Generation Interconnection Feasibility Study Report Request # GI-2008-11

200 MW Wind Powered Generator Facility
Interconnecting at Ault Substation in the 4th Quarter 2011

PSCo Transmission Planning
July 1, 2009

Executive Summary

The purpose of the Interconnection Feasibility Study is to provide a preliminary evaluation of the feasibility and 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.

On September 19, 2008, Public Service Company of Colorado (PSCo) and the Customer signed a Generator Interconnection Feasibility Study Agreement to evaluate the feasibility of interconnecting a 200 MW wind powered generation plant at the Western Area Power Administration (WAPA) Ault 230 kV bus. The Customer requested the primary Point of Interconnection (POI) to be the 230 kV bus at the Ault Substation. No secondary POI was requested.

The Customer's 200 MW generation facility would consist of 80 Clipper 2.5 MW wind turbines, interconnecting to a 34.5 kV collector system, located in Weld County. The study modeled a single 34.5/230 kV transformer at the generation facility, that would connect to the 230 kV bus at the Ault substation through a 30-mile single-circuit 230kV overhead transmission line. The Customer-proposed Commercial Operation Date[1] is December 31, 2011, with an assumed back-feed for site energization date of June 30, 2011. Based on projected equipment lead-times and other transmission project in service dates, the commercial operation and back-feed dates requested by the Customer are not feasible. An earliest date that 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 tentatively scheduled for May 2015.

This request was studied as both an Energy Resource[2] (ER) and a Network Resource (NR)[3]. The study included steady-state power flow and short-circuit studies only, and

[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] **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

did not include transient dynamic stability analysis. A summary of these studies is provided in the report. 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 2012. Based upon the study results, no power can be delivered to the PSCo load-serving system without adversely impacting the transmission system.

Energy Resource

An interconnection of the Customer facilities to the WAPA-Rocky Mountain Region Ault 230 kV Substation is feasible; however, 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, TOT7, etc.) and the operational status of transmission facilities. Interconnection will be available at the Ault 230 kV bus; however, no delivery would be available without network upgrades.

Network Resource

As a NR request, PSCo evaluated the network to determine the upgrades required to deliver the full 200 MW of the wind facility the PSCo native load customers. The following network upgrades are required to deliver the full 200 MW of wind generation:

- Ault – Cherokee 230 kV Project: A 230 kV transmission line is installed between the Ault substation and the Cherokee substation, proposed in accordance to SB07-100, with a proposed in service date of May 2015

Estimated costs of the Ault-Cherokee 230kV Project is approximately $ 70.6 million and includes:

- $ 685,000 for Customer Funded PSCo Interconnection Facilities
- $ 435,000 for PSCo Network Upgrades for Interconnection
- $ 69,460,000 for PSCo Network Upgrades for Delivery

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nonfirm 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.

[3] **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.

A system one-line diagram showing the proposed infrastructure to meet the delivery requirements is shown below in Figure 1 along with the interconnection details.

Additional details of the studies can be found in the Appendix. Any Interconnection Agreement (IA) requires that certain conditions be met, as follows:

1. The conditions of the Interconnection Guidelines[4] are met.
2. A single point of contact is given to Operations to manage the Transmission System reliably for all wind projects (GI-2008-11) as found in the Interconnection Guidelines.
3. Customer must show the ability to operate the wind generation within the required +/- 0.95 power factor range during all operating conditions (0 MW to 200 MW) as measured at the Point of Interconnection (POI).

These studies determined the following:

- The Customer's wind power generating station, at the full wind output 200 MW, would meet the voltage and power factor requirements, without installing additional static and/or dynamic VAR support equipment at either the Customer's site or near the Western's Ault 230 kV POI. The station is able to operate within the +/- 0.95 power factor requirement as measured at the POI for the system scenario studied (heavy summer demand case) with the wind generation facility on-line.
- The Customer' wind power generating station, with the generating station off-line at 0 MW, would not meet PSCo's +/- 0.98 power factor requirement for loads as measured at the POI. During that condition, the generating facility is operating as a load for station service and approximately 10 MVAR is injected from the Customer's 230 kV transmission line into the Ault 230 kV POI. Therefore, the Customer would need to install approximately 10 MVAR of inductive reactance so that the facility can operate within the required power factor range for a load (between 0.98 leading and lagging power factor) when the wind generation facilities are off-line.
- The Customer's wind power generating station (a 200 MW Wind Farm connected to the Ault 230 kV bus) with network upgrades (an Ault-Cherokee 230 kV line) does not have an adverse impact on the reliability of the system.

WAPA owns the Ault Substation. Interconnecting at the Ault Substation would require WAPA to design and construct new facilities at the Ault Substation. PSCo and the developers would need to work with WAPA as affected parties to develop the interconnection design and costs.

Figure 1 below provides a simplified one-line of the study area.

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

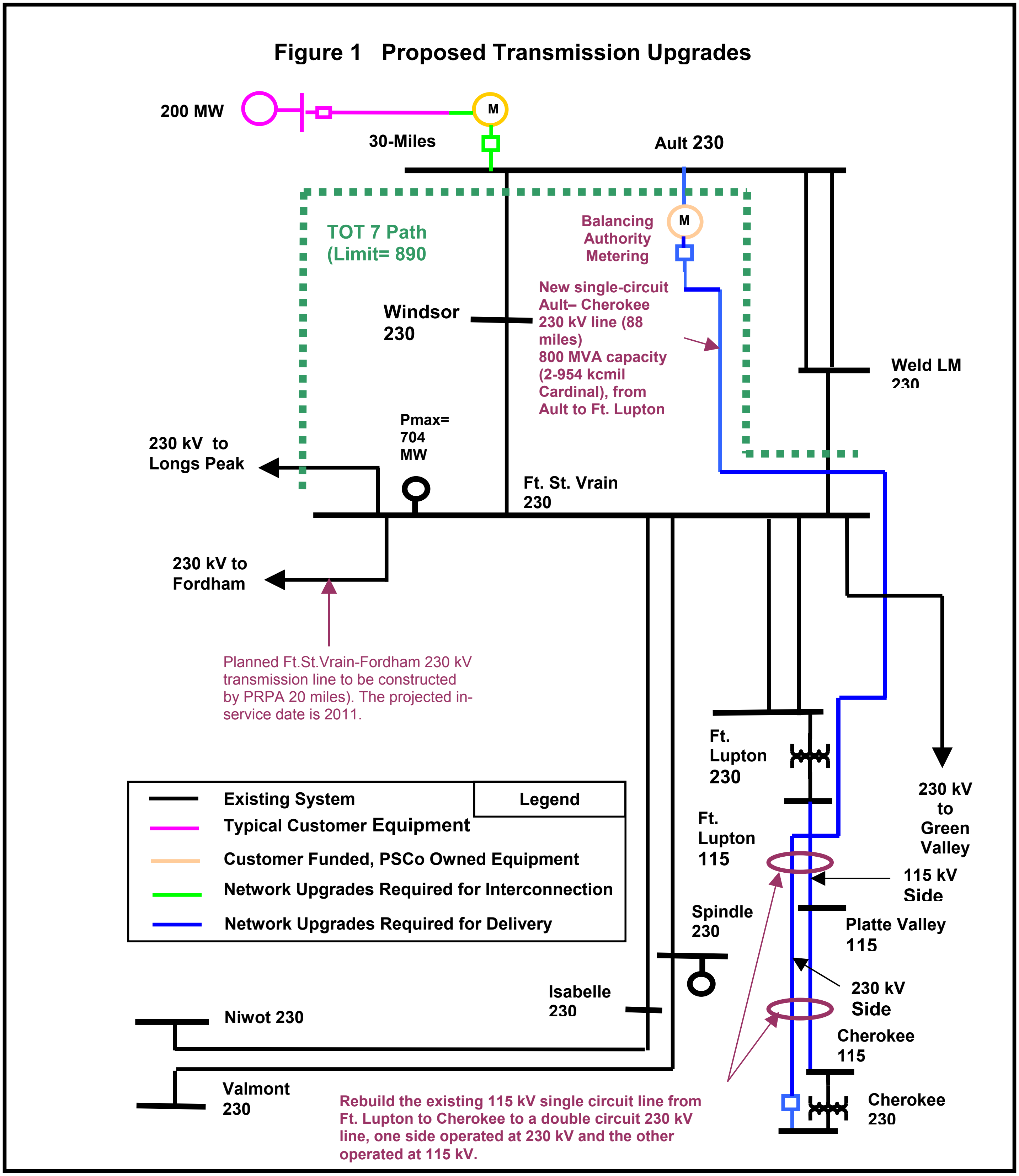
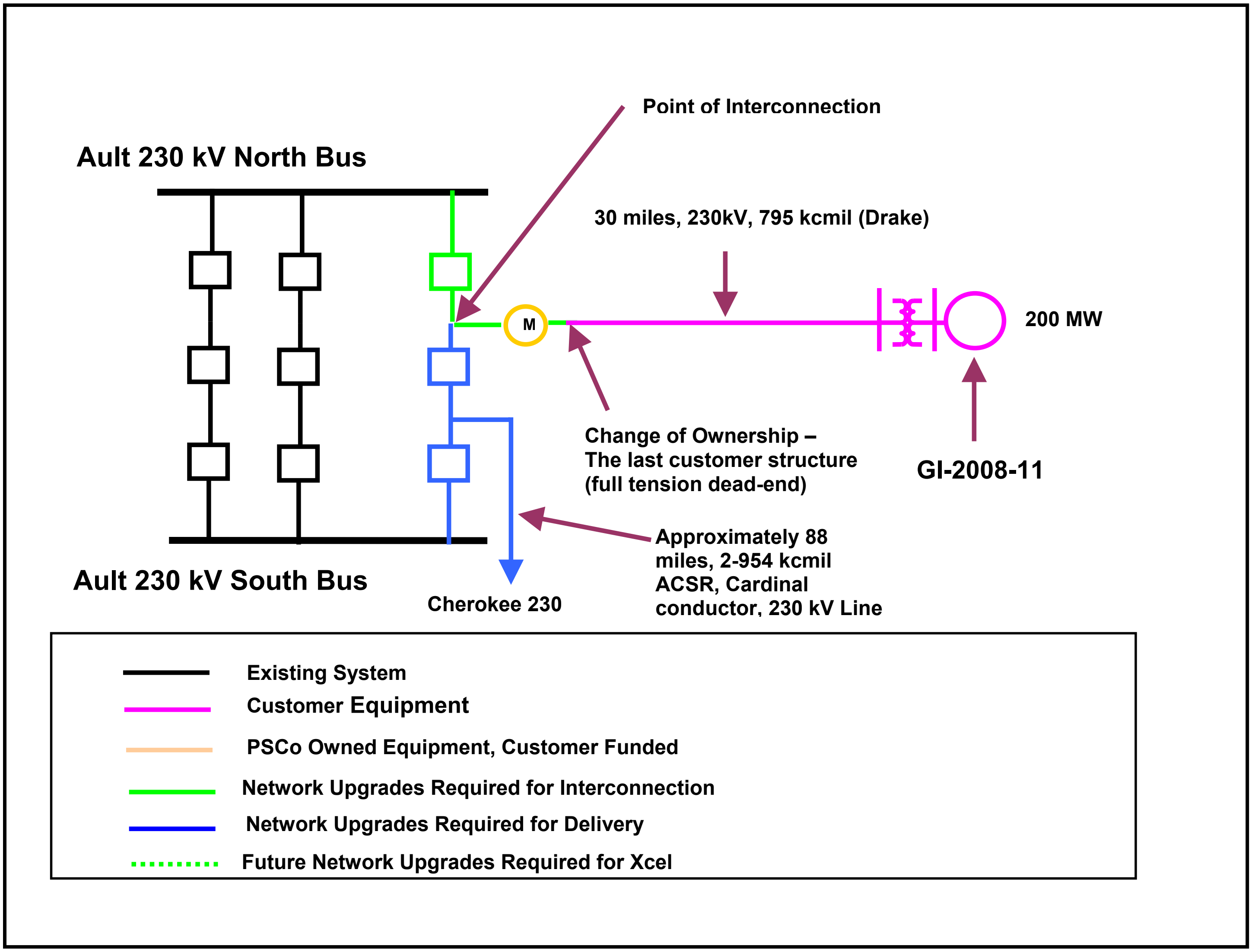


Figure 1 Proposed Transmission Upgrades
200 MW
M
30-Miles
Ault 230
TOT 7 Path
(Limit= 890
Balancing
Authority
Metering
M
New single-circuit
Ault– Cherokee
230 kV line (88
miles)
800 MVA capacity
(2-954 kcmil
Cardinal), from
Ault to Ft. Lupton
Windsor
230
Weld LM
230
Pmax=
704
MW
230 kV to
Longs Peak
Ft. St. Vrain
230
230 kV to
Fordham
Planned Ft.St.Vrain-Fordham 230 kV
transmission line to be constructed
by PRPA 20 miles). The projected in-
service date is 2011.
Ft.
Lupton
230
230 kV
to
Green
Valley
Legend
Existing System
Typical Customer Equipment
Customer Funded, PSCo Owned Equipment
Network Upgrades Required for Interconnection
Network Upgrades Required for Delivery
Ft.
Lupton
115
115 kV
Side
Spindle
230
Platte Valley
115
230 kV
Side
Isabelle
230
Niwot 230
Cherokee
115
Valmont
230
Rebuild the existing 115 kV single circuit line from
Ft. Lupton to Cherokee to a double circuit 230 kV
line, one side operated at 230 kV and the other
operated at 115 kV.
Cherokee
230

Figure 2 below provides a simplified one-line of a portion of the Ault Substation and the proposed 200 MW wind generation facility

Figure 2: Simplified One-Line of the Ault Substation and the Proposed 200 MW Wind Generating Facility



Introduction

PSCo Transmission received a large generator interconnection request (GI-2008-11) to interconnect 80 Clipper Wind Turbines, each wind turbine rated at 2.5 MW, for a total of 200 MW of generation, with a proposed commercial operation date of December 31, 2011, and a back feed for site energization date of June 30, 2011. The proposed 200 MW Wind Farm would be located in Weld County, Colorado, and will be interconnected into Western Area Power Administration's (WAPA) transmission system via a Customer planned 30-mile radial 230 kV line.. The Customer has requested this project be evaluated as an Energy Resource (ER) and a Network Resource (NR) with the energy going to PSCo native load customers.

Study Scope and Analysis

The Interconnection Feasibility Study evaluated the feasibility of providing 200 MW of firm energy from the POI at Ault Substation to the PSCo load center. It consisted of power flow and short circuit analyses. The power flow analysis provided a preliminary identification of any thermal or voltage limit violations resulting for the interconnection, and for a NR request, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified any circuit breaker short circuit capability limits exceeded as a result of the Interconnection, and for a NR request, the delivery of the proposed generation to PSCo loads.

.For this project WAPA, Platte River Power Authority (PRPA) and Tri-State Generation and Transmission (TSG&T) are affected parties in this study. PSCo has contacted affected utilities during the course of this study.

Power Flow Study Models:

Power flow studies were based on a PSCo-developed 2012 heavy summer stressed TOT 7 base case that was developed from the Western Electricity Coordinating Council (WECC) 2012 heavy summer base model that was approved on November 15, 2007. Generation in the PSCo 2012 heavy summer budget case was dispatched to create a relatively high north-to-south power flow in order to stress the TOT 7 transfer path. This stressed case was used as a benchmark comparison prior to the addition of the Customer proposed 200 MW wind generation facility at the Ault substation. Table 1 lists the flows on the TOT3 and TOT7 transfer paths that impact the study area. Definitions of the TOT3 and TOT7 transfer paths are found below.

Table 1: Stressed TOT Flows For Benchmark Case

Base Case	Path Name	Path Flow North-to-South (MW)
2012HS	TOT 3	1321.0
	TOT 7	632.7

The Customer's 200 MW wind facility was modeled as a single lumped equivalent 200 MW, 34.5 kV conventional generator, operating at +/- 0.95 p.f. (without any additional VAR support). Since step-up transformer data was not provided by the Customer, generation was assumed to be tied to two (2) 34.5/230 kV, 110 MVA step-up transformers. A 30-mile, 230 kV Customer transmission line was used to connect the generating facility to the POI. The Customer specified the transmission line would be overhead, single-circuit, and 30 miles in length; however, transmission line characteristics were not provided and were therefore assumed to be based on single, 795-kcmil ACSR (Drake) conductor. Studies show that approximately 10 MVAR of reactive support will be required to maintain ideal bus voltage at the POI. For dispatching to the PSCo native loads, the Customer's generation was scheduled (re-dispatched) to offset other PSCo generation in the southern PSCo system by reducing generation in the area.

Path Definitions

The generation interconnection request impacts the power transfer path TOT 7 [5]. The TOT 7 transfer path provides a path for power transfers into the northern metro Denver area and is also known as Path 40 in the WECC Path Rating Catalog. The loads in the study area consist of Zone 754 and Zone 706 in the WECC power flow case.

TOT 7

TOT 7 is WECC-defined power transfer path located in 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 is shown in Figure 1. The path has a maximum WECC-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 study area called the "Colorado-Big Thompson generation" or CBT. The TOT 7 path owners include PRPA and PSCo. The facilities for this study that comprise TOT 7 are as follows:

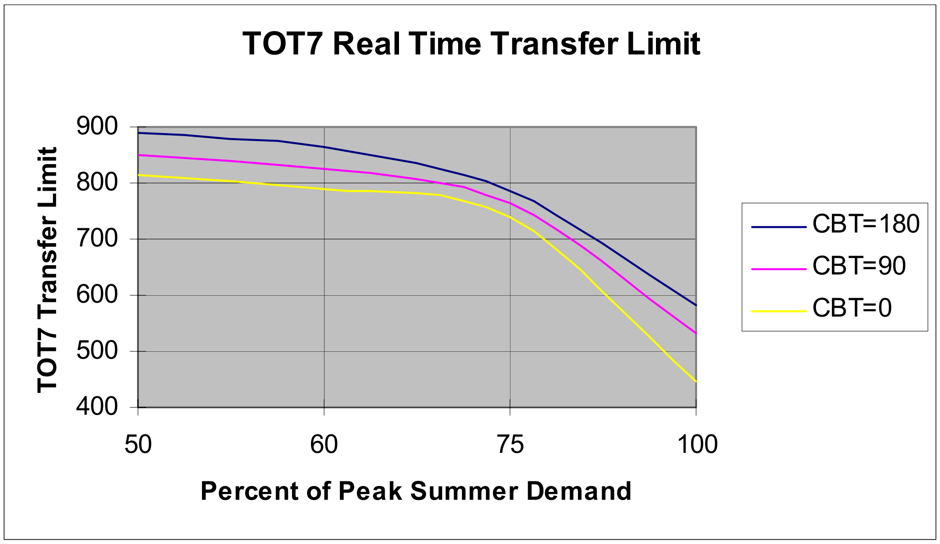
Transmission Line	Metered End
Ault-Windsor 230 kV	Ault
WeldPS-Ft.St.Vrain 230 kV	Weld
Longs Peak-Ft.St.Vrain 230 kV	Ft.St.Vrain

The WECC-accepted north-to-south rating of 890 MW means there is a maximum power transfer capability of 890 MW on the transmission lines crossing the TOT boundary, while allowing for the possible occurrence of a transmission facility outage without the occurrence of an overload. 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 CBT system. As demand in the local area increases, the TOT 7 real-time transfer limit decreases. Similarly, as the CBT generation decreases, the TOT 7 real time rating decreases. Figure No. 2 summarizes the results from a previous operating study, and illustrates this effect. The TOT 7 transfer limit for various levels of demand (expressed as a percentage of the 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 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 demand increases, the TOT 7 Real Time

[5] The TOT 7 transfer path is shared between PSCo and PRPA.

Transfer Limit decreases to approximately 580 MW at the point where the demand reaches 100% of summer peak. Similarly, plots of the TOT 7 Real Time Transfer Limit for levels of 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 No. 2: TOT 7 Real Time Transfer Limit



The local area has experienced a steady increase in demand over the last few years. As a result, the real-time rating of the TOT 7 transfer path has decreased. In response to this large demand increase and the corresponding decrease in the TOT 7 real-time rating, the TOT 7 Path owners, PSCo and PRPA, have initiated transmission planning studies to identify ways to restore the TOT 7 real-time rating to the 890 MW, the level of the accepted rating. PSCo and PRPA must continue to meet their contractual obligations as the local area demand increases.

<u>TOT 3</u>

TOT 3 is WECC-defined power transfer path located on the northern boundary of the study area. TOT 3 is comprised of transmission lines that allow power to be transferred from southeast Wyoming to northeast Colorado. The path has a maximum WECC-accepted north-to-south rating of 1605 MW; however, the real-time path rating is highly dependant on generation schedules at Laramie River Station, the Stegall and Sidney DC ties, the Pawnee Station and the Brush generartion facilities. The TOT 3 path owners include Western Area Power Administration (Western), Tri-State G&T (Tri-State), Basin Electric Power Cooperative (BEPC) and PSCo. The facilities that comprise TOT 3 are as follows:

Transmission Line	Metered End
Archer-Ault 230 kV	Archer
Laramie River-Ault 345 kV	Laramie River
Laramie River-Story 345 kV	Laramie River
Cheyenne-Ponnequin 115 kV	Cheyenne

Sidney-Sterling 115 kV	Sidney
Sidney-North Yuma 230 kV	Sidney

Power Flow Studiy Criteria

PSCo adheres to NERC Reliability Standards[6] and WECC Criteria[7] as well as internal company criteria for planning studies. The Category A and Category B criteria are used for this study:

Category A – System Normal
"N-0" System Performance Under Normal (No Contingency) Conditions (Category A)
NERC Standard TPL-001-0

Voltage:	0.95 to 1.05 per unit
Line Loading:	100 percent of continuous rating
Transformer Loading:	100% of highest 65 °C rating

Category B – Loss of generator, line, or transformer (Forced Outage)
"N-1" System Performance Following Loss of a Single Element (Category B)
NERC Standard TPL-002-0

Voltage:	0.90 to 1.10 per unit
Line Loading:	100 percent of continuous rating
Transformer Loading:	100% of highest 65 °C rating

Power Flow Study Process

The PSCo 2012 heavy summer budget case (the Benchmark Case) had a TOT3 north-to-south interface flow of 1321.0 MW, and TOT 7 north-to-south interface flow of 632.7 MW.. The generation was dispatched at the following locations to create the stressed case:

Table 2: Generator Schedules in the Stressed Case

Generation Location	Generation (MW)
MBPP 1 & 2	1135.0
Yellow Tail 1 - 2 Swing	112.8
Yellow Tail 3 – 4	120.0
Sidney DC	200.0
Stegall DC	100.0
Rawhide	708.0
Ft. St. Vrain	820.0
CBT Units	147.6

To create the study case, it was necessary to add the proposed 200 MW wind farm and transmission line from the proposed Customer site to WAPA's Ault Substation. The

[6] Specifically NERC TPL-001-0 through 004-0 Standards
[7] April 2008 TPL – (001 thru 004) – WECC – 1 – CR – System Performance Criteria

Customer did not provide all of the information needed to model the proposed 200 MW wind farm, nor did they provide the information needed to model the 30-mile 230kV transmission line. Therefore, PSCo Transmission Planning developed this information.

The operating limits of the lumped wind generation facility were estimated by assuming eighty (80) 2.5 MW wind turbine generators connected by way of 34.5/0.69 kV step-up transformers directly to a 34.5kV collector bus. The Customer provided the data to model the 34.5/0.69kV step-up transformers, as well as the operating characteristics of a single wind turbine generator. The Customer indicated that the wind turbine generators can operate between +/- 0.95 power factor (p.f.) The maximum and minimum reactive power that each wind turbine generator could deliver to the 34.5kV bus was calculated and the calculated single turbine limits were multiplied by eighty (80), the equivalent to the number or turbines used, in order to provide an estimate of the lumped generation operating limits at the 34.5 kV collector bus.

The project was then studied by connecting the calculated 200 MW, lumped equivalent conventional generator at the Ault Substation, as described in the request. The following modifications were applied to the base case for this project:

1. A 34.5 kV collector bus and 200 MW equivalent wind turbine generator were added to the case

2. Two (2) 34.5/230 kV, 110 MVA autotransformers were modeled at the Customer generation site in the case using the data from equivalent existing transformers.

3. A 230 kV bus and 30-mile, 230 kV transmission line were added for the project and connected to the Ault 230 kV bus (POI). The transmission line constants (resistance, reactance, susceptance and rating) were calculated assuming 1-795 kcmil (Drake) ACSR conductor.

4. The 200 MW of generation was sinked to the Lamar DC tie by exporting 200 MW out of the PSCo balancing authority to SPP.

Power Flow Study Results and Conclusions

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[8] Specifically NERC TPL-001-0 through 004-0 Standards
[9] April 2008 TPL – (001 thru 004) – WECC – 1 – CR – System Performance Criteria
[10] Western Electricity Coordinating Council (WECC)
[11] Assumptions at the end of the report state that 60 months includes the Colorado CPCN process for the recommended Network Upgrades for Delivery.

Three study cases using proper generation dispatch to stress the power flows as mentioned above were evaluated under system intact and outage conditions. The first case was used as a benchmark with no additions made to the budget case. The second case includes the proposed 200 MW wind generation facility and associated interconnection facilities. The third case includes the addition of the Ault – Cherokee 230 kV line. Automated contingency power flow simulations were completed on these cases, switching out single elements one at a time for all of the elements (lines and transformers) in the study area (zones 706, 754, 753, 703, 700).

The studies were then compared to each other, identifying criteria violations in the study area that were a direct result of the addition of the 200 MW wind generation facility connected to the Ault Substation and delivering power to PSCo native load customers. These violations are listed in Table 3 below. Although the addition of the Ault – Cherokee 230 kV line eliminated the overloads caused by the addition of the 200 MW of wind generation, two line elements were overloaded as a result, and are highlighted in the table. These two line element overloads are necessary Network Upgrades. As per the PSCo FAC-009 list the Denver Terminal – Gray Street line rating has been revised from 116 MVA to 219 MVA, and the Denver Terminal – Lacombe line rating has been revised from 565 MVA to 817 MVA, thereby eliminating the overloaded conditions on these two elements.

Table 3: Single Contingency Criteria Violations After the Addition of the Proposed Ault 200 MW Wind Facility

		NECOLOBenchmark		NECOLOBenchmark_200MW_AULT		NECOLOAULT_CHEROKEE_200MW			
MONITORED ELEMENT	BRANCH RATING	Cont MVA	Loading %	Cont MVA	Loading %	Cont MVA	Loading %	X---LABEL--X	Contingency
70048 GREENVAL 230.00 70526 IMBODEN 230.00 1	435.0			460.0	103.5%			SINGL1 52	70048 [GREENVAL 230.00] 70528 [SPRUCE 230.00] CKT 1
70148 DENVTM 115.00 70208 GRAY ST 115.00 1	109.0					116.0	105.5%	SINGL1 33	70041 [ARVADA 115.00] 70108 [CHEROKEE 115.00] CKT 1
70149 DENVTM 230.00 70324 LACOMBE 230.00 1	490.0					565.0	115.2%	SINGL1 211	70266 [LOOKOUT 230.00] 70480 [WESTPS 230.00] CKT 1
70192 FTLUPTON 230.00 70529 JLGREEN 230.00 1	478.0			487.0	102.6%			SINGL1 164	70192 [FTLUPTON 230.00] 70605 [HENRYLAK 230.00] CKT 1
70252 LAKEWOD2 115.00 70354 RIDGE 115.00 1	75.0			76.0	100.4%			SINGL1 194	70251 [LAKEWOD1 115.00] 70354 [RIDGE 115.00] CKT 1
70410 ST.VRAIN 230.00 70471 WELD PS 230.00 1	478.0			535.0	110.0%			SINGL1 297	70474 [WINDSOR 230.00] 73011 [AULT 230.00] CKT 1
70447 VALMONT 230.00 70592 SPNDLE 230.00 1	478.0			486.0	100.9%			SINGL1 262	70410 [ST.VRAIN 230.00] 70544 [ISABELLE 230.00] CKT 1
70463 WATERTON 115.00 70464 WATERTON 230.00 T2	100.0			100.0	100.1%			SINGL1 24	70037 [ARAPAHOB 115.00] 70165 [ENGLE3TP 115.00] CKT 1
70471 WELD PS 230.00 73212 WELD LM 230.00 1	637.0			669.0	103.4%			SINGL1 297	70474 [WINDSOR 230.00] 73011 [AULT 230.00] CKT 1
70526 IMBODEN 230.00 70528 SPRUCE 230.00 1	435.0			450.0	101.8%			SINGL1 52	70048 [GREENVAL 230.00] 70528 [SPRUCE 230.00] CKT 1
73011 AULT 230.00 73212 WELD LM 230.00 1	478.0			510.0	104.6%			SINGL1 360	73011 [AULT 230.00] 73212 [WELD LM 230.00] CKT 2
73011 AULT 230.00 73212 WELD LM 230.00 2	478.0			510.0	104.6%			SINGL1 359	73011 [AULT 230.00] 73212 [WELD LM 230.00] CKT 1

PSCo Transmission Planning began studying network upgrades to resolve the transmission system criteria violations that would be the result of the 200 MW wind generation facility at the Ault Substation and schedule to PSCo load serving customers. Some of the proposed network upgrades include the following:

- Transmission Alternative A:
  - Additional 230 kV line from Ault to Timberline
- Transmission Alternative B
  - Additional 230 kV line from Weld to Ft. Lupton
  - Additional 230 kV line from JL Green to Cherokee
- Transmission Alternative C
  - Additional 230 kV line from Weld to Ft. Lupton
  - Additional 230 kV line from JL Green to Cherokee
  - Additional 230 kV line from Windsor to Weld
- Transmission Alternative D
  - Additional 230 kV line from Ault to Timberline
  - Additional 230 kV line from Weld to Ft. Lupton
  - Additional 230 kV line from JL Green to Cherokee
  - Additional 230 kV line from Ft. St. Vrain to JL Green
  - Additional 230 kV line from Windsor to Weld
- Transmission Alternative E
  - Additional 230 kV line from Ault to Timberline
  - Additional 230 kV line from Weld to Ft. Lupton
  - Additional 230 kV line from JL Green to Cherokee
  - Additional 230 kV line from Ft. St. Vrain to JL Green
  - Additional 230 kV line from Ft. St. Vrain to Ft. Lupton
  - Additional 230 kV line from Windsor to Weld
- Transmission Alternative F
  - Additional 230 kV line from Ault to Timberline
  - Additional 230 kV line from Weld to Ft. Lupton
  - Additional 230 kV line from JL Green to Cherokee
  - Additional 230 kV line from Ft. St. Vrain to JL Green
  - Additional 230 kV line from Ft. St. Vrain to Ft. Lupton
  - Additional 230 kV line from Spindle to JL Green
  - Additional 230 kV line from Windsor to Weld

The preferred alternative identified would be to construct an 88-mile Ault to Cherokee 230 kV line. The line would not interconnect at Ft. St. Vrain or Ft. Lupton substations.

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[12] It should be noted that all existing wind projects that are to be on-line by the In-service date of this project have been modeled at 10% of their total MW rating. This proposed facility has been modeled at the full 200 MW rating.

[13] **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.

The study addressed the Energy Resource and Network Resource issues. The following paragraphs summarize the study conclusions.

Energy Resource

Interconnection to the PSCo network is feasible however, firm capacity is not available due to existing overloads and firm transmission commitments, and is not possible without the construction of network reinforcements. This Study has determined that an increase in the generation injected at the Ault 230 kV bus directly increases the loading/overloading on the PSCo regional transmission system. Therefore, firm capacity is not available as a result of these overloads, other firm transmission commitments, and is not possible without the construction of network reinforcements. Non-firm transmission capability may be available depending of marketing activities, dispatch patterns, generation levels, demand levels, import path levels (TOT 3, etc.) and the operational status of transmission facilities.

Network Resource

As a NR request, PSCo evaluated the network to determine the upgrades required to deliver the full 200 MW of the wind facility to PSCo native load customers.

Power flow studies demonstrate that PSCo's transmission system cannot accommodate this generation interconnection request at the Ault 230kV POI without significant transmission additions.The recommended Network Upgrades for Delivery that will accommodate the full 200 MW from this project are listed below with an estimated total cost of the these upgrades at approximately $ 70.6 million and include:

- $ 685,000 for Customer Funded PSCo Interconnection Facilities
- $ 435,000 for PSCo Network Upgrades for Interconnection
- $ 69,460,000 for PSCo Network Upgrades for Delivery

The required Network Upgrade for Delivery include the following:

- Ault – Cherokee: Construct a new 88-mile 230 kV transmission 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 230 kV line from Ault to just outside of the Ft. Lupton Substation. 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 load-serving substations and the other side operated at 230 kV completing the circuit from Ault to Cherokee
- Cherokee – Lacombe: In the initial contingency study analysis this line segment was overloaded with the addition of the Ault – Cherokee line; however, after verifying the line limitations, it was determined that the line

rating in the case of 444 MVA was incorrect, and is actually 859 MVA. This increased rating eliminates the overload on the line, thereby removing it from the required network upgrades

- Denver Terminal – Gray Street: In the initial contingency study analysis this line segment was overloaded with the addition of the Ault – Cherokee line; however, after verifying the line limitations, it was determined that the line rating in the case of 109 MVA was incorrect, and is actually 219 MVA. This increased rating eliminates the overload on the line, thereby removing it from the required network upgrades
- Denver Terminal – Lacombe: In the initial contingency study analysis this line segment was overloaded with the addition of the Ault – Cherokee line; however, after verifying the line limitations, it was determined that the line rating in the case of 490 MVA was incorrect, and is actually 817 MVA. This increased rating eliminates the overload on the line, thereby removing it from the required network upgrades

The estimated cost is a "scoping" (+/-30%) preliminary cost and is based on typical construction costs for previous projects of similar construction. The length of time required to complete the project is approximately 60 months[14] from the date of Authorization to Proceed.

In addition the Customer's wind power generating station, with the generating station off-line at 0 MW, would not meet PSCo's +/- 0.98 power factor requirement for loads as measured at the POI. During that condition, the generating facility is operating as a load for station service and approximately 10 MVAR is injected from the Customer's 230 kV transmission line into the Ault 230 kV POI. Therefore, the Customer would need to install approximately 10 MVAR of inductive reactance so that the facility can operate within the required power factor range for a load (between 0.98 leading and lagging power factor) when the wind generation facilities are off-line.

Joint transmission studies would be required with all affected utilities to obtain regulatory and industry acceptance of a new TOT 7 transfer limit along with the proposed infrastructure improvements, if the Customer chooses to continue this interconnection request. This study only examined system criteria violations before and after the integration of GI-2008-11. It did not examine or propose a new transfer limit of the path or allocate the rights between TOT 7 owners PSCo and PRPA. The WECC path rating process requires joint transmission studies to demonstrate that the new rating would not negatively impact other transfer paths and neighboring systems.

Voltage Control Studies at the Point of Interconnection

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

[14] Assumptions at the end of the report state that 60 months includes the Colorado CPCN process for the recommended Network Upgrades for Delivery.

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 Point Of Interconnection shall be maintained in the ideal voltage range for the appropriate Colorado region and bus type (regulating[15] or non-regulating) as determined in the Rocky Mountain Area Voltage Coordination Guidelines[16]. 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 [17]. It is understood that sufficient reactive power reserve must be maintained on

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

[16] 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.

[17] 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".

generating units to allow them to dynamically regulate voltage for extreme system conditions.
a.

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.

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 (MVAR, voltage--34.5 kV or 230 kV), and the locations of those facilities that may be needed for acceptable performance during the commissioning testing.

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.

Short Circuit Study Results

A breaker duty study was conducted to determine if the fault current (single-line-to ground or three-phase) exceeds the interrupt ratings of any circuit breakers at the Ault Substation or the Cherokee Substation. The duty study compared the short-circuit model with the proposed new generation injected at the Ault Substation and the addition of the Ault-Cherokee 230kV line to a model without the generation and network upgrade, and identified which breakers are within 5% of their fault interruption rating as a result of the generation. Per PSCo policy, these breakers would require replacement and would be categorized as network upgrades. Table 4 summarizes the anticipated fault currents that could be expected after the addition of GI-2008-11.

[18] 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".

Table 4: Short-circuit Study Results With and Without the Proposed 200 MW Wind Farm

System Condition	Three-phase (amps)	Thevenin System Equivalent Impedance (R,X) (ohms)	Single-line-to-ground (amps)	Thevenin System Equivalent Impedance (R,X) (ohms)
Ault 230kV Bus **After** to the Addition of the Wind Generation Facility and Network Upgrades	I_1=26,218.4 I_2=I_0=0 I_A=I_B=I_C=26,218.4	Z1(pos)= 0.40986,5.04817 Z2(neg)= 0.42007,5.05078 Z0(zero)= 0.65887,5.13710	I_1=I_2=8,674.24 $3I_0$=26,022.7 I_A=26,022.7 I_B=I_C=0	Z1(pos)= 0.40986,5.04817 Z2(neg)= 0.42007,5.05078 Z0(zero)= 0.65887,5.13710

The results of the short-circuit analysis faulted at the Ault 230 kV bus show that none of the circuit breaker's fault interruption ratings at the Ault Substation would be exceeded as a result of the new generation.

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

The fault currents at the Ault Substation are 26,022.7 amps for a single-line to ground fault and 26,218.4 amps for a three-phase fault. These values assume little to no fault current contribution from the proposed wind facility. These values assume little to no fault current contribution from the proposed wind facility.

A detailed diagram of the 200 MW wind farm short circuit information can be found in the Appendix.

Costs Estimates and Assumptions

The Customer has requested a 200 MW Wind Generation Project interconnecting at Ault 230kV Substation. A 30-mile 230kV radial transmission line will connect the Customer's collector site with the PSCo transmission system at the Point of Interconnection. The estimated total cost for all required interconnection and network (delivery) upgrades is **$70,580,000.**

The estimated costs shown for interconnection facilities are indicative estimates with no level of accuracy. Ault Substation is owned by Western Area Power Administration. Scoping estimates will ultimately be provided by Western. The estimated costs shown for network upgrades required for delivery are scoping estimates with an accuracy of +/- 30 %. All estimates are based on 2009 dollars and typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the siting, engineering, design, procurement and construction of these new PSCo facilities. This estimate did not include the cost for any other Customer owned equipment and associated design and engineering.

The following tables list the improvements required to accommodate the interconnection and the delivery of the Project. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to change upon more detailed analysis.

Table 4: PSCo Owned; Customer Funded Interconnection Facilities

Element	Description	Cost Est. Millions
Ault 230kV Substation	Interconnect Customer to tap the bus at the Ault 230kV substation. The new equipment includes: • 230kV bidirectional metering • Three 230kV combination CT/PT instrument transformers • One 230kV, 3000 amp gang switch • Associated electrical equipment • Associated foundations and structures • Associated transmission line communications, relaying and testing	**$0.580**
	Transmission – labor to install slack span into Ault Substation. Materials furnished by Customer.	**$0.075**
	Customer Generator Communication to Lookout.	**$0.010**
	Customer Load Frequency/Automated Generator Control and Generator Witness Testing.	**$0.010**
	Siting and Land Rights support for required easements, reports, permits and licenses.	**$0.010**
	Total Cost Estimate for Customer Interconnection Facilities	**$0.685**
Time Frame	**To design, procure and construct**	**18 Months**

Table 5: PSCo Owned; PSCo Funded Interconnection Facilities

Element	Description	Cost
Ault 230kV Substation	Interconnect Customer to tap the bus at the Ault 230kV substation. The new equipment includes: • One 230kV, 3000 amp, gas circuit breaker • One 230kV, 3000 amp gang switch • Associated foundations and structures • Associated yard surfacing, landscaping, fencing and grounding	**$0.425**
	Siting and Land Rights support for required easements, reports, permits and licenses	**$0.010**
	Total Estimated Cost for PSCo Interconnection Facilities	**$0.435**
Time Frame	**To design, procure and construct**	**18 Months**

Table 6: PSCo Network Upgrades for Delivery

Element	Description	Cost Est. Millions
Ault-Ft. Lupton 230kV OH Transmission Line	Construct approximately 59 miles of single circuit 230kV line at 800 MVA rating. Bundled 954 kcmil "Cardinal" conductor - approximately 20 DE structures, 390 tangent structures, 410 total structures.	**$28.950**
Ft. Lupton-Cherokee 230kV OH Transmission Line	Construct approximately 29 miles of double circuit 230kV line at 800 MVA rating. Bundled 954 kcmil "Cardinal" conductor. Rebuild existing 115kV line to double circuit 230kV, energize one circuit at 230kV, one circuit at 115kV - approximately 43 DE structures, 188 tangent structures, 231 total structures.	**$30.015**
Ault-Cherokee 230kV OH Transmission Line	S&LR's activities (study, site, permit, acquire easements, conduct public and jurisdictional meetings) associated with the construction of approximately 88 miles of transmission line.	**$7.945**
Ault 230kV	Substation modifications and new line termination equipment	**$1.800**

Element	Description	Cost Est. Millions
Substation	required for the Ault-Cherokee 230kV OH Transmission Line construction.	
Cherokee 230kV Substation	Substation modifications and new line termination equipment required for the Ault-Cherokee 230kV OH Transmission Line construction.	**$0.750**
	Total Estimated Cost for PSCo Network Upgrades for Delivery	**$69.460**
Time Frame	**To site, design, procure and construct**	**72 Months**

Assumptions

- The cost estimates provided are "scoping estimates" with an accuracy of +/- 30% (except as noted above).
- Cost estimates provided for all interconnection facilities are indicative estimates with no level of accuracy. WAPA will be responsible for scoping estimates and design for facilities at the Ault Substation for the facilities study.
- Estimates are based on 2009 dollars.
- There is no contingency added to the estimates. AFUDC is not included.
- Labor is estimated for straight time only – no overtime included.
- The Generator is not in PSCo's retail service territory. Therefore no costs for retail load metering are included in these estimates.
- PSCo (or it's Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- The estimated time to site, design, procure (long lead time materials) and construct the interconnection facilities is at least 18 months, and is completely independent of other queued projects and their respective ISD's.
- A CPCN will not be required for interconnection facility construction.
- A CPCN will be required for the Network Upgrades for delivery
- Customer will string OPGW fiber into substation as part of the transmission line construction scope.
- PSCo crews to perform checkout, relay panel construction and final commissioning.

No new substation land required. Substation work to be completed within existing property boundaries.

APPENDIX

A. System Intact Contingency Analysis Comparison for Network Upgrades

				NECOLO Benchmark		NECOLO Benchmark 200 MW at Ault		NECOLO with Ault – Cherokee 230 kV and 200 MW at Ault	
Monitored Facility (Line or Transformer) From Bus To Bus	Type	Line Owner	Branch Rating MVA	N-0 Flow in MVA	N-0 Flow in % of Rating	N-0 Flow in MVA	N-0 Flow in % of Rating	N-0 Flow in MVA	N-0 Flow in % of Rating
70107 CHEROKEE 230 70324 LACOMBE 230 1	LN	PSCo	444*[1]					543*[1]	122*

*[1] The rating of the line from Cherokee to Lacombe has been revised as per the FAC 009 list to 859 MVA and is no longer overloaded.

B. N-1 Contingency Analysis Comparison for Network Upgrades

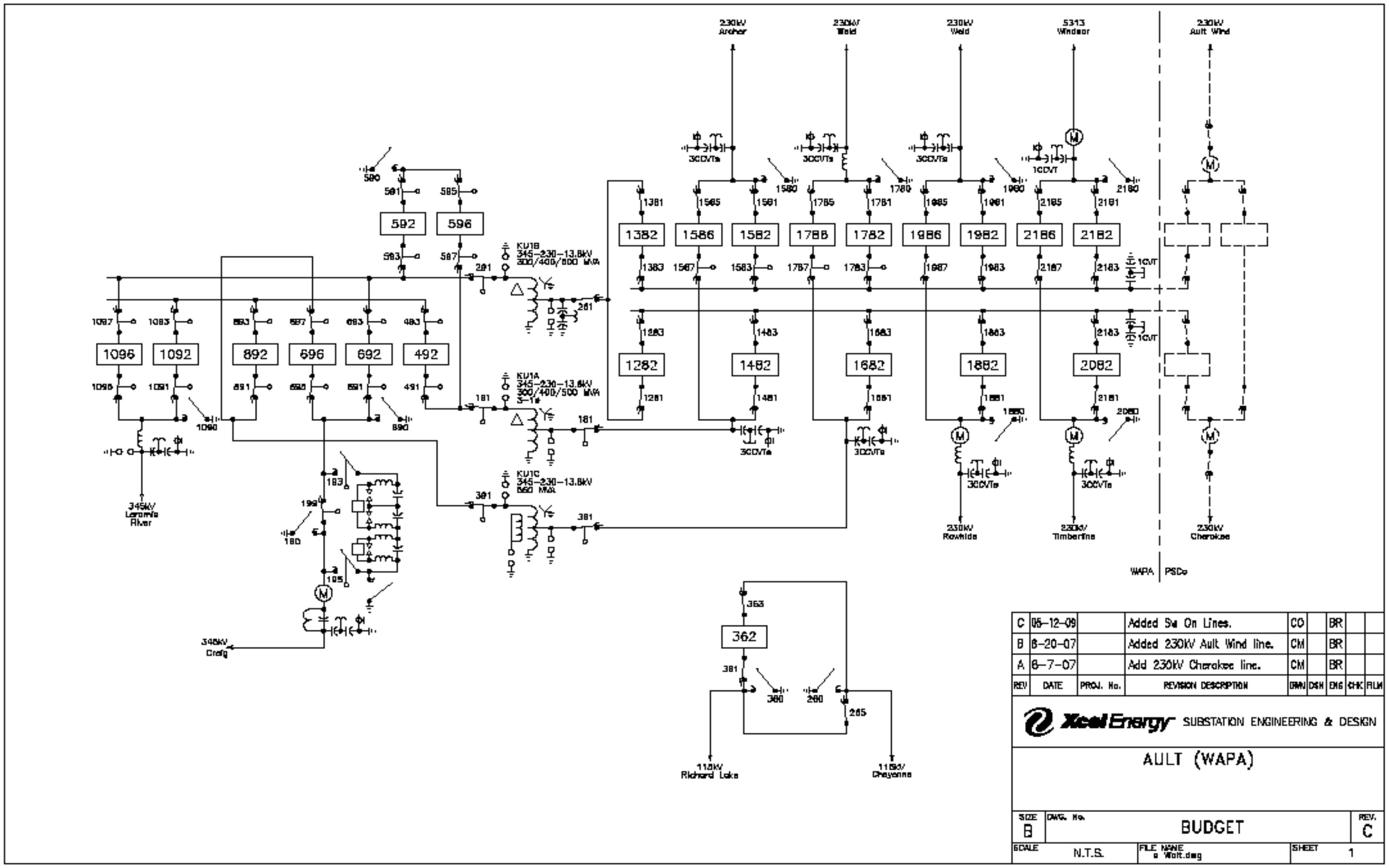
				NECOLO Benchmark		NECOLO Benchmark 200 MW at Ault		NECOLO with Ault – Cherokee 230 kV and 200 MW at Ault		
Monitored Facility (Line or Transformer) From Bus To Bus	Type	Line Owner	Branch Rating MVA	N-0 Flow in MVA	N-0 Flow in % of Rating	N-0 Flow in MVA	N-0 Flow in % of Rating	N-0 Flow in MVA	N-0 Flow in % of Rating	N-1 Contingency Outage From Bus To Bus
70148 DENVTM 115 70208 GRAY ST 115 1	LN	PSCo	109*[2]					116	105.5	70041 ARVADA 115 70108 CHEROKEE 115 CKT 1
70149 DENVTM 230 70324 LACOMBE 230 1	LN	PSCo	490*[3]					565	115.2	70266 LOOKOUT 230 70480 WESTPS 230 CKT 1

*[2] The rating of the line from Denver Terminal to Gray Street has been revised as per the FAC 009 list to 219 MVA and is no longer overloaded.

*[3] The rating of the line from Denver Terminal to Lacombe has been revised as per the FAC 009 list to 817 MVA and is no longer overloaded.

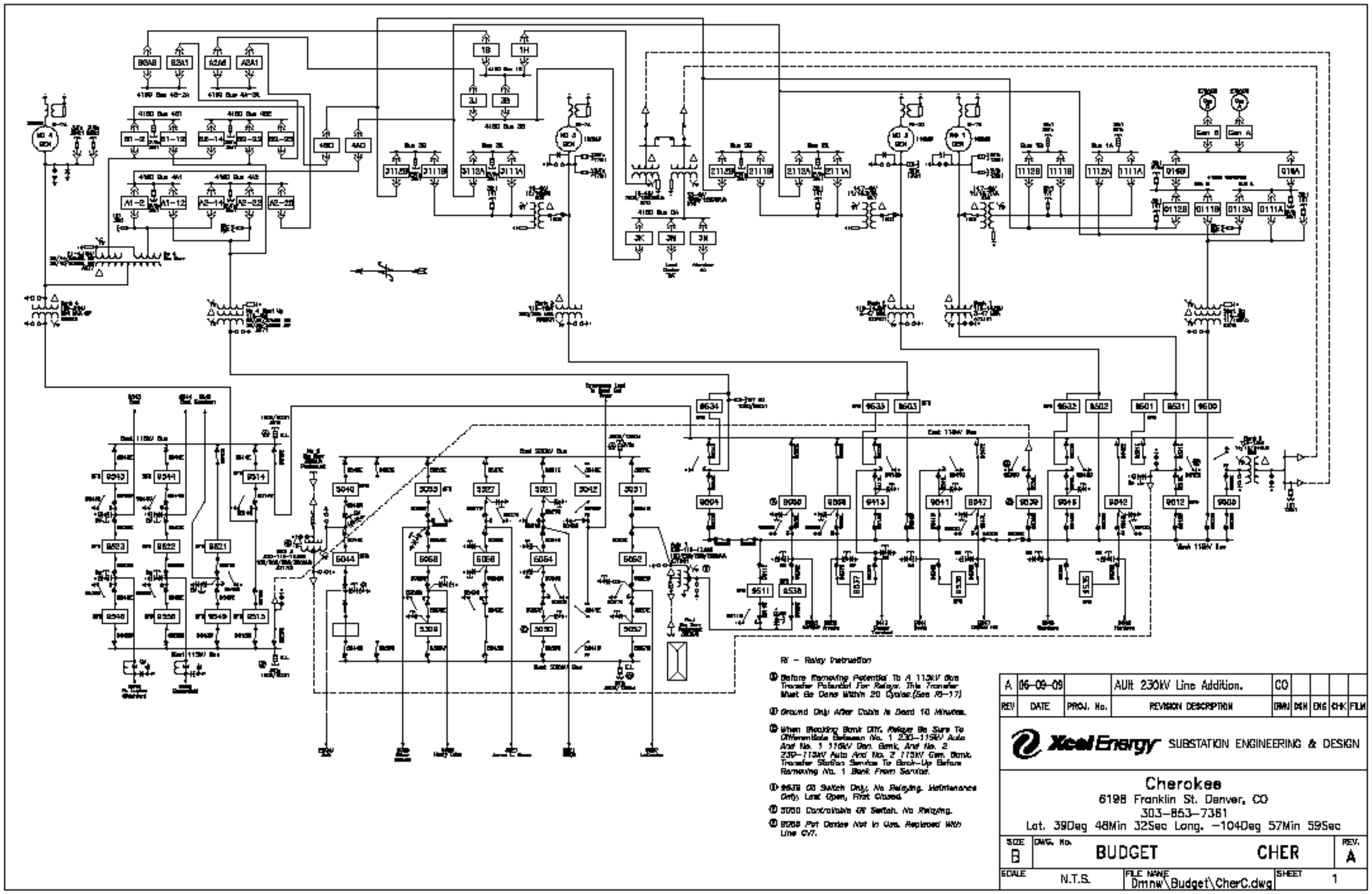
C. Ault Substation Proposed One-Line

A revised one-line diagram of the Ault Substation after the addition of the proposed transmission line to the wind generating facility and the proposed Ault-Cherokee 230 kV Transmission Line is shown below. The revision is based on a PSCo Substation Engineering estimate. It does not reflect a design that Western might use to terminate the proposed transmission line to the wind generating facility or the proposed Ault-Cherokee 230 kV transmission line.



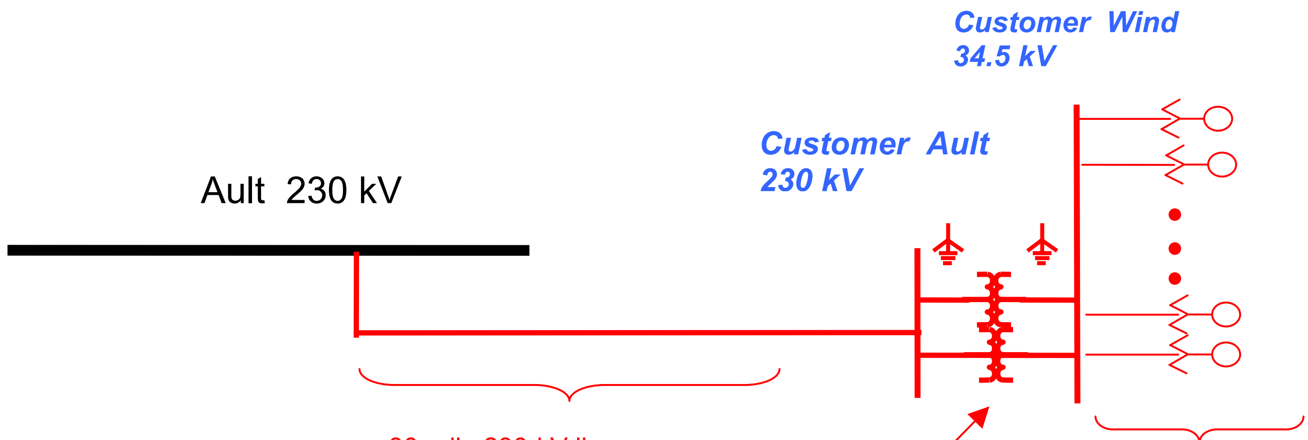
D. Cherokee Substation Proposed One-Line

A revised one-line diagram of the Cherokee Substation after the addition of the proposed Ault-Cherokee 230 kV Transmission Line is shown below.



E. Short Circuit Information

GI-2008-11
200 MW Wind Farm
Short Circuit Information
(80 Clipper Liberty C93 2.5 MW Wind Turbines)



30-mile 230-kV line
795 kcmil ACSR

R1=0.00664
X1=0.04426
B1=0.08707
R0=0.03281
X0=0.13399
B0=0.06035
(100 MVA Base)

Two 230GrY-34.5GrYkV 65/85/110 xfmrs each with R1=0.002 p.u. and X1=0.086 p.u. on a 100 MVA Power Base and 230kV Voltage

80 Clipper Liberty C93 2.5 MW Wind Turbines

Each 2.5 MW wind turbine has an associated 2.75 MVA 34.5**Y**-0.69**Y**kV xfmr at a 5.75% impedance on a 2.75 MVA base with no load losses <0.2% of the xfmr kVA rating and total losses <1.2% of the xfmr rating at rated voltage.

Clipper Liberty 2.4 MW turbine Xd" = j 999999 (a high value) on a 100 MW base in order to simulate a 1.11 p.u. current for fault conditions. During transmission system faults, the inverters are capable of supplying up to 1.11 p.u. current for up to 150 ms if the line voltage at the inverter terminals does not drop below 0.1 pu as a result of the fault.

Existing System

GI-2008-11 – 200 MW Wind Farm