of this feasibility study report, identifying any transmission facility overloads and possible new projects that may be required as a result of this interconnection.

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

Stand Alone Results

The stand-alone analysis consisted of a comparative study of the system behavior with the addition of the Customer's 200 MW project to the PSCo system compared with that associated with the existing PSCo system. The 2013 HS2A Approved Base Case in PSS/E Version 30.2 that was approved on November 15, 2007 was suggested at the Scoping Meeting for the study. The study base case reflects the system topology and load forecast for the 2013 summer peak demand period.

Energy Resource (ER)

The results of the feasibility study indicate that the firm ER Injection capability is 0 MW for the 200 MW wind generation facility expansion. Firm capacity 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)

The Feasibility Study determined that the NR Injection capability is 200 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. Necessary Network Upgrades are discussed in Table 10.

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 2013 heavy summer peak load as a part of their annual five-year project identification process, from the WECC approved 2013 HS2A Base Case.

Power Flow Study Scope

The generation interconnection request impacts two power transfer paths – the "TOT 7" Path and the "South of Ft. St. Vrain Path (SSV)". The TOT 7 transfer path provides a path for power transfers into the northern Denver Metro Area and is also known as Path

40 in the WECC Path Rating Catalog. The "South of Ft. St. Vrain" transfer path is a conduit for power transfers across TOT 7 and generation schedules at Ft. St. Vrain in the Denver Metro Area. The loads in the study area consist of Zone 754 and Zone 706 in the WECC power flow case.

A. TOT 7

"TOT 7" is WECC defined power transfer path located within the study area. TOT 7 is comprised of transmission lines that allow power to be transferred between northeast Colorado and the north Denver Metro Area. The path has a maximum accepted north-to-south rating of 890 MW; however, the real-time path rating is highly dependant on the level of demand in the Foothills Area and the on-line generation in the area called the Colorado-Big Thompson generation. The TOT 7 path owners include Platte River and PSCo.

The facilities that comprise TOT 7 are as follows:

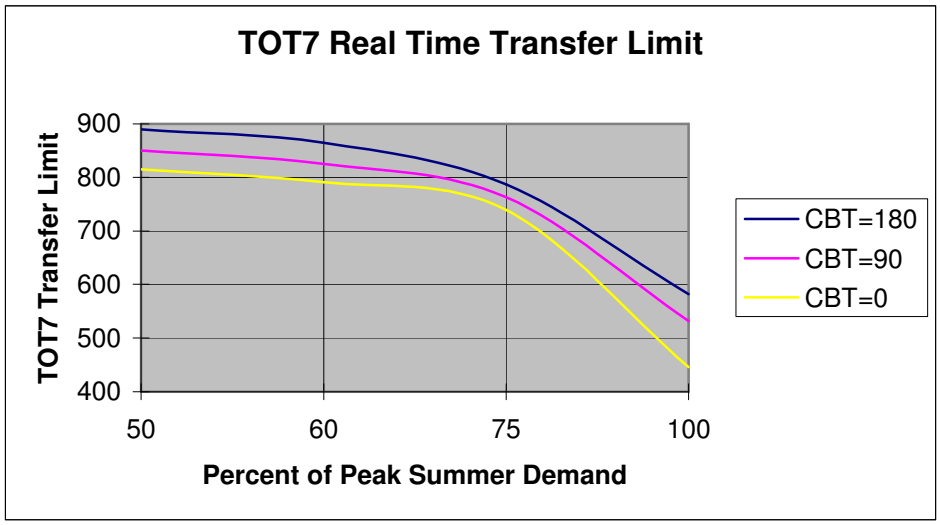
Transmission Line	**Metered End**
Ault-Windsor 230 kV	Ault
WeldPS-Ft.St.Vrain 230 kV	Weld
Longs Peak-Ft.St.Vrain 230 kV	Ft.St.Vrain

The TOT 7 Transfer Path has a WECC-accepted north-to-south rating of 890 MW. That means that it can transfer 890 MW of power while allowing for the possible occurrence of a transmission facility outage for the system conditions selected. The ability to transfer power across the TOT 7 Transfer Path is impacted by the level of local demand and level of hydroelectric generation of the Colorado-Big Thompson9 system. As demand in the Foothills Area increases, the TOT 7 real-time transfer limit decreases. Similarly, as the Colorado-Big Thompson (CBT) generation decreases, the TOT 7 real time rating decreases. Figure 1 below illustrates this effect. The TOT 7 transfer limit for various levels of demand (expressed as a percentage of the Foothills Area peak summer demand) and various levels of CBT generation are plotted. The blue line represents the TOT 7 transfer limit with CBT generation at 180 MW. At a Foothills Area demand level of 50% of summer peak demand, the TOT 7 transfer limit is 890 MW, the WECC-accepted rating of the transmission path. With CBT generation fixed at 180 MW, as the Foothills Area demand increases, the TOT 7 real time transfer limit decreases to approximately 580 MW at the point where the demand reaches 100% of summer peak.

[9] **The Colorado-Big Thompson Project (CBT)** is a trans-mountain water diversion system that diverts water from the Colorado River headwaters on the western slope to the Big Thompson River, a South Platte River tributary on the eastern slope, for distribution to project lands and communities. Hydroelectric facilities on the Big Thompson River include Big Thompson 4.2 kV No. 1, Estes 6.9 kV No. 1,2 and 3, Mary's Lake Power Plant 6.9 kV No. 1, Pole Hill 13.8 kV No. 1, and Flat Iron 13.8 kV No. 1, 2 and 3. Operating studies conducted by PSCo and Platter River Power Authority have demonstrated that as the CBT generation decreases, the transfer limit of TOT7 decreases.

Similarly, plots of the TOT 7 real time transfer limit for levels of Foothills Area demand at a CBT generation fixed at 90 MW and fixed at 0 MW are also displayed. The graph demonstrates the decrease in the TOT 7 real time transfer limit as CBT generation decreases.

Figure 3: TOT 7 Real Time Transfer Limit



The Foothills Area has experienced a steady increase in demand over the last several years. As a result, the real-time rating of the TOT 7 transfer path has decreased.

B. South of Ft. St. Vrain (SSV)

The "South of Ft. St. Vrain" (SSV) Path is a PSCo internal power transfer path on the south end of the study area. South of Ft. St. Vrain is comprised of 230 kV transmission lines lines that allow power to be transferred into the Denver Metro Area from Ft.St.Vrain. The South of Ft. St. Vrain path must accommodate the TOT 7 flow with generation at Ft. St. Vrain. The north-to-south path rating is approximately 1500 MW and is comprised of the following transmission facilities:

Transmission Line	Metered End
Ft. St. Vrain-Ft. Lupton 230 kV #1	Ft. St. Vrain
Ft. St. Vrain-Ft. Lupton 230 kV #2	Ft. St. Vrain
Ft. St. Vrain-Green Valley 230 kV	Ft. St. Vrain
Ft. St. Vrain-Spindle 230 kV	Ft. St. Vrain
Ft. St. Vrain-Isabelle 230 kV	Ft. St. Vrain

The 2013HS case that will be used for the study will be stressed. That means that transfers across TOT 7 will be increased until a single contingency results in an overload of one of the TOT 7 elements. This case represents the starting point for studies.

Two power flow case model generation dispatch scenarios were evaluated. A benchmark or base dispatch model (to establish a reference) was developed without the addition of the proposed generation ("Base Case"), and a second model was developed with the proposed 200 MW of generation (GI-2008-30) included ("Gen Case").

The Customer's facility was modeled as one 199.5 MW lumped-equivalent generators with an associated 34.5-230 kV main generator step-up transformer. The actual wind farm is to consist of 133 GE 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 230 kV. The wind generation facility would be connected to Ault substation by a radial transmission line, 35 miles long, at the 230 kV bus.

A bundled 795 kcmil ACSR (Drake) conductor was used for the radial line connecting the proposed facility to PSCo system. The line impedance parameters for the 35 mile line were calculated by PSCo using the PSS®E program, TMLC. Data for the 765 kcmil, 230 kV transmission line was calculated to be (r = 0.004436; x = 0.03790; b = 0.14732).

Customer data provided with the generation interconnection request indicated that the wind turbine generators would be compensated to be able to provide reactive power up to 0.95 power factor leading and lagging at the generators. The equivalent generator was modeled with a maximum capacity of 0.0 to +199.5 MW and -81.0 to +54.4 MVAR, with reactive power generation in the model adjusted to regulate the voltage on the 230 kV bus to equal the base case voltage at the Ault 230 kV POI (1.00).

The Gen Case was re-dispatched to lower other PSCo Balancing Authority (Area 70) generation by 200 MW in the south. Reductions were made at locations that would maintain or maximize the south-to-north stress level in the case. The new generation from GI-2008-30 was accommodated by decreasing generation at Ft. St. Vrain, Manchief, Spindle and Spruce as shown in Table 1:

Table 1: Case Generation Schedules

Station / Interface	Base Case (MW)	Gen Case (MW)	Difference
Ault 230 kV	0.0	199.5	+ 199.5
Fountain Valley 1	40	15	- 25
Fountain Valley 2	40	15	- 25
Fountain Valley 3	40	15	- 25
Fountain Valley 4	40	15	- 25

Fountain Valley 5	0	0	0
Fountain Valley 6	0	0	0
Commanche 2	360	335	- 25
Commanche 3	790	765	- 25
Lamar DC	50	0	- 50
TOTALS	1360.0	1359.5	0.5

Power Flow Study Process

Automated contingency power flow studies were completed on all power flow models using the Siemens PTI PSS®E program, switching out single branch elements one at a time for all of the branch 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.

Power Flow Results

Thermal Overloads

The power flow for the base case converges without the need for reactive support in the system intact (N-0) and single line contingency (N-1) cases.

The base case has the several system intact (N-0) thermal overloads, as described in Table 2.

Table 2: Base Case System Intact Thermal Overloads

FROM			TO						Percent of MVA Rating
Number	Name	Voltage	Number	Name	Voltage	ID	Owner	MVA Rating	BASE
73004	ALCOVA	115	73137	MIRACLEM	115	1	WALM	80	101.2
73004	ALCOVA	115	73137	MIRACLEM	115	2	WALM	80	100.8
73071	DAVEJTPS	115	65425	DAVEJOHN	115	1	WALM	109	108.4

Plans by Western to up-rate the lines in their area need to be determined.

When GI-2008-30 is modeled to deliver 200 MW to the 230 kV bus at Ault with all transmission facilities in service, the power flow case converges without the need for reactive support in the system intact (N-0) case and for all single line contingencies (N-1).

The thermal results for the single line contingency (N-1) analysis when 200 MW are connected to the Ault 230 kV substation are shown in Table #. If a transmission branch was not overloaded either for system intact (N-0) or single contingency (N-1) conditions prior to the addition of the proposed 200 MW generating facility, and the addition of the proposed 200 MW generation facility resulted in a new overload, the overloaded facility was listed in the table 3.

Table 3: AC Contingency Thermal Results

FROM			TO						Percent of MVA Rating	
Number	Name	Voltage	Number	Name	Voltage	ID	Owner	MVA Rating	BASE CASE	GI 2008-30
70410	ST.VRAIN	230	70471	WELD_PS	230	1	PSC	564	87.5	101.0
70410	ST.VRAIN	230	70474	WINDSOR	230	1	PSC	490	88.3	100.7
70471	WELD_PS	230	73212	WELD_LM	230	1	PSC	637	98.0	110.7
70474	WINDSOR	230	73011	AULT	230	1	PSC	490	93.9	106.4
73011	AULT	230	73212	WELD_LM	230	1	WALM	478	99.3	110.1
73011	AULT	230	73212	WELD_LM	230	2	WALM	478	99.3	110.1

Connecting the new wind generation facility to the 230 kV bus at Ault without any reinforcements causes several lines in PSCO's system as well as Westerns's system to overload. Since several lines would be overloaded under contingency conditions when the GI-2008-30 facility is connected to the Ault substation, network upgrades are necessary to accommodate the injection of 200 MW at the Ault 230 kV substation.

In order to alleviate these overloads the following network reinforcements have been considered in the case:

Table 4: Studied Alternatives

Option	Description
Option 1 - AC	Add an Ault - Cherokee Line
Option 2 - AT	Add an Ault - Timberline Line
Option 3 - WF	Add a Weld PS - Ft.Lupton Line
Option 4 - WF_JC	Add a Weld PS - Ft.Lupton Line and a JL Green - Cherokee Line
Option 5 - WF_JC_WW	Add a Weld PS - Ft.Lupton Line, a JL Green - Cherokee Line, and a Windsor - Weld PS Line
Option 6 - AT_WF_JC_FJ_WW	Add an Ault - Timberline Line, a Weld PS - Ft.Lupton Line, a JL Green - Cherokee Line, a Ft.St.Vrain - JL Green Line, and a Windsor - Weld PS Line

The thermal results of the AC contingency analysis with the proposed reinforcements were compared with the base case, as shown in Table 5.

Table 5: AC Contingency Thermal Results for the Network Reinforcement Options

FROM	TO		Percent of MVA Rating							
Name	Name	ID	BASE CASE	GI 2008-30	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5	OPTION 6
ST.VRAIN	WELD_PS	1	87.5	101.0	-	-	-	-	-	-
ST.VRAIN	WINDSOR	1	88.3	100.7	-	-	100.4	100.6	-	-
WELD_PS	WELD_LM	1	98.0	110.7	-	106.6	129.2	129.6	138.2	136.1
WINDSOR	AULT	1	93.9	106.4	-	102.3	106.1	106.4	140.5	138.1
WASHINGT	JLGREEN	1	86.4	-	-	-	-	-	-	111.4
AULT	WELD_LM	1	99.3	110.1	-	106.7	126.4	126.8	108.7	106.7
AULT	WELD_LM	2	99.3	110.1	-	106.7	126.4	126.8	108.7	106.7

As indicated in Table 5, Option 1 (adding a new Ault – Cherokee 230 kV Line) is the only solution that mitigates all thermal overload violations. The other options each have merit but are inferior to Option 1. Option 6 actually creates a new thermal overload violation on the Washington – JL Green 230 kV Line; therefore, it is not recommended as the preferred alternative.

Based upon the steady-state analysis performed for the feasibility study, the full 200 MW generation output of the GI-2008-30 project could be provided to PSCo after the Network Upgrade of the Ault – Cherokee 230 kV Line has been completed. The Ault – Cherokee 230 kV Line Network Upgrade includes the following:

- Construct a new 88-mile 230 kV transmission (345 kV construction) line using a two-conductor bundle of 954 kcmil "Cardinal" conductor per phase from the Ault Substation to Cherokee Substation. The line will consist of a single 59-mile line from Ault to just outside of Ft. Lupton. From this point the line will become a 29-mile double circuit 230 kV line by rebuilding the existing 115 kV line from Ft. Lupton to Cherokee on 230 kV structures with one side operated at 115 kV for the Tri-State Generation and Transmission (TSGT) load-serving substations, and the other side operated at 230 kV completing the circuit from Ault to Cherokee. The portion of the circuit from Ft. Lupton to Cherokee could be constructed for future 345 kV operation as there is sufficient existing right-of-way; however, adding a 345 kV yard at the Cherokee Substation may not be feasible.

This Network Upgrade is part of the SB-07-100 mandate and will be handled as a transmission upgrade project in the PSCo Capital Construction Budget process. A CPCN will be required by the CPUC for the construction of the Ault – Cherokee 230 kV Line.

Voltage Criteria Violations

The base case has one system intact (N-0) voltage criteria violations, as described in Table 6.

Table 6: Base Case System Intact Voltage Violations

Number	Name	Base KV	Owner	Voltage p.u.
73009	ARCHER	230	WALM	0.948

There are no new voltage violation for the single line contingency (N-1) analysis when 200 MW are connected to the Ault 230 kV substation for any case in the study.

Reactive Power Requirements

The voltage at the 230 kV bus at Ault is 1.00 per unit in the benchmark case without GI-2008-30. No reactive support is required to get the case to solve when GI-2008-30 is connected to the 230 kV Ault bus. It was determined that the reactive power into the Ault 230 kV POI when GI-2008-30 is injecting 200 MW is -21.5 MVAR (a 0.994 pu power factor). This is within the +/- 0.95 pu power factor criteria. Therefore, there are no additional reactive power requirements when GI-2008-30 is at full operation.

Table 7: Reactive Power Requirements

	Ault POI Voltage	Ault POI Reactive Power (MVAR)	Reactive Power Compensation Required (MVAR)
Wind Farm (200 MW)	1.00	-21.5	none
Wind Farm (0 MW)	1.00	14.8	-14.8

During periods of minimal wind generation, line charging associated with the 35 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. To restore the power factor at the POI to near unity and minimize the potential of high voltage on the wind farm, 14.8 MVAR of switched reactors would be needed.

These models did not include any of the Customer'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 230 kV line configuration used should also be taken into account in more detailed future studies.

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 or 230 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-2008-30 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, to provide more dynamic reactive power 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 generators, collector system, transformers and transmission line will be necessary to proceed.

No switched capacitors will be needed to meet the voltage criteria at the POI near maximum generation. 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. Furthermore, the actual taps used on the Customer's main 34.5 - 230

kV transformers will directly impact the operating voltages and related reactive capabilities for the project wind generation facility.

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 Ault. Once the interconnection is made, at the 230 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 200 MW GI-2008-30 generation project delivered to the Ault POI could result in the overloading of facilities in the PSCo regional transmission system. Therefore, the 200 MW NR value requested will require interconnection and Transmission Network Upgrades. After these upgrades are complete, the 200 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.

Short Circuit Analysis

The short circuit study results show that the fault current levels for all buses studies are within the interrupting ratings of the breaker; therefore, the project and associated infrastructure will not cause fault current to exceed the circuit breaker ratings.

The fault currents at the Tap Substation are 21,116 Amps for a single-line to ground fault and 22,860 Amps for a three-phase fault. These values assume little to no fault current contribution from the proposed wind facility.

Costs Estimates and Assumptions

Scoping level cost estimates for Interconnection and Network/Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by WAPA and PSCo Engineering. The cost estimates are in 2010 dollars with escalation and contingencies applied (AFUDC is not included) and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the siting support, engineering, design, and construction of these new Western and PSCo facilities. This estimate does not include the cost for any other Customer owned equipment and associated design and engineering.

The estimated total cost for the required upgrades is **$67,350,000**. These estimates do not include costs for any other Customer owned equipment and associated design and engineering. 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 a more detailed and refined design.

Table 8 – PSCO Owned; Customer Funded Interconnection Facilities

Element	Description	Cost Est. Millions
Western's Ault 230kV Substation	Interconnect Customer at Western's Ault 230kV Substation. The new equipment includes 230 kV bi-directional metering, control area boundary metering, relaying and associated equipment and material.	**$0.482**
	Transmission tie line into substation.	**$0.232**
	Customer Generator Communication to Lookout.	**$0.032**
	Customer LF/AGC and Generator Witness Testing.	**$0.134**
	Siting and Land Rights for required easements, reports, permits and licenses.	**$0.010**
	Total Cost Estimate for Customer Interconnection Facilities	**$0.890***
Time Frame	Site, design, procure and construct	**30 Months**

*Cost provided from the Western Cost Estimates found in the Appendix

Table 9 - Western Owned; Customer Funded Network Upgrades for Interconnection

Element	Description	Cost
Western's Ault 230kV Substation	Interconnect Customer at Western's Ault 230kV Substation. New 230kV line termination requiring the following equipment: • one 230kV 40 kA, 3000 amp, circuit breaker • two 230kV, 3000 amp gang switches • electrical bus work • required steel and foundations • minor site work (station wiring, grounding)	**$1.200***
Time Frame	Design, procure and construct	**30 Months**

*Cost provided from the Western Cost Estimates found in the Appendix

Xcel Energy

Table 10 – Network Upgrades for Delivery (Infrastructure Upgrades)

Element	Description	Cost Est. Millions
Western's Ault 230kV Substation	New 230kV line termination requiring the following equipment: • two 230kV 40 kA, 3000 amp, circuit breakers • four 230kV, 3000 amp gang switches • electrical bus work • metering, control, relaying and testing • required steel and foundations • minor site work (grading, fencing, grounding)	**$2.400***
PSCo's Cherokee 230kV Switching Station	New 230kV line termination requiring the following equipment: • one 230kV, 50 kA, 3000 amp circuit breaker • two 230kV 2000 amp gang switches • electrical bus work • metering, control, relaying and testing • required steel and foundations	**$0.560**
230kV Transmission Line Construction	New single circuit Ault –Ft. Lupton 230kV line (59 miles) 800 MVA capacity, bundled 954 kcmil (Cardinal) conductor.	**$27.630**
	Convert the existing 115kV line from Ft. Lupton to Cherokee to double circuit 230kV operation with 800 MVA capacity. One circuit will connect to the new Ault 230kV line just outside of Ft. Lupton where as the other will be operated at 115kV to serve the 115 kV stations along the way to Cherokee (29-miles).	**$27.480**
Siting and Permitting	Obtain necessary siting, permits, easements and ROW as required.	**$7.190**
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$65.260**
	Total Cost of Project	**$67.350**
Time Frame	**Site, design, procure and construct**	**60 Months**

*Cost provided from the Western Cost Estimates found in the Appendix

Assumptions

- Scoping level estimates for Network/Infrastructure Upgrades for Delivery (+/- 30% accuracy) were developed by Western and PSCo Engineering.
- Estimates are based on 2010 dollars (appropriate contingency and escalation applied).
- AFUDC has been excluded.
- Labor is estimated for straight time only – no overtime included.
- Lead times for materials were considered for the schedule.
- The Wind Generation Facility is not in PSCo's retail service territory. Therefore, no costs for retail load metering are included in these estimates.
- Western, PSCo (or it's Contractor) crews will perform all construction, wiring, testing and commissioning for Western or PSCo owned and maintained facilities.
- The estimated time to design, procure and construct the interconnection facilities is approximately 30 months after authorization to proceed has been obtained.
- This project is completely independent of other queued projects and their respective ISD's.
- A CPCN will not be required for the interconnection facilities construction.
- A CPCN will be required for the Network Upgrades for Delivery
- Western may require the Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- All necessary substation expansions will be determined by Western.
- Implementation of the recommended infrastructure for delivery will require that existing facilities be taken out of service for sustained periods. In most cases, these outages cannot be taken during peak load periods due to operational constraints. As a result, the estimated time frame for implementation could be increased by 3-6 months.
- A siting study will be required if network upgrades for delivery. Extensive public involvement is anticipated. Permit applications and possible minor right-of-way acquisition will be required. Land use permits will be required from multiple local jurisdictions.