Generation Interconnection
System Impact Study Report
Request # GI-2007-4

300 MW Wind Powered Generator Expansion (600 MW Total)
Interconnecting at Ault Substation in the 4th Quarter 2014

PSCo Transmission Planning
March 31, 2009

A. Executive Summary

PSCo Transmission received a generator interconnection request to determine the system impact of interconnecting a 300 MW expansion of new Customer wind turbine generation into the PSCo transmission system. The requested Point of Interconnection (POI) would be at the Ault Substation 230 kV bus. The GI-2007-4 request was studied as a 300 MW expansion of the GI-2007-3 wind generation project for a total of a 600 MW injection at the Ault Substation. This request was studied as both an Energy Resource[1] (ER) and a Network Resource (NR)[2]. The Commercial Operation Date[3] requested by the Customer is November 1, 2014. The assumed In-Service Date[4] for back feed is May 1, 2014.

The System Impact Study was performed using the 2014 heavy summer case and included steady-state power flow and dynamic stability studies. A summary of these studies is provided in the report. Based upon the study results, no power can be delivered to the Ault 230 kV bus without adversely impacting the transmission system. An interconnection of the Customer facilities to the Western Area Power Administration-Rocky Mountain Region (Western) 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. Interconnection will be available at the Ault 230 kV bus; however, no delivery would be available without network upgrades. Non-firm transmission capability may be available

---

[1] **Energy Resource Interconnection Service (ER Interconnection Service)** shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or 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.

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

[3] **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.

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

depending on marketing activities, dispatch patterns, generation levels, demand levels, import path levels (TOT3, etc.) and the operational status of transmission facilities.

PSCo evaluated the network to determine the upgrades required to deliver the full 600 MW (300 MW from GI-2007-3 and 300 MW of expansion) of the wind facility to PSCo native load customers. The PSCo system between the Ault Substation and the PSCo System includes one WECC[5] recognized transfer path – TOT7. The TOT 7 transfer path is a constrained interface between the Northern Colorado Area and the North Denver Metro Area. The TOT 7 transfer limit depends on the Foothills Area demand and the level of generation from the Colorado-Big Thompson (CBT) Hydro Project units. Power flow studies demonstrate that PSCo's transmission system cannot accommodate this interconnection request from the POI under the operating scenarios studied without significant transmission additions. The 600 MW generation injection crosses TOT 7, which is a constrained path depending on the Foothills Area demand conditions and CBT generation. The TOT 7 capacity is fully committed by existing firm reservations and there are system criteria violations that reduce the use of the Total Transfer Capability (TTC) on TOT7. Generation injection will require significant transmission additions.

The recommended Network Upgrades for Delivery that will accommodate the full 300 MW from this project are listed below with an estimated total cost of the these upgrades at approximately $65.01 million and include:

- $ 0.89 million for Customer Funded PSCo Interconnection Facilities
- $ 0.41 million for PSCo Network Upgrades for Interconnection
- $63.71 million for PSCo Network Upgrades for Delivery

The required Network Upgrade for Delivery include the following:

- 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.

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[6] from the date of Authorization to Proceed.

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 both GI-2007-3 and GI-2007-4. 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

[5] **Western Electricity Coordinating Council (WECC)**
[6] Assumptions at the end of the report state that 60 months includes the Colorado CPCN process for the recommended Network Upgrades for Delivery.

transmission studies to demonstrate that the new rating would not negatively impact other transfer paths and neighboring systems.

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[7] are met.
2. A single point of contact is given to Operations to manage the Transmission System reliably for all wind projects (GI-2007-3 and GI-2007-4) 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 600 MW) as measured at the Point of Interconnection (POI).

These studies determined the following:

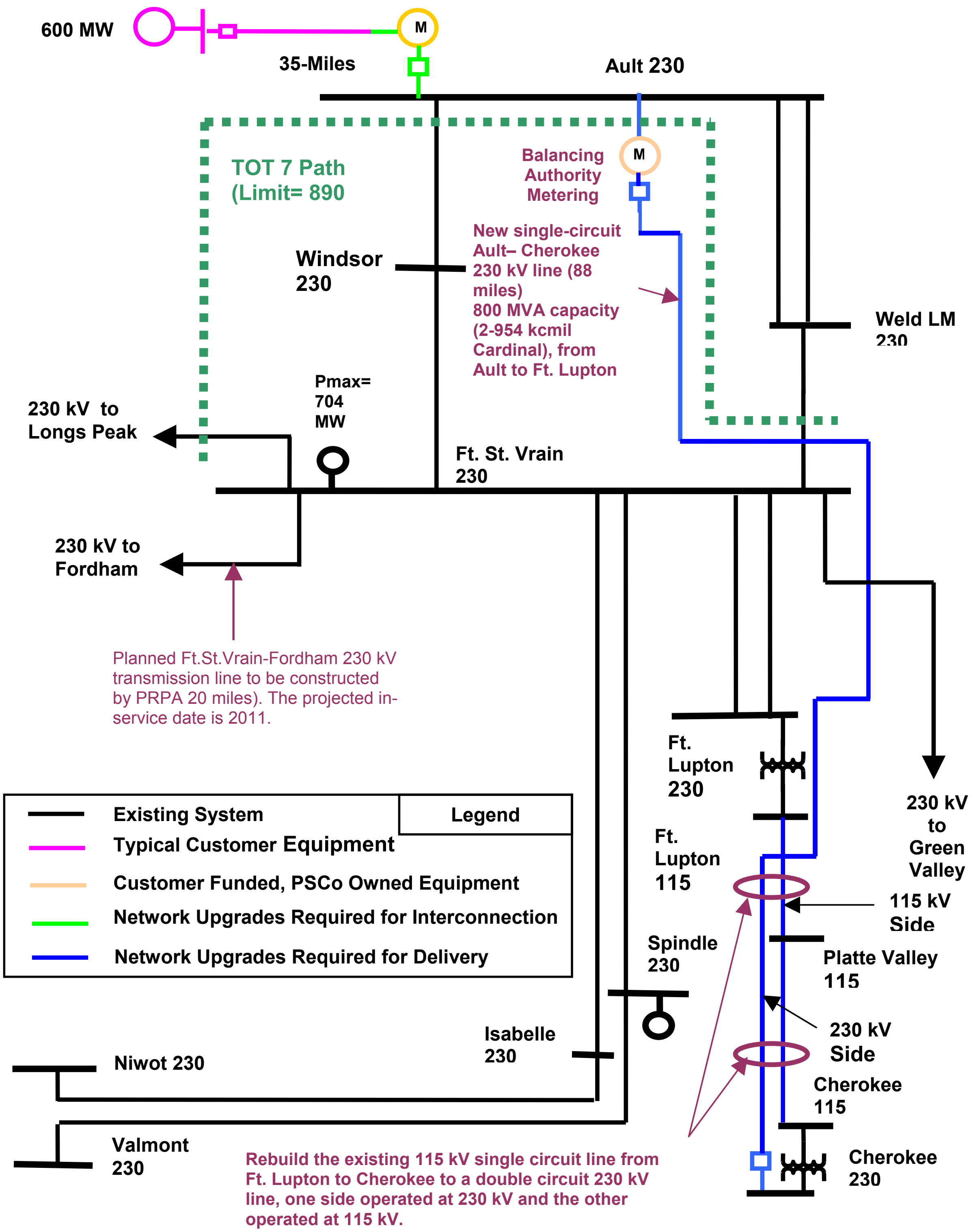
- The Customer's wind power generating station, at the full wind output 600 MW, would meet the voltage and power factor requirements, without installing additional static and/or dynamic VAR support equipment at either the Customer's site or near the Western's Ault 230 kV POI. The station is able to operate 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 16 MVAR is injected from the Customer's 230 kV transmission line into the Ault 230 kV POI. Therefore, the Customer would need to install inductors 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 300 MW Wind Farm expansion along with GI-2007-3 generation of 300 MW connected to the Ault 230 kV bus) with network upgrades (an Ault-Cherokee 230 kV line) does not have an adverse impact on the response of the system to severe system disturbances. All generation remained on line, except where disconnected from the system. All oscillations were positively damped and voltage deviations on nearby 115 kV and 230 kV buses were well within criteria, with no low voltage ride-through (LVRT) issues.

Western owns the Ault Substation. Interconnecting at the Ault Substation would require Western to design and construct new facilities at the Ault Substation. PSCo and the developer would need to work with Western as an affected party to develop the interconnection design and costs.

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

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

Figure 1 Proposed Transmission Upgrades



B. Introduction

PSCo Transmission received a large generator interconnection request (GI-2007-4) to interconnect a 300 MW wind farm expansion at Ault substation consisting Acciona AW1500 Wind Turbine with each wind turbine rated at 1.5 MW. This request would be an expansion of the proposed 300 MW Wind Farm (GI-2007-3) and would be located northwest of Ft. Collins, Colorado. This facility would interconnect into the transmission system via a Customer-owned 35-mile radial 230 kV transmission line terminating at the POI, the 230 kV bus of the Ault Substation. The Customer requested that this project be evaluated as a Network Resource (NR) and an Energy Resource (ER) with the energy going to PSCo native load customers.

Western and PRPA would be affected parties. PSCo will be coordinating the studies with both organizations.

C. Path Definitions

The generation interconnection request impacts the power transfer path TOT 7 [8]. 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 ability to transfer power across the TOT 7 Transfer Path is impacted by the level of Foothills Area demand and level of hydroelectric generation of the Colorado-Big Thompson 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. These variables are considered for any study that considers transfers across the TOT7 Transfer Path.

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

D. Study Criteria

PSCo adheres to NERC / WECC criteria as well as internal company criteria for planning studies. The criteria for the power flow study and the stability study are as follows:

1. Power Flow Studies

PSCo adheres to NERC Reliability Standards[9] and WECC Criteria[10] 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

2. Transient Stability Studies

Transient stability analyses for system intact initial conditions will be performed at the appropriate dispatch for the peak demand scenario. The transient stability criteria require that all machines remain in synchronism, all voltage swings should be damped, and voltage/frequency performance must meet the following performance criteria:

- Following fault clearing for single contingencies, voltage on load buses may not dip more than 25% of the pre-fault voltage or dip more than 20% of the pre-fault voltage for more than 20 cycles.
- For double contingencies (i.e., breaker failures), voltage on load buses may not dip more than 30% of the pre-fault voltage or dip more than 20% of the pre-fault voltage for more than 40 cycles.

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

E. Power Flow Study Models

Western Electricity Coordinating Council (WECC) creates the operating and planning cases for transmission planning studies. For this study, PSCo used the 2015 HS1SA approved base case (approved on April 6, 2007) that was modified for 2014 summer conditions (base case).

The wind farm would consist of 200 1.5-MW turbines for a total project output of 300 MW. The wind turbine proposed for the Project is the Acciona AW1500 Wind Turbine and each wind turbine is rated at 1.5 MW with a +0.93 to -0.93 power factor, i.e. it can produce or absorb 0.59 MVAR of reactive power. The Acciona wind turbine operates at a terminal voltage of 12 kV, which is then stepped up to 34.5 kV by a generator step up transformer installed at the base of the tower. The 34.5 kV output from the turbines is collected at the Project substation via underground feeder cables. Preliminary layout for the Collector System has been provided. As per the layout, the Collector System is comprised of 20 feeder circuits, with 10 turbines connected to each feeder. Except for one, all feeder circuits have been equivalenced for representation in PSS/E. One feeder circuit has been modeled with adequate detail to study the wind turbine behavior. The 34.5 kV bus at the substation is divided into two separate buses with 10 feeders on each bus. Two 34.5/230 kV transformers step up the wind farm output to the 230 kV level for interconnection to the PSCo system via a project-owned 35 mile 230 kV transmission line. The Point of Interconnection (POI) is at the Ault 230 kV bus. Each wind turbines regulates its local generator bus to a 1.04 per unit voltage. Each 34.5/230 kV transformer controls the 34.5 kV side voltage, holding it at/under 1.02 per unit.

F. Power Flow Study Results and Conclusions

Power flow studies were performed using the PSS/E software called “Managing and Utilizing System Transmission (MUST)” and it was determined that Network Upgrades would be required to accommodate the 600 MW interconnection request and that these transmission upgrades would be needed to increase the TOT 7 transfers under heavy summer demand conditions. Transmission alternatives were developed in the GI-2007-4 Feasibility Study to allow an increase of the TOT 7 transfers assuming 2014 heavy summer demand conditions with CBT generation on-line along with the proposed 600 MW wind facility interconnecting at Ault. The preferred alternative identified would be to construct an 88-mile Ault-Cherokee 230 kV line. The line would not interconnect at the Ft. St. Vrain or Ft. Lupton substations. This alternative allowed the 600 MW of wind generation to be scheduled across TOT 7 without violating system criteria.

The proposed 300 MW wind farm expansion, the GI-2007-3 300 MW wind generating facility, a 35-mile transmission line from the wind farm to the Ault 230 kV bus and a new Ault-Cherokee 230 kV line, were modeled in the study case and the case re-dispatched. Facility outages were simulated and the results are listed in Table 1 below.

Table 1: Contingency Results for Scenario 2 (Wind Farm Interconnection at the Ault 230 kV Bus with a new Ault-Cherokee 230 kV Line)

** From bus ** ** To bus ** CKT	Type	Cont MVA	Base Flow	Branch Rating	Loading %	Contingency
70107 CHEROKEE 230 70324 LACOMBE 230 1	LN	460.2	397.0	444.0	103.6	70107 CHEROKEE 230 70355 RIDGE 230 1

The apparent overload of the Cherokee-LaCombe 230 kV line is due to a reduced rating of 444 MVA for the branch. Transmission Engineering has studied the transmission line and has increased the line rating to 858 MVA (per FAC-009). The studies demonstrate that the proposed Ault-Cherokee 230 kV line would allow the full 600 MW wind generating station to be a PSCo network resource.

Energy Resource (ER) Evaluation

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

The study has determined that the Customer may interconnect as a Network Resource after the required Network Upgrades for Delivery are completed. Interconnection as an Energy Resource will require the same Network Upgrades to deliver the requested generation level on a firm basis. Some non-firm transmission capability may be available depending upon generation dispatch levels, demand levels, import path levels (TOT3, etc), and the operational status of transmission facilities.

Network Resource (NR) Evaluation

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

The power flow analysis provided a preliminary identification of any thermal or voltage limit violations resulting from the interconnection, and for an NR scenario, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo loads. The study found that significant Network Upgrades would be required to accommodate the 600 MW interconnection request and that these transmission upgrades would be needed to increase the TOT 7 transfers under heavy summer demand conditions. The Network Upgrades included an 88-mile Ault-Cherokee 230 kV line along with line terminations at the Ault and Cherokee substations.

G. Reactive Power Margin at the POI (Ault 230 kV Bus)

PSCo's wind generation studies have the following principles pertaining to reactive power at the POI.

- Interconnecting to the PSCo bulk transmission system requires the Customer to adhere to certain interconnection requirements. Many of these requirements are contained in the Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater than 20 MW (Guidelines).
- The Interconnection Guidelines make reference to interconnection requirements resulting from FERC Order 661A. FERC Order 661A describes the interconnection requirements for wind generation plants.
- PSCo System Operations conducts commissioning tests prior to the commercial in-service date for a Customer's facilities.

The Customer must adhere to 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 (POI) shall be maintained in the ideal voltage range for the appropriate Colorado region and bus type (regulating[11] or non-regulating) as determined in the Rocky Mountain Area Voltage Coordination Guidelines[12]. 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 should not 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 [13]. It is understood that sufficient

[11] 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'.

[12] 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.

[13] 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".

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 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.
8. 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.

Item 1 makes reference to the wind generating plant maintaining a power factor within the range of 0.95 leading to 0.95 lagging, measured at the POI, if the Transmission Provider's System Impact Study shows that such a requirement is necessary to ensure safety or reliability. The System Impact Study examined the 300 MW expansion along with GI-2007-3 (300 MW) for a total of 600 MW injected into the Ault 230 kV bus.

The power flow studies show that the wind generation facility is within criteria when the wind farm is operating at full output. With the wind farm generating at a 600 MW maximum output, the customer's facilities (line plus wind generation site) absorb 31 MVAR of reactive power and the power factor is within the required 0.95 lagging/leading range. Based on the scenarios considered, the wind generating facility appears to operate within the 0.95 lagging and 0.95 leading power factor range with the voltages at the POI remaining within criteria at full output. The Rocky Mountain Area Voltage Coordination Guidelines (that were developed by the Voltage Coordination Guidelines Subcommittee (VCGS) of the Colorado Coordinated Planning Group) indicate that system should be operated in such a way that Ault 230 kV bus voltage (regulated bus) in Foothills Area should remain within an ideal voltage range from 1.0 p.u and 1.04 p.u. The study results show that for the operating conditions simulated, the voltages at the Ault 230 kV POI are at 1.026 p.u., within the voltage range of (1.00 p.u. to 1.04 p.u.) for a controlled bus. The results of the reactive margin studies are listed in Table 2 below.

Table 2: Wind Farm Reactive Power Capability Results

	POI (Ault) Voltage	POI (Ault) MVAR (+/-)	Reactive Power Required at POI (MVAR)
Wind Farm max MVAR	1.026	31	0
Line Charging Scenario (all units off-line)	1.021	-16	16

With the Customer wind units off-line, 16 MW is injected into the POI from Customer's 230 kV transmission line (at an Ault 230 kV bus voltage of 1.021 p.u., that is within the voltage range of 1.00 p.u. to 1.04 p.u. for a controlled bus. However, the power factor under these conditions is 0.9 lagging, outside the required power factor range for loads; therefore, approximately 16 MVAR of inductors could be needed to bring the power factor within the required range. The Ault Substation is owned by Western; therefore, the requirement to add 16 MVAR of reactors will need to be discussed with Western.

The study did not investigate all possible operating conditions including single circuit and double circuit outages. Further study work would be required to study the impact of the proposed wind generating facility on the power factor and voltage at the POI.

NOTE - It is the responsibility of the Customer to determine what type of equipment is required (CVAR, added switched capacitors, SVC, reactors, etc.) and at what final ratings (MVAR, voltage 34.5 kV, 230 kV) and location (Ault 230 kV POI) will be necessary to meet these reactive power controllability requirements. Furthermore, the actual voltage tap ratios used for the Customer's main 230 - 34.5 kV transformers will directly impact the operating voltages and related reactive capabilities for the Ault wind generating facility. The Customer should review these issues in determining the final design requirements for this equipment (CVAR, transformer voltage tap ratios and MVA, etc.).

H. Transient Stability Analyses Results and Conclusions

1. Study Data

The benchmark stability analysis started from a WECC-approved 2014HS power flow base case, with the associated machine model data for the 2014 summer peak period. This case has been used in recent stability analyses for several other generator system impact studies. Generation from the new project is assumed to displace generation from the existing Comanche units. The Acciona AW1500 Wind Turbine model was developed for use with PSS™E version 30.0 and hence is not compatible with version 30.2. Consequently, the base case scenario was studied using PSS™E version 30.2 whereas the new generation scenario was studied using PSS™E version 30.0.

2. Methodology

Initially, the stability analysis was performed for the benchmark case. After reviewing the data for reasonableness and obtaining a flat start with the benchmark case, dynamic simulations were performed for both the benchmark case and the case with the new wind generation (GI-2007-4) for a common set of system disturbances to determine if the addition of the new wind generation would have any adverse impacts on the system.

Rotor angles, mechanical and electrical power, generator terminal voltages, and frequency were monitored for representative generating units throughout control areas 70 and 73. In addition, voltages at the 115 kV, 230 kV, and 345 kV buses in areas 70 and 73 were also monitored.

3. Study Criteria

WECC planning criteria including voltage deviation criteria for system response after disturbances was used in the analysis. Specifically, WECC requires that for a single contingency, transient voltage dips cannot exceed 25% at load buses, or 30% at non-load buses, cannot exceed 20% for more than 20 cycles at any load bus, cannot have a post-transient voltage deviation exceed 5% at any bus, and the frequency cannot dip below 59.6 Hz for 6 cycles or more at a load bus. For multiple contingencies, transient voltage dips cannot exceed 30% at any bus and cannot exceed 20% for more than 40 cycles at any load bus, cannot have a post-transient voltage deviation exceed 10% at any bus, and frequency cannot dip below 59.0 Hz for 6 cycles or more at a load bus. The addition of any new generation cannot produce a system performance that is out of compliance with the values stated above.

4. Disturbance Scenarios

A list of faults near the proposed GI-2007-4 Project were developed that should provide a reasonably thorough evaluation of system performance (see Tables 3 and 4). Fifteen three-phase faults on single 230 kV or 345 kV circuits were studied, with fault clearing in 5 cycles, for 230 kV, or 4 cycles, for 345 kV. In addition, five three-phase faults were studied that required the tripping of two circuits in 5 cycles.

5. Results

The results of the stability analysis indicate that the proposed project (a 300 MW Wind Farm expansion along with GI-2007-3 generation of 300 MW connected to the Ault 230 kV bus) with network upgrades (an Ault-Cherokee 230 kV line) does not have an adverse impact on the response of the system to severe system disturbances. All generation remained on line, except where disconnected from the system. All oscillations were positively damped and voltage deviations on nearby 115 kV and 230 kV buses were well within criteria, with no low voltage ride-through (LVRT) issues.

Table 3 and Table 4 list the transient stability scenarios studied.

Table 3: List of (N-1) Bus Faults Used in Dynamics Study

Fault				Cleared Circuit 1						
Location			Duration	Bus 1			Bus 2			
Name	KV	Number	(Cycles)	Name	kV	Number	Name	kV	Number	Circuit
Ault	230	73011	4	Ault	230	73011	Ault	345	73012	3
Ault	345	73012	4	Ault	345	73012	LRS	345	73108	1
Ault	230	73011	5	Ault	230	73011	Rawhide	230	73165	1
Rawhide	230	73165	5	Rawhide	230	73165	TimberIn	230	73199	1
Ault	230	73011	5	Ault	230	73011	TimberIn	230	73199	1
Ault	230	73011	5	Ault	230	73011	Weld	230	73212	1
Cheyenne	230	73536	5	Cheyenne	230	73536	SnowyRng	230	73571	1
Ault	230	73011	5	Ault	230	73011	Archer	230	73009	1
Ault	230	73011	5	Ault	230	73011	Windsor	230	70474	1
LRS	345	73108	4	LRS	345	73108	Ault	345	73012	1
Rawhide	230	73165	5	Rawhide	230	73165	Ault	230	73011	1
Archer	230	73009	5	Archer	230	73009	Ault	230	73011	1
Ault	230	73011	5	Ault	230	73011	Cherokee	230	70107	1
Ault	230	73011	5	Ault	230	73011	Nwreactive	230	70667	1
NewWind	230	70651	5	NewWind	230	70651	New34_2	35	70666	2

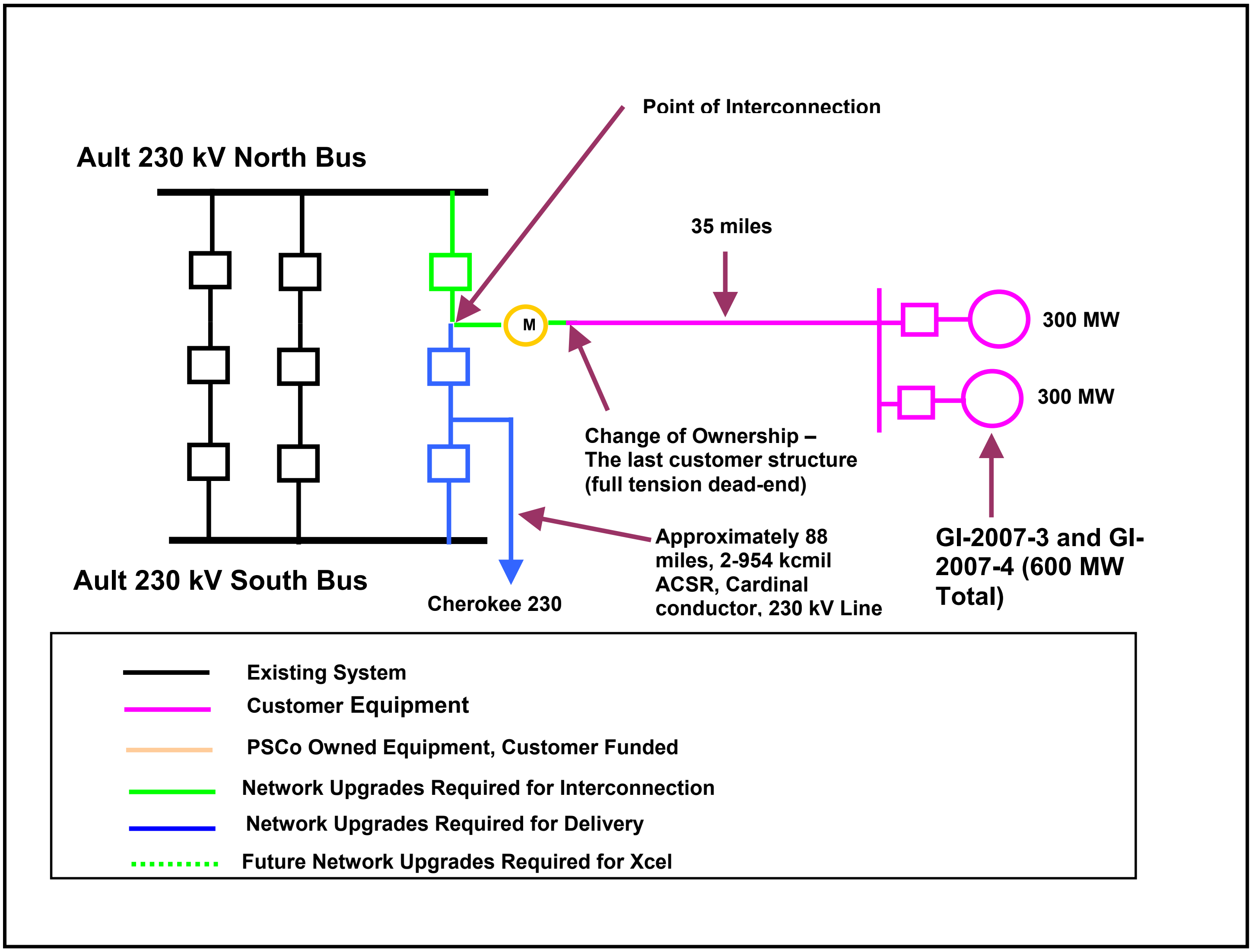
Table 4: List of (N-2) Bus Faults Used in Dynamics Study

				Cleared Circuit 1							Cleared Circuit 2						
Location			Duration	Bus 1			Bus 2			Ckt	Bus 1			Bus 2			Ckt
Name	kV	Number	(Cycles)	Name	kV	Number	Name	kV	Number		Name	kV	Number	Name	kV	Number	
Rawhide	230	73165	5	Rawhide	230	73165	TimberIn	230	73199	1	Rawhide	230	73165	Ault	230	73011	1
Ault	230	73011	5	Ault	230	73011	TimberIn	230	73199	1	Ault	230	73011	St. Vrain	230	70410	1
Ault	230	73011	5	Ault	230	73011	Weld	230	73212	1	Ault	230	73011	Weld	230	73212	2
Ault	230	73011	5	Ault	230	73011	Windsor	230	70474	1	Ault	115	73552	Nunn	115	73145	1
Ault	230	73011	5	Ault	230	73011	Archer	230	73008	1	Ault	115	73552	Cheyenne	115	73043	1

I. Costs Estimates and Assumptions

The estimated total cost for the required upgrades for is $ 65.01 million. The estimated costs shown are (+/-30%) estimates in 2008 dollars (no escalation applied) and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the engineering, design, and construction of these new PSCo facilities. This estimate did not include the cost for any other Customer owned equipment and associated design and engineering.

Figure 2 Simplified One-Line of a Portion of the Ault Substation and the Proposed 600 MW Wind generating facility



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. If this project advances to the Facilities Study stage, more accurate cost estimates will need to be developed by Western..

Costs Estimates and Assumptions

The estimated total cost for the required upgrades for is $ 65,013,000.

The estimated costs shown are (+/-30%) estimates in 2008 dollars (no escalation applied) and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the engineering, design, and construction of these new PSCo facilities. This estimate did not include the cost for any other Customer owned equipment and associated design and engineering.

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 5 – PSCo Owned; Customer Funded Interconnection Facilities

Element	Description	Cost Est. Millions
Western's Ault 230 kV Substation	Interconnect Customer at Western's Ault 230 kV 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		**12 Months**

Table 6: PSCo Owned; PSCo Funded Interconnection Facilities

Element	Description	Cost
Western's Ault 230 kV Substation	Interconnect Customer at Western's Ault 230 kV Substation. New 230 kV line termination requiring the following equipment: • one 230 kV circuit breaker • two 230 kV gang switches • electrical bus work • required steel and foundations • minor site work (station wiring, grounding)	**$0.412**
Time Frame		**12 Months**

Table 7 – PSCo Network Upgrades for Delivery

Element	Description	Cost Est. Millions
Western's Ault 230 kV	New 230 kV line termination requiring the following equipment: • two 230 kV amp, circuit breakers	**$0.850**

Element	Description	Cost Est. Millions
Substation	• four 230 kV gang switches • electrical bus work • metering, control, relaying and testing • required steel and foundations • minor site work (grading, fencing, grounding)	
PSCo's Cherokee 230 kV Switching Station	New 230 kV line termination requiring the following equipment: • one 230 kV circuit breaker • two 230 kV gang switches • electrical bus work • metering, control, relaying and testing • required steel and foundations	**$0.561**
230 kV Transmission Line Construction	New single circuit Ault –Ft. Lupton 230 kV line (59 miles) 800 MVA capacity, bundled 954 kcmil (Cardinal) conductor.	**$27.630**
	Convert the existing 115 kV line from Ft. Lupton to Cherokee to double circuit 230 kV operation with 800 MVA capacity. One circuit will connect to the new Ault 230 kV line just outside of Ft. Lupton where as the other will be operated at 115 kV 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.	**$7.19**
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$63.711**
	Total Cost of Project	**$65.013**
Time Frame		**60 Months**

Assumptions for Alternatives

- The cost estimates provided are "scoping estimates" with an accuracy of +/- 30%.
- Estimates are based on 2008 dollars (no escalation applied).
- There is no contingency added to the estimates.
- AFUDC is included for network upgrades, excluded in delivery upgrades.
- Labor is estimated for straight time only – no overtime included.
- PSCo (or it's Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- The Wind Site is not in PSCo's service territory. The local utility will provide station service power to the generator. Assumed no additional metering required
- The estimated time for design and construction of PSCo network upgrades for interconnection is at least 60 months, and is completely independent of other queued projects and their respective ISD's.
- It is anticipated that in order to construct the PSCo network upgrades for delivery, a Certificate of Public Convenience and Necessity (CPCN) will be required by the Colorado Public Utilities Commission (CPUC). The estimated time frame for the CPCN process, siting, permitting, easement and right-of-way acquisition, design and construction for the PSCo network upgrades is at least 28 months from the time the

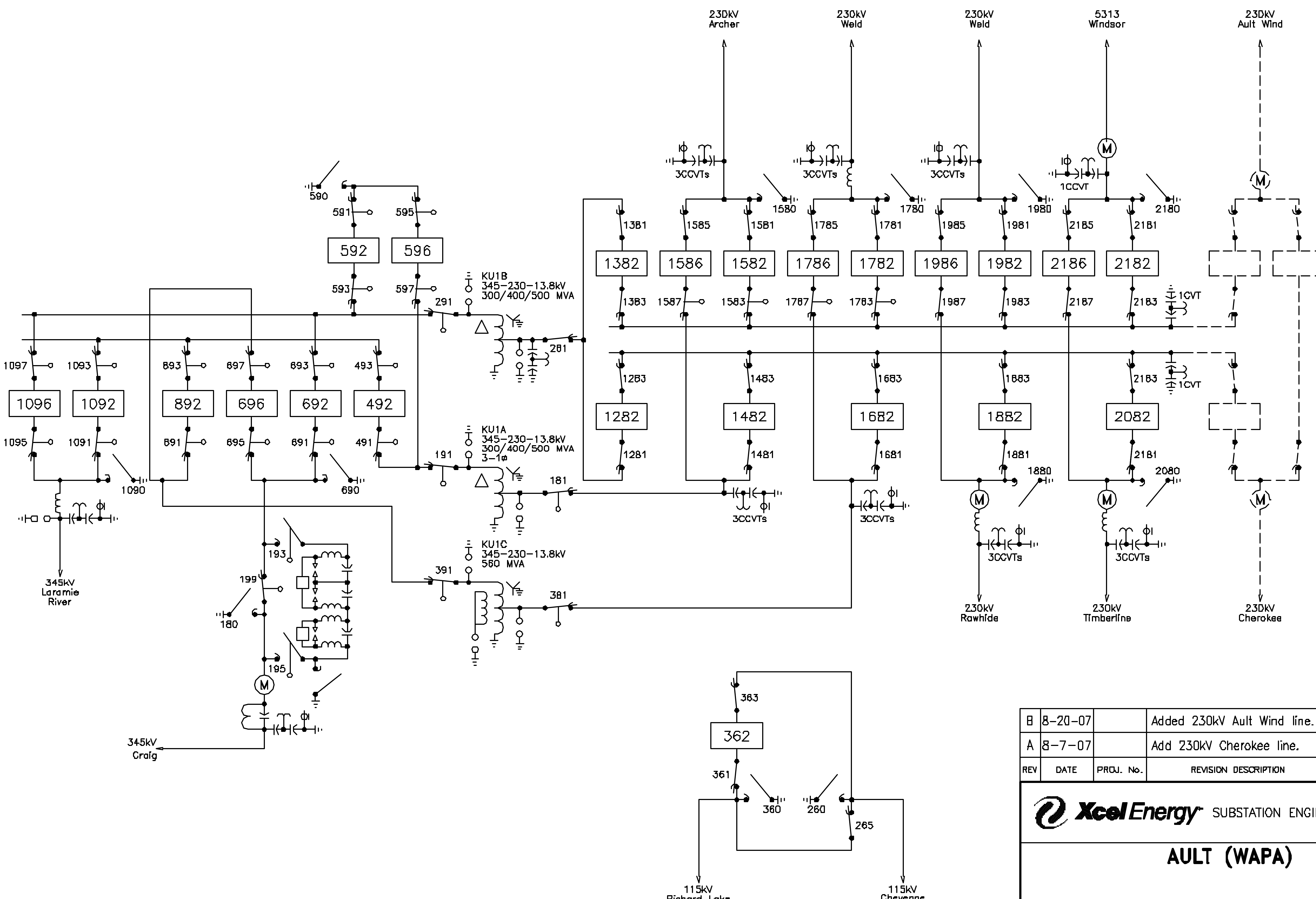
Interconnection Agreement is fully executed. This time frame is also based on other identified assumptions for Siting and Land Rights, Substation Engineering and Transmission Engineering as listed below.

- 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.
- No additional land will be required at Ault Substation.

APPENDIX

A. 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.



B	8-20-07		Added 230kV Ault Wind line.	CM		BR		
A	8-7-07		Add 230kV Cherokee line.	CM		BR		
REV	DATE	PROJ. No.	REVISION DESCRIPTION	DWN	DSN	ENG	CHK	FILM

Xcel Energy SUBSTATION ENGINEERING & DESIGN

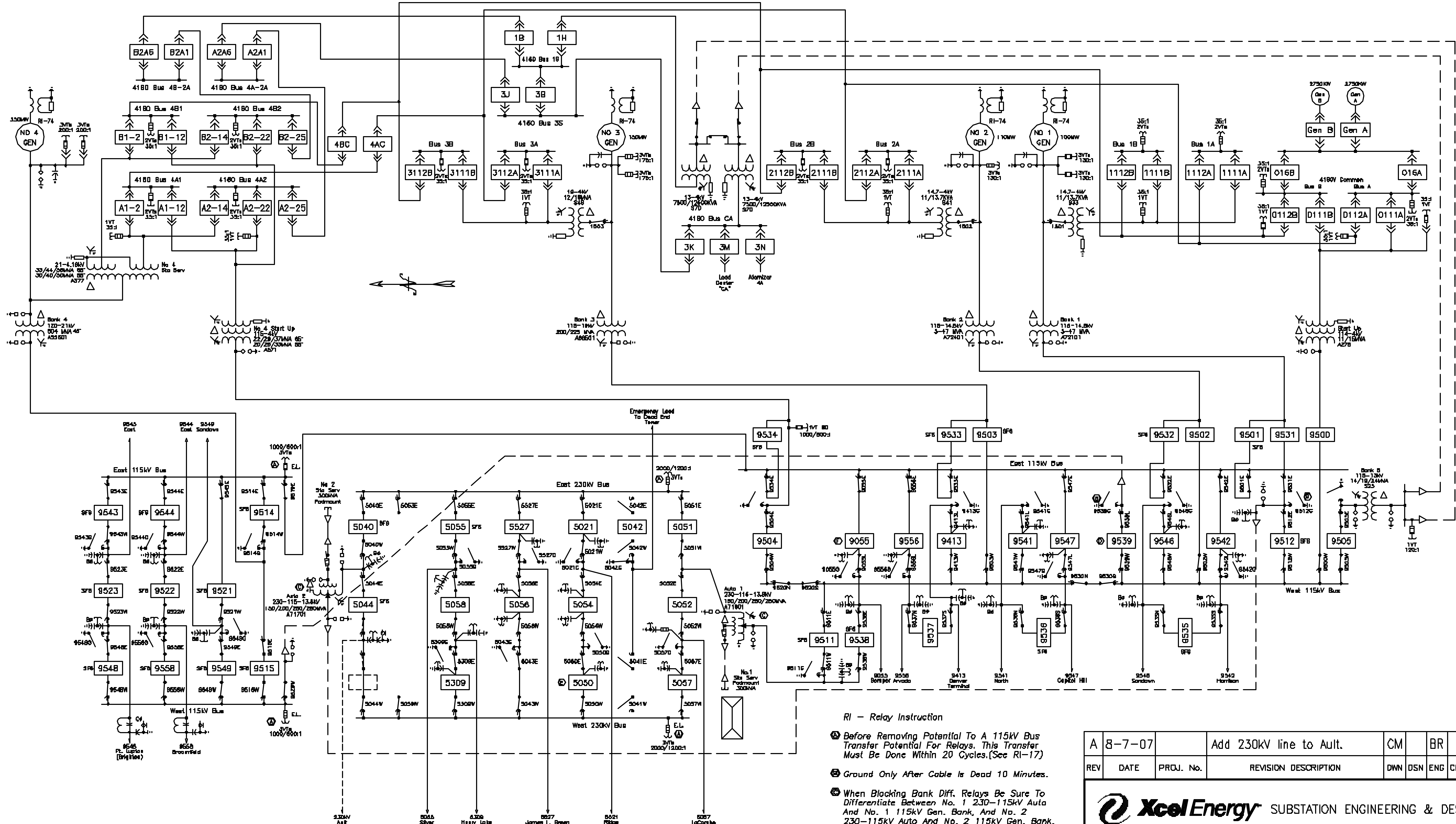
AULT (WAPA)

SIZE **B** DWG. No. **BUDGET** REV. **B**

SCALE N.T.S. FILE NAME HL\Budget\Walt.dwg SHEET 1

B. 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.



RI – Relay Instruction

Ⓐ Before Removing Potential To A 115kV Bus Transfer Potential For Relays. This Transfer Must Be Done Within 20 Cycles.(See RI-17)

Ⓑ Ground Only After Cable Is Dead 10 Minutes.

Ⓒ When Blocking Bank Diff. Relays Be Sure To Differentiate Between No. 1 230–115kV Auto And No. 1 115kV Gen. Bank, And No. 2 230–115kV Auto And No. 2 115kV Gen. Bank. Transfer Station Service To Back-Up Before Removing No. 1 Bank From Service.

Ⓓ 9539 Oil Switch Only, No Relaying. Maintenance Only, Last Open, First Closed.

Ⓔ 5050 Controllable Oil Switch. No Relaying.

Ⓕ 9055 Pot Device Not In Use. Replaced With Line CVT.

REV	DATE	PROJ. No.	REVISION DESCRIPTION	DWN	DSN	ENG	CHK	FILM
A	8-7-07		Add 230kV line to Ault.	CM		BR		

Xcel Energy SUBSTATION ENGINEERING & DESIGN

Cherokee

6198 Franklin St. Denver, CO

303-853-7361

Lat. 39Deg 48Min 32Sec Long. -104Deg 57Min 59Sec

SIZE	DWG. No.		REV.
B	BUDGET	CHER	A

SCALE	FILE NAME	SHEET
N.T.S.	Dmnw\Budget\CherPl.dwg	1

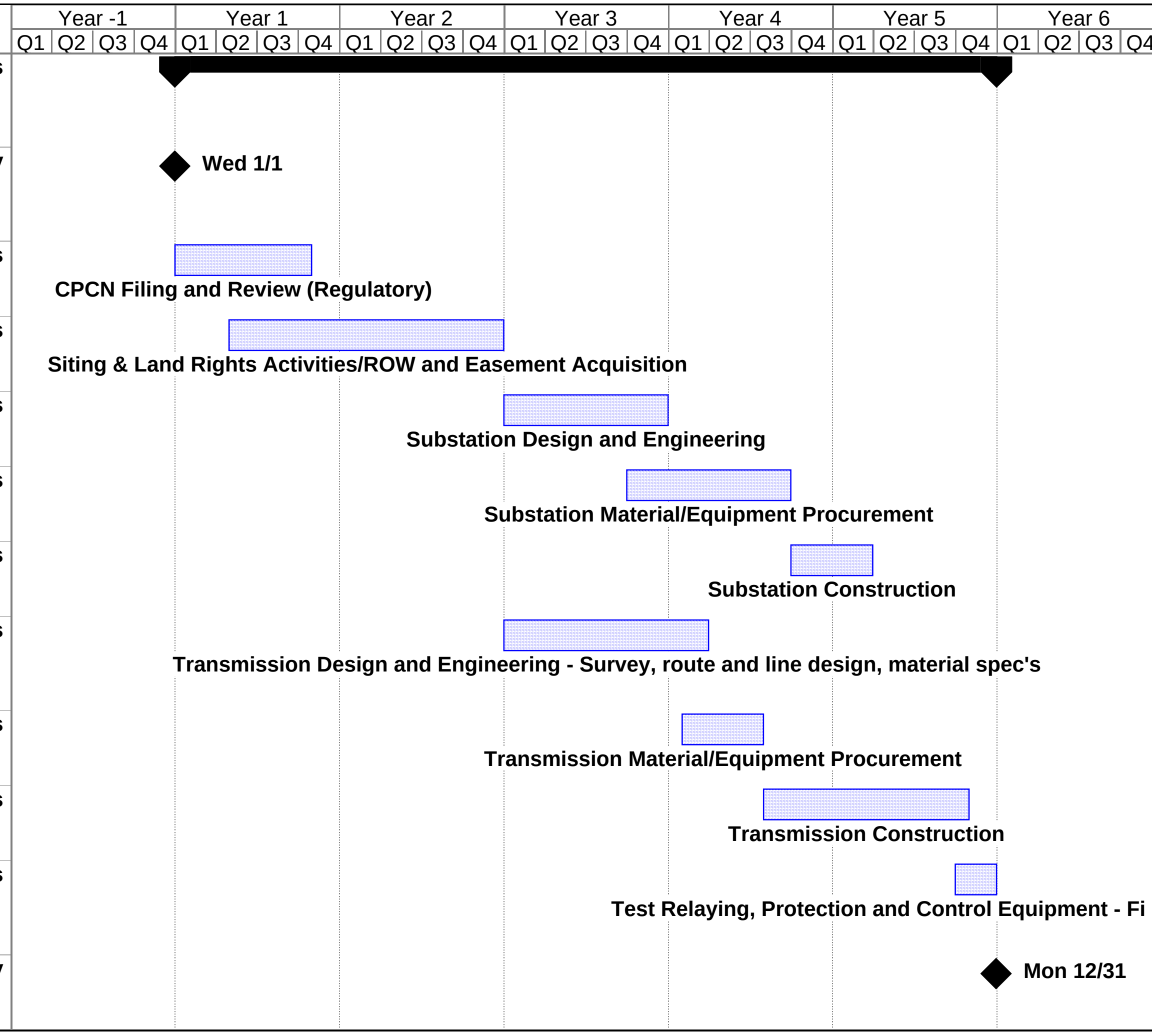
8/7/2007 8:50:12 AM

C. Schedule

A generic schedule that represents the estimated time frame for the CPCN process, siting, permitting, easement and right-of-way acquisition, design and construction for the PSCo network upgrades is shown below.

GI-2007-4 (SIS Report)
300 MW Wind Generation Interconnecting at Ault Substation

ID	Task Name	Duration
1	**GI-2007-4 (SIS Report) 300 MW Wind Generation Interconnecting at Ault Substation**	**1826 days**
2	**Authorization to Proceed - Day One Execution of Interconnection Agreement**	**1 day**
3	**CPCN Filing and Review (Regulatory)**	**304 days**
4	**Siting & Land Rights Activities/ROW and Easement Acquisition**	**611 days**
5	**Substation Design and Engineering**	**365 days**
6	**Substation Material/Equipment Procurement**	**365 days**
7	**Substation Construction**	**182 days**
8	**Transmission Design and Engineering - Survey, route and line design, material spec's**	**455 days**
9	**Transmission Material/Equipment Procurement**	**181 days**
10	**Transmission Construction**	**457 days**
11	**Test Relaying, Protection and Control Equipment - Final Commissioning**	**92 days**
12	**Completion Date**	**1 day**



Project: Schedule 2-17-09
Date: Tue 2/17/09

Task	Rolled Up Task	External Tasks
Progress	Rolled Up Milestone	Project Summary
Milestone	Rolled Up Progress	Group By Summary
Summary	Split	