Wind Integration Study Report
Of Existing and Potential
2003 Least Cost Resource Plan Wind Generation

Xcel Energy Transmission Planning

April 2006

I. Summary

This Interconnection System Impact Study Report summarizes the analyses of current and potential future wind generation in the Public Service Company (PSCo) of Colorado electrical system. Presently, PSCo has about 280 MW of wind resources connected to its transmission system in Colorado. Those resources consist of four projects: The 30 MW Ponnequin Facility; the 30 MW Ridge Crest (Peetz) facility; the 160 MW Colorado Green Wind Farm; and most recently, as a result of the 2003 Least Cost Resource Plan Renewable Energy Request for Proposals, the 60 MW Spring Canyon project. Based on the current All-Source Solicitation, it appears likely that an additional 775 MW of wind generating capacity may be added to the system in the next two years. Therefore, the total potential wind generating capacity on the PSCo system will be about 1,057 MW by 2008. Table 1 lists the existing and potential wind projects and Figure 1 provides a visual representation of where they are located.

Table 1 Existing and Potential Wind Projects for PSCo

Facility	Interconnection	Capacity (MW)	Existing /New	In Service Date
Ponnequin	Ponnequin ties into the Cheyenne – Ault 115kV line.	30	Existing	Jan 1999
Ridge Crest	Peetz, (on the Sidney – Sterling 115kV line), via a 2-mile 115kV line.	30	Existing	Sep 2001
Colorado Green	Lamar, via a 44-mile 230kV line.	162	Existing	Dec 2003
Spring Canyon	Spring Canyon ties into the Sidney – N.Yuma 115kV line	60	Existing	Jan 2006
Logan	Pawnee, via a 70-mile 230kV line.	400	New	Jul 2007
CO Green Expansion	Lamar, (connects to the existing Co. Green facility)	75	New	Oct 2007
Cedar Creek	Ties into the RMEC-Green Valley 230kV lines, via a 50-mile 230kV line.	300	New	Dec 2007

Conclusions & Recommendations

1. The PSCo transmission system is able to accommodate the full complement of existing and potential wind generation. Note that during peak load periods, gas-powered generation may be reduced to accommodate the wind resources, if necessary.

2. Powerflow (steady state) analysis indicates that the wind projects can be integrated into the PSCo system with no adverse affects. Studies of both system intact and single contingency scenarios did not reveal any overloaded facilities or voltage violations caused by the wind facilities.

3. The studied wind facilities do not put the PSCo transmission system at risk of any transient or voltage instability[1]. Studies show that the electric system can withstand the complete loss of any of the projects.

[1] Operating procedures are utilized for disturbances in the Lamar area.

4. Studies showed that the low voltage ride-through (LVRT) capabilities of the wind generation were effective on all but the existing Ridge Crest project. Although the older machines in use at Ridge Crest don't have the controls or capabilities of the newer machines, there is no impact to the reliability of the regional system operation.

II. Background

This Study Report was prepared in partial response to Item No. 3 of the August 6, 2004 Stipulation between the Staff of the Colorado Public Utilities Commission and Public Service Company of Colorado (PSCo) with respect to wind studies. Item No. 3 stated the following:

"The Company shall perform powerflow and stability analyses, using 2007 power flow cases, of the portfolio of resources selected by the Company in response to the Renewable Energy RFP approved by the Commission in Docket 04A-325E. Public Service will use its reasonable best efforts to employ the latest commercially available models to assess the wind generation's impact on the stability of the Public Service system. To the extent such analyses identify problems with system stability, the Company will recommend appropriate solutions to address these problems. Public Service will also evaluate the reliability impacts of potential wind generation in its long-term planning studies."

Subsequent to the issuance of the Renewable Energy RFP, an All Source RFP was issued in which both wind generation proposals as well as thermal generation proposals were submitted. Therefore, although the Stipulation recommended using 2007 study models, this study focuses on the issues of system performance as expected in the year 2008 to illustrate the analyses for not only the resources selected from the Renewable Energy RFP, but also include renewable energy projects that have been indicated by Xcel Energy Markets (XEM) as potential candidates in the All-Source RFP. Additional studies are being performed to fully evaluate the impacts of the entire All-Source collection of resources.

This study also models potential thermal resources that could be in service in 2008. Those resources are discussed in more detail in the following Methodology section.

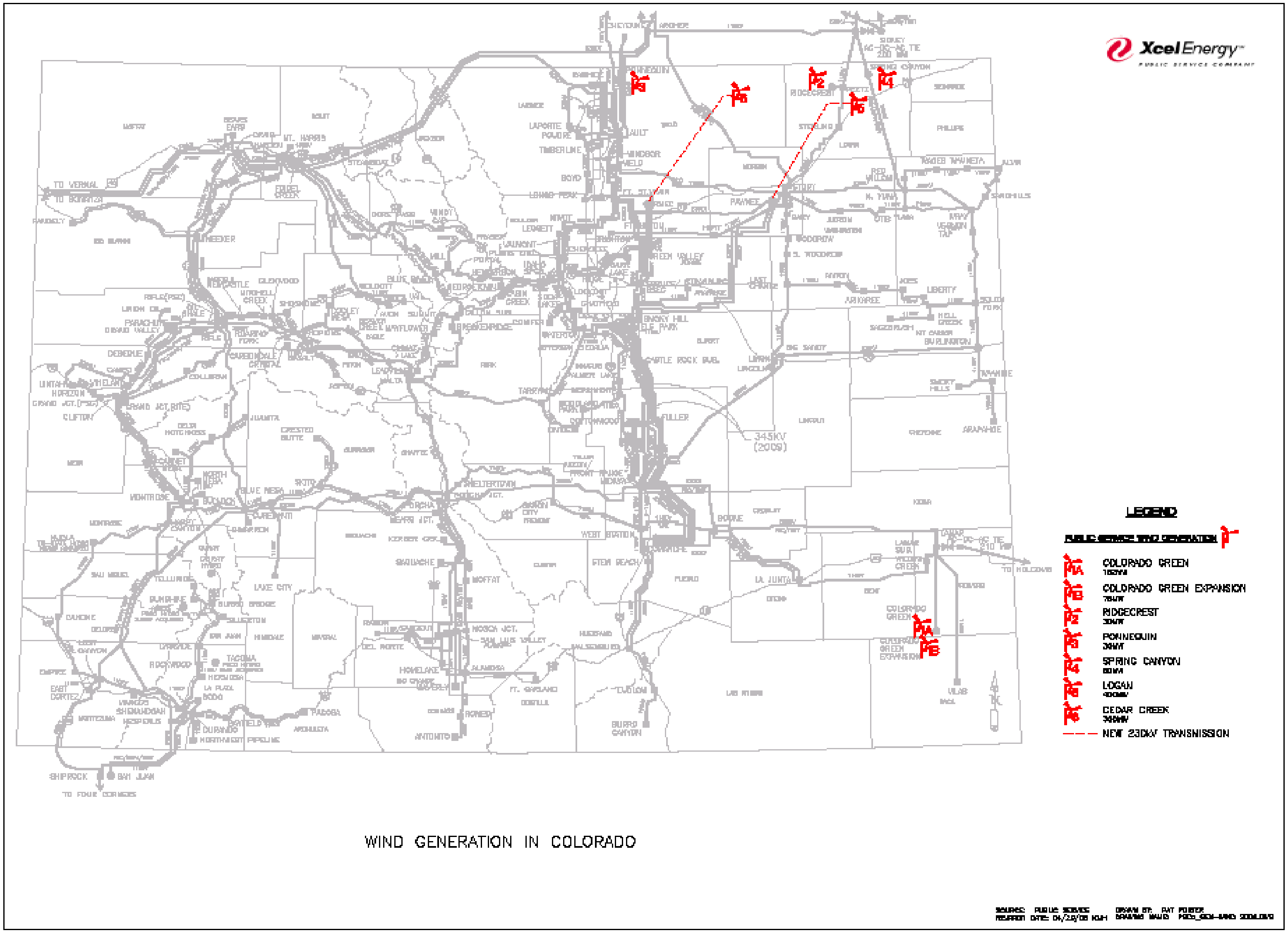

Figure 1 General Locations of Wind Projects in PSC

III. Methodology

A. System Models

Studies were conducted using 2008 system models and used two load levels. A peak load case was created by modeling maximum expected summer loads. In addition, a minimum load case was created to model a spring season scenario. Since experience shows that wind generation is highest during light load periods, the minimum load case provides a good model to test the ability of the system to accommodate maximum levels of wind power penetration. The study area was essentially the state of Colorado, which in the system models includes the powerflow areas of PSCo and Western Area Power Administration's Rocky Mountain Region (Western RM). For all cases, the PSCo control area slack bus was the Cherokee No. 3 generator, and the Western RM control area slack bus was at Yellowtail. The system models were prepared using existing Western Electricity Coordination Council (WECC) models. The WECC cases represent the entire Western Interconnection in full detail at the planning level. Dynamics (transient stability) system models were set up for both load scenarios. The models were tested under non-disturbance conditions to verify that the system is in balance before any disturbance testing was conducted.

1. Peak Load

The summer peak case was built from the 2007 HS2A WECC-approved base case. The PSCo powerflow area load was derived from the 2008 summer peak forecast provided by PSCo's Regulated Risk Service & Generation Modeling Group on April 26, 2005. The Western RM control area demand for the 2008 heavy summer case was obtained by averaging the control area demand in the 2007 HS2A WECC-approved case and the control area demand in the 2009 HS1A WECC-approved case. For the peak load models, the PSCo powerflow area load was about 7550 MW, and the Western RM load was about 4500 MW.

Generation in the Western-RMR control area was adjusted to account for the increase in demand from the 2007 heavy summer case. A representative generation dispatch was used to serve the load change in the PSCo control area. The wind generation dispatch is discussed under Section B, Wind Representation. In order to evaluate the capabilities of the system for firm transfer levels, the case was modified to simulate high TOT 3 and north to south system flows. Modifications resulted in increasing Tot 3 flows from 1,185 MW north-to-south to 1,445 MW north-to-south and increased the TOT7 flow from 565 MW north-to-south to 763 MW north-to-south.

2. Minimum Load

The 2008 Spring Minimum Load case was based on a WECC-approved 2006 Light Spring Load Case (2006LSP2-SA). The refinements applied to complete the case for the PSCo system that were used in this wind integration study included a further load reduction by approximately 25% from the original 2008 light load case. This was done after reviewing the information on the actual load levels on an hourly basis for the entire year of 2005. This information indicated that the original WECC case had a "low" load but not a minimum load condition. The PSCo loads in the 2008 Spring power flow case were then scaled to match the minimum load experience in 2005 adjusted for load growth. The entire remainder of WECC load was left unchanged in order to leave the load/generation balance undisturbed in that part of the system. For the minimum load models, the PSCo powerflow area load was about 2900 MW, and the Western RM load was about 2800 MW.

The generation dispatch was significantly different for the minimum load case than for the peak case. The generating schedule applied was such that all gas-fired generation except the generators at the Rocky Mountain Energy Center (RMEC) were modeled off-line, the wind generation was assumed to be at maximum output (1057 MW), and the remaining PSCo generation in the case is coal-fired. Details of the minimum dispatch are shown in Appendix A.

3. Transmission

The expected transmission system configuration for the 2008 heavy summer season was modeled for all cases. Significant planned PSCo transmission projects represented in the case included the following:

- Denver Terminal – Dakota – Arapahoe 230-kV line
- Chambers 230/115-kV Transmission Intertie Project
- Capitol Hill – North 115-kV underground line upgrade
- Conoco – Sandown 115-kV line project
- Second Sulphur 230/115-kV autotransformer
- Sulphur-Parker 115 kV #2
- Walsenburg – Gladstone 230-kV line (Tri-State G&T project)

B. Wind Representation

1. Generation Modeling

As previously discussed, there are four existing wind projects interconnected to the PSCo system, which have a total nameplate capacity of 282 MW. Based on information at the time of this report, there is the potential for an additional 775 MW of wind capacity that could be added by 2008. Table 2 presents a tabulation of the machine manufacturer and type, as well as the number of such machines at each site, for both existing projects and the potential wind farms based on information from bidders. This information was used to create the wind models for system studies.

Table 2 Wind Generation Locations and Machine Types

Wind Project	Manufacturer	Number of Machines	Type	Machine Size (MW)	Total (Apx MW)
Existing:					
Ponnequin	Vestas	15	47A	0.66	10
Ponnequin	NEG Micon	29	NM 48	0.70	20
Ridge Crest	NEG Micon	33	NM900/52	0.90	30
Spring Canyon	GE	40	1.5 sle	1.50	60
Colorado Green	GE	108	1.5 sle	1.50	162
New:					
Logan	GE	266	1.5 sle	1.50	400
Cedar Creek	GE	200	1.5 sle	1.50	300
Co. Green Expansion	GE	50	1.5 sle	1.50	75

Each of the existing and potential wind farms are comprised of a number of wind turbines, each with their own step-up transformers, with the high-side typically 34.5 kV. The 34.5-kV collector system will deliver the power generated by these individual turbines to the transmission system with one or more 34.5/230- or 34.5/115-kV transformers. For this study, all of the wind turbines connected to the major step-up transformers were aggregated to an equivalent single generator with generator step up transformer that was connected to the bulk transformer. Figure 2 shows how the wind generation was typically modeled, using the Colorado Green as the example. Each of the two generators in Figure 2 is the electrical equivalent of 54 individual 1.5 MW turbines, with the 0.575/34.5 kV transformer the equivalent of the 54 individual units.

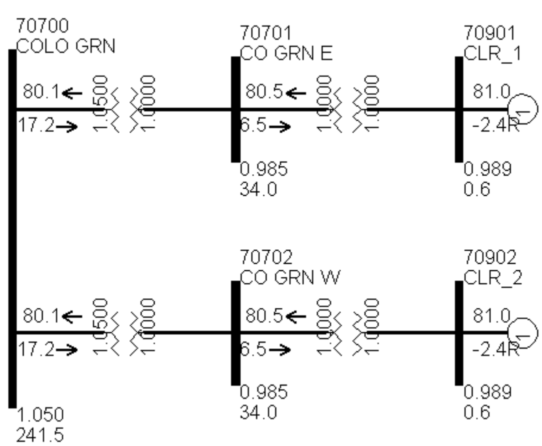

Figure 2 Typical Wind Farm Representation

The power flow cases were modified to represent the existing and potential wind farms in this manner, to enable both steady state and stability analyses to be readily performed.

Most of the wind turbine capacity (close to 1000 MW) that will be on the PSCo system in 2008 is currently expected to be GE 1.5 MW wind turbines. In addition, there are a number of Vestas units at Ponnequin. With the cooperation of their manufacturers, detailed modeling of both of these types of wind turbines have been developed for PSS/E that will predict their response in both steady state and system disturbance conditions. At the present time, there are no dynamic models of the NEG Micon NM48 wind turbines like those at Ponnequin available for use with PSS/E. Since they were installed at the same time as the Vestas units and the Ponnequin site can only provide 30 MW, that capacity has been modeled using the Vestas models; this is consistent with the approach that has been used in other stability studies for generation in this area. The NEG Micon NM900/52 wind turbines at Ridge Crest are older induction generators that do not have the power electronics like the newer GE turbines to help provide reactive power support. The Ridge Crest turbines have been modeled as an aggregated 30 MW induction generator.

2. Interconnections

The Cedar Creek generation was modeled as being interconnected to both 230-kV circuits between RMEC and Green Valley through a 50-mile 230-kV line from the project.

The Logan generation was modeled as being interconnected to the Pawnee bus through a 70-mile 230-kV line from the project.

The Colorado Green Expansion was modeled at the Colorado Green 230kV bus, which is where the existing Colorado Green generation is connected.

3. Dispatch

The peak load models reflect the generation pattern that may be expected for the summer peak. The Colorado Green generation was fixed at 60 MW, which is a good historical level of generation during peak load periods. Ponnequin, Spring Canyon, and Ridge Crest generation were modeled off line, since their typical output is zero or very low during the summer peak periods. Figure 3 shows the wind generation level for July 17, 2005, which was the peak load day for that year. In the peak models, gas-fired generation in the vicinity of the Cedar Creek and Logan wind projects was reduced to accommodate the wind generation. If necessary, this will be the expected operation of those facilities. After allowing for line losses of about 8.5 MW on the radial line from Cedar Creek, generation at RMEC was reduced by 291.5 MW to accommodate the net power delivered to the PSCo system from Cedar Creek. Generation at the two combustion turbines at Manchief and other gas-fired generation at Brush, were reduced by 378 MW to accept the wind output delivered from the Logan project.

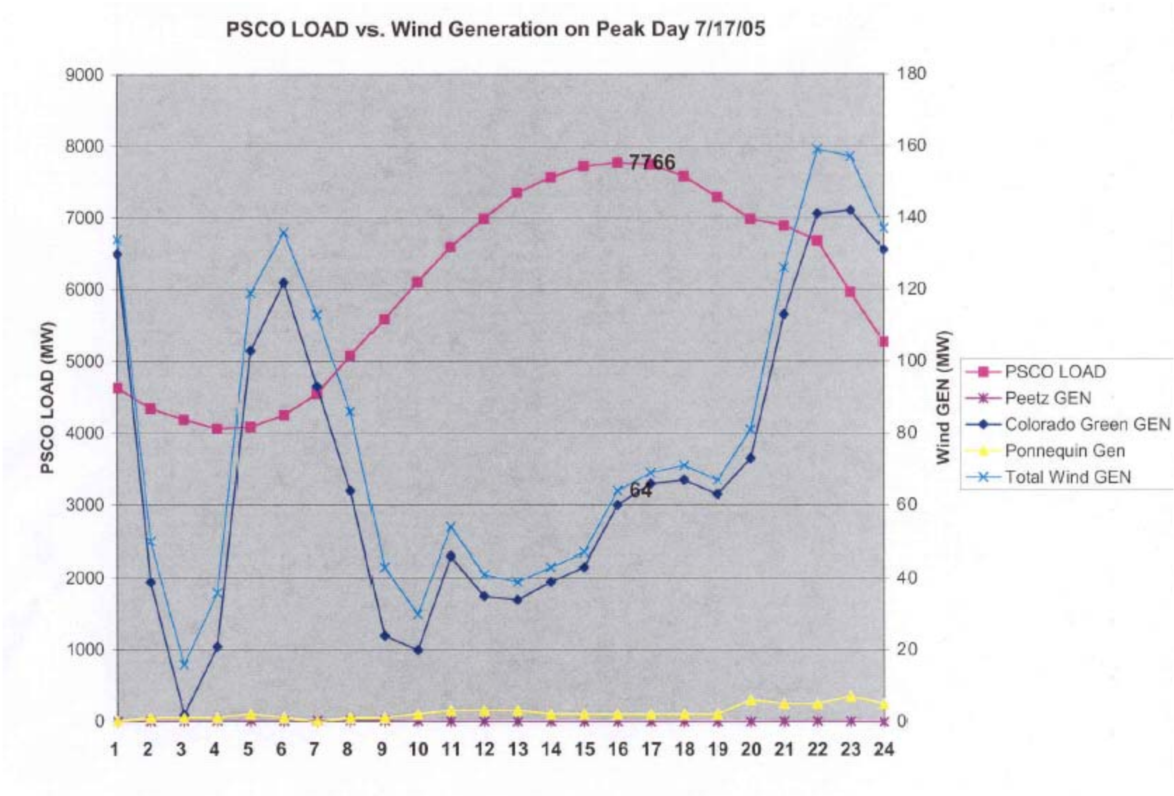

Figure 3 Typical Wind Generation for a Peak Day

In the minimum load cases, the wind projects were modeled at full name plate capacity.

C. Additional Resources

During the course of the All-Source Solicitation, Transmission Plannning has evaluated several "portfolios" of generation resources, including not only wind, but also several thermal projects. These studies included some potential thermal generation being considered in the All-Source evaluation. These projects were also discussed in the All-Source RFP Bid Evaluation Report, dated December 2005. The thermal resources modeled in these studies are shown in Table 3.

Table 3 Potential 2008 Resources from All-Source Solicitation

Bid	Capacity - MW	Type of Resource	In Service Date
G025	260	Gas-fired CTs	6/1/07
G029	270	Gas-fired CTs	5/1/07

The resources listed in Table 3 were added to both the peak and the minimum load models.

D. Software

The development of power flow cases and the stability analyses for this study used Siemens PTI's PSS/E version 29.4 software. Steady state contingency analysis used MUST version 7.0 to identify lines or transformers that would be overloaded under base case or single contingency conditions. The V-Q analysis to evaluate voltage stability by evaluating reactive reserve margins used the latest release of PSS/E, version 30.1.

IV. Planning Criteria

The Study evaluated the transmission requirements associated with the interconnection of the potential resources to the PSCo Transmission System. The Study consisted of steady state power flow analysis and dynamic stability analyses. The power flow analysis identified thermal or voltage limit violations. PSCo adheres to NERC/WECC Reliability Criteria, as well as internal Company criteria for planning studies. During system intact conditions, criteria are to maintain transmission system bus voltages between 0.95 and 1.05 per-unit of system normal conditions, and steady state power flows within 1.0 per-unit of all elements thermal (continuous current or MVA) ratings. Operationally, PSCo tries to maintain a transmission system voltage profile ranging from 1.02 per-unit or higher at generation buses, to 1.0 per-unit or higher at transmission load buses. Following a single contingency element outage, transmission system steady state bus voltages must remain within 0.90 per-unit and 1.10 per-unit, and power flows within 1.0 per-unit of the element's continuous thermal ratings. Impacts on the neighboring utilities were monitored, and were addressed in the scope of this study as appropriate.

The NERC/WECC Planning Standards for System Performance was followed for the stability analysis. In the WECC Disturbance-Performance criteria, for the loss of a single element (line or transformer), the maximum allowed voltage dip after fault clearing is 25% for load buses. This dip cannot exceed 20% for more than 20 cycles. The allowed post-transient voltage deviation, 1 to 3 minutes after the fault, is 5% for all buses. In addition, the frequency at any bus cannot be below 59.6 Hz for 6 cycles or more at any load bus.

V. Steady-State Analysis

A. Peak Load

The studies were benchmarked by running contingency analysis on the peak case without the additional wind generation. All buses, lines and transformers of 69 kV and above in the PSCo and Western RM study areas were monitored. Single contingency analysis was performed for all lines and transformers within the same area. Outages of single generating units were also studied. The results were reviewed for violations in the areas around the interconnection points.

Next, contingency analysis was conducted on models that included the additional wind generation to determine the electric system's capability to carry the additional generation from new facilities. The results were compared to the benchmark analysis that did not contain the new generation. Lines and transformers that exhibited higher loadings with the additional generation than in the benchmark cases were identified, as well as any significant voltage deviations.

Results

- Since the new wind generation associated with Logan, Cedar Creek, and Colorado Green Expansion were offset by nearby gas generation and the Lamar DC Tie, no element loadings or voltage deviations due to the additional wind projects were identified.
- For the loss of the full 400 MW of wind generation at Logan, studies showed that the thermal generation around Pawnee would be able to maintain voltage at the Pawnee 230-kV bus at 1.03 pu and the voltage at the Logan 230 kV bus would be relatively unchanged at 1.041 pu.
- For the loss of the full 300 MW of wind generation at Cedar Creek, and without the loss of the radial line, voltage at the Cedar Creek 230-kV bus remained near 1.035 pu, and the units at RMEC maintained voltage on that 230-kV bus at 1.03 pu.

B. Minimum Load

Benchmark and contingency analyses were performed as with the peak load models. In addition, some studies were performed to test the ability to control system voltages to within the allowable range under WECC pre-contingency criteria. This involved removing all the wind generation and replacing it by already operating coal-fired steam units at Pawnee, Comanche, and Cherokee. Voltages at the radial ends of the wind project interconnection lines and the collector systems were checked to verify that they did not exceed 105% of nominal voltage. Both Logan and Cedar Creek projects had slightly high voltage before any changes were made in coal unit generator voltages, but minor changes in the voltage set points, on the order of 1%, were adequate to reduce reactive flows by about 10 MVAR in the areas of the projects. This was enough to bring them into compliance, and still leave 30-40% of the reactive power capability of the steam units available for other possible voltage control needs.

Results:

- Contingency analysis did not reveal any issues, as would be expected at this low a system loading.
- The voltage profile was also found to be quite good with minimal shifts in reactive generation to maintain a smooth voltage profile across the system. In general, the system voltages were close to 100% of nominal value.
- There were no significant voltage deviations when compared to the benchmark results.
- For the prospective loss of the full 400 MW of generation at Logan, studies showed that there is more than adequate capability to manage the swing on internal generation as well as lightly loaded tie lines.

VI. Dynamics Analysis

The objective of this assessment was to review system performance with the addition of the new resources and, if necessary, identify options that could improve system stability during periods of system stress.

The dynamics case setup for this analysis used the WECC model database for dynamics data. All wind machines were represented by the most recently developed PTI wind generator dynamic models available for the machines. All but the NEG Micon machines have sophisticated blade pitch control, VAR control and low-voltage ride-through capability, as well as relaying to remove them from service where the voltage and wind conditions are possibly damaging to either the system or the machines. A non-disturbance case was modeled to verify that dynamics modeling would initiate properly and to establish a good benchmark for performance.

A. Peak Load

The system intact stability analysis was performed to determine the effects that adding the three wind farms and two potential combustion turbine facilities as part of the All-Source Solicitation would have on the transient stability of the system by comparing the responses both with and without the additional resources. A number of disturbances were modeled and are included in Appendix B, Table B-1. The disturbances focused on the regions near the points of interconnection for the added resources, but several general system disturbances were also modeled. All of the studied faults were three-phase faults, with most on the 230-kV system, with faults cleared in 4 cycles. All disturbance cases initiated the fault at 0.2 seconds and were run for 10 seconds. For the PSCo existing generating resources, generator buses were monitored for rotor angles, electric power, terminal voltage, mechanical power, speed and frequency. Additionally, voltages on all buses operating at 230-kV and above were monitored.

Results

All disturbances except for one were found to be stable and well damped. The exception was for a fault at Boone, and subsequent tripping of the Boone – Lamar 230-kV circuit. However, this is an existing condition, and operating procedures are in place to trip the Lamar DC Tie and the existing wind generation as needed. Appendix C lists the disturbances and shows that there are no violations of the maximum transient voltage deviation criteria. Reviewing the results of this analysis, the system response is well damped.

At the end of the 10-second analysis, the transient voltage deviations for two were slightly above 5%:

- For a disturbance that modeled a fault at Laramie River Station (LRS) and the subsequent clearing of the fault by opening the LRS – Ault 345-kV circuit, the voltage at Ponnequin was about 6% below the pre-fault level. However, as the powerflow studies showed, once tap-changing transformers and switched capacitors have the chance to operate, the voltage at Ponnequin will increase to acceptable pre-fault levels.

- For a disturbance that modeled a fault on the St. Vrain – Isabelle 230-kV circuit, the voltage at the Isabelle 230-kV bus was about 5.5% below the pre-fault level. However, it was determined that these results are due to the potential thermal project in the region, and not associated with any of the wind projects.

With a fault at Pawnee that is cleared in 4 cycles, the voltage at the Logan wind farm was above 0.60 pu. Similar results were seen at the Cedar Creek wind farm for a fault at the interconnection point for Cedar Creek near RMEC. Since these two wind farms will have low voltage ride through capability and are interconnected through a long transmission line, system disturbances that are not on the radial line to the wind farms should not impact their operation and would allow them to remain online during peak load periods.

A fault and subsequent loss of the Logan facility and radial transmission line does not have any impact on the stability of the system other than the loss of generation and the resultant change in machine angles. There does not appear to be any issues with voltages at the potential wind farms based on the use of GE turbines as proposed and the long transmission lines.

B. Minimum load

A total of 49 disturbances were modeled for the minimum load conditions and are listed in Appendix B, Table B-2. Of these, 48 were three phase faults followed by a line or transformer trip. The only non-fault test was for the sudden loss of generation at Pawnee. In some of the contingencies, the loss of a single line also caused loss of generation as well. This is true for the radial 230 kV lines that interconnect the Logan, Cedar Creek, and Colorado Green projects.

All cases tested except the two for the Ridge Crest site and the loss of Boone – Lamar 230 kV line were found to be stable, and low voltage ride-through constraints met. It should be noted that in some cases the low voltage constraint conditions are such that the wind machines should shut down, and they did. This was found to be true for the Spring Canyon and Ponnequin cases where the fault applied was at the project's interconnection bus. Testing of the ability to "ride through" fault conditions at more remote buses were found to be successful in all cases, including for the interconnection points for the Logan and Cedar Creek projects.

The instability of the Ridge Crest Project is tied to the vintage of the NEG Micon 900/52 wind machines. These machines have very limited ability to respond to system conditions, since they have no internal reactive power control or production capability, have fixed blade position and none of the relaying to facilitate otherwise low voltage ride-through. However, due to the breaker configuration on the Sidney – Sterling 115kV line, in actual practice, a fault on that line would result in the entire line and the wind farm being taken out of service. Therefore there would be no impact to the surrounding transmission system.

VII. Reactive Reserve Analysis

Recently the major problem occurring with US electric systems is voltage collapse. The Canadian-Northeast blackout is an example of the high cost of a system voltage collapse. It requires considerable effort to study and identify if a system is susceptible to such an event. Voltage collapse is mitigated by the addition of new generating units with the capability producing reactive power. Generator ratings of 0.85 power factor output provide the most mitigation. The addition of high voltage transmission lines lowers the I^2X_L or MVAR requirement and produces reactive power as a function of line charging. Both the addition of generation and transmission lines directly or indirectly are a part of the generation bids, so the system in the short term should be less likely to enter into voltage collapse.

Based on the results of the transient stability analyses that indicated a well-damped system where voltages returned to prefault levels, the stability performance of the PSCo system appears to be robust around the major load center, the Denver metropolitan area. The two significant wind farms included in this study (Logan and Cedar Creek) are expected to be connected to the PSCo system near other generation that will generally be running during peak periods. Thus to evaluate the reactive reserve impact of adding new wind generation, the long radial lines to the PSCo system from the wind farms and the other potential All-Source generation, the reactive reserve analysis needed to be focused on some other location in the transmission system, somewhat removed from generation but still in the study region. The Daniels Park 230-kV bus was selected as the bus to use for this analysis.

To test the premise that the new generation including wind farms coupled with the transmission system additions should reduce the likelihood of voltage collapse, a QV analysis was conducted at the Daniels Park 230 kV Substation. Two cases were selected for analysis. The first case benchmarked the performance before any new generation is added. The second case included the potential All-Source generation for 2008. The worst single contingency outage appeared to be the loss of the Pawnee to Daniels Park 230 kV line. The case with added generation has substantially more reactive power available than the benchmark case.

For the benchmark case, the loss of the Pawnee – Daniels Park 230-kV circuit, the reactive reserve margin was found to be about 400 MVAR. For the case with the added generation, the reactive reserve margin was found to be about 580 MVAR. Plots of the QV analysis are shown in Appendix D. The difference between the minimum and the zero MVAR axes is the MVAR margin. The lower the minimum point the more margin, and the better the system is able withstand voltage collapse.

Therefore, the generation additions provide more reactive margin and the PSCo system will be even stronger in terms of it ability to withstand a voltage collapse situation.

Appendix A

Table A- 1 Generation Summary for 2008 Minimum Load Conditions

BUS#	NAME BSKV	ID	Machine Status	PGEN	QGEN	PMAX	PMIN	Power Swing Capability Up	Power Swing Capability Down
Fossil Fueled Generators									
70103	CHEROK1 15.5	1	On	60.0	-9.7	117.0	50.0	57.0	-10.0
70104	CHEROK2 15.5	1	On	60.0	-9.9	114.0	50.0	54.0	-10.0
70105	CHEROK3 20.0	1	On	67.5	-15.1	165.0	50.0	97.5	-17.5
70106	CHEROK4 22.0	1	On	200.0	-16.0	383.0	150.0	183.0	-50.0
70119	COMAN 1 24.0	1	On	230.0	40.7	360.0	200.0	130.0	-30.0
70120	COMAN 2 24.0	1	On	230.0	40.2	365.0	200.0	135.0	-30.0
70310	PAWNEE 22.0	1	On	340.0	100.5	530.0	300.0	190.0	-40.0
70350	RAWHIDE 24.0	1	On	100.0	40.5	290.0	45.0	190.0	-55.0
70446	VALMONT 20.0	1	On	113.0	45.3	188.0	100.0	75.0	-13.0
70588	RMEC1 18.0	1	On	112.0	12.3	192.0	67.0	80.0	-45.0
70589	RMEC2 18.0	1	On	112.0	12.3	192.0	67.0	80.0	-45.0
70591	RMEC3 18.0	1	On	106.0	17.8	201.0	25.0	95.0	-81.0
				1,730.5				1,366.5	-426.5
Pumped Storage Hydro									
70069	CABCRKA 13.8	1	On	-115.0	-20.9	162.0	-120.0	277.0	-5.0
70070	CABCRKB 13.8	1	On	-115.0	18.8	162.0	-120.0	277.0	-5.0
				-230.0				554.0	-10.0
Lamar DC Tie		1	On	-50.0	-34.2	210.0	-210.0	260.0	-160.0
Wind Generators									
70723	RDGCREST34.5	1	On	29.7	-3.2	29.7	0.0	0.0	-29.7
70901	CLR_1 .575 (Co Green)	1	On	81.0	10.3	81.0	0.0	0.0	-81.0
70902	CLR_2 .575 (Co Green)	1	On	81.0	10.3	81.0	0.0	0.0	-81.0
70903	CLR_3 .575 (W014A)	1	On	75.0	26.0	81.0	0.0	6.0	-75.0
70915	CLR_1 .575 (Logan)	1	On	166.3	31.4	166.5	0.0	0.2	-166.3
70916	CLR_2 .575 (Logan)	1	On	166.3	31.4	166.5	0.0	0.2	-166.3
70917	CLR_3 .575 (Logan)	1	On	65.9	6.1	66.0	0.0	0.1	-65.9
70921	CLR_1 .575 (Spring C)	1	On	60.0	6.4	60.0	0.0	0.0	-60.0
70922	Cedar Creek_1	1	On	150.0	18.7	150.0	0.0	0.0	-150.0
70923	Cedar Creek_2	1	On	150.0	18.7	150.0	0.0	0.0	-150.0
70931	CLR_1 .690 (Ponnequin)	1	On	5.3	-2.6	5.3	0.0	0.0	-5.3
70932	CLR_2 .690 (Ponnequin)	1	On	5.3	-2.6	5.3	0.0	0.0	-5.3
70933	CLR_3 .690 (Ponnequin)	1	On	5.3	-2.6	5.3	0.0	0.0	-5.3
70934	CLR_4 .690 (Ponnequin)	1	On	5.3	-2.6	5.3	0.0	0.0	-5.3
70935	CLR_5 .690 (Ponnequin)	1	On	4.6	-2.3	4.6	0.0	0.0	-4.6
70936	CLR_6 .690 (Ponnequin)	1	On	4.6	-2.3	4.6	0.0	0.0	-4.6
				1,055.6				6.5	-1,055.6

The dispatch process will be significantly different for the spring minimum load case. As one might expect in looking at minimum load conditions, the transmission system was lightly loaded. The generating schedule applied was such that all gas-fired generation except the generators at the Rocky Mountain Energy Center (RMEC) were out of service, the wind generation was assumed to be at maximum output, and the remaining PSCo generation in the case is coal-fired. Also, the Cabin Creek Pumped Storage Project was assumed to be pumping at nearly full capability. The system load plus Cabin Creek plus losses was approximately 3,278 MW. As can be seen in Table 5, the coal-fired units are operating above their minimum allowable operating points. With the RMEC units operating, the ability to load-follow is adequate. If there were a sudden increase in load, the Cabin Creek pumping operations could be curtailed, or even put into generating mode. Further, in the unlikely event that there were a sudden drop in the level of wind across the entire eastern part of Colorado, there is more than adequate capability to increase generation on already-operating units, as noted in Table 5 under the "Up" Power Swing Capability heading. There is even some further room for lower load with this schedule, as seen in the "Down" column. With the ability to use RMEC and Cabin Creek to manage load swings of approximately 500 MW or more, there is little likelihood of having to manage coal unit pulverizer cycling in a disadvantageous way, or for there to be concern of putting coal units into boiler flame stability danger. Further, there is high likelihood that one or more of the large coal units will be out of service for maintenance, a typical use of this time period's low demand.

Appendix B

Table B- 1 Peak Load Stability Disturbance List

		Faulted End	Circuit Faulted	From Bus No	To Bus No
General Contingencies					
	GCON1	Comanche	Comanche - Midway 230 kV	70122	70286
	GCON2	Comanche	Comanche - Fuller 230 kV	70122	73477
	GCON3	Daniels Park	Daniels Park - Midway PS 230 kV	70139	70286
	GCON4	Midway PS	Midway PS - Daniels Park 230 kV	70286	70139
	GCON5	Lookout	Lookout - Cabin Creek 230 kV	70266	70072
	GCON6	Lookout	Lookout - West PS 230 kV	70266	70480
	GCON7	Cherokee	Cherokee - Lacombe 230 kV	70107	70324
	GCON8	Boone	Boone - Midway PS 230 kV	70061	70286
	GCON9	Boone	Boone - Lamar 230 kV	70061	70254
	GCON10	Boone	Boone - Comanche 230 kV	70061	70122
	GCON11	Lamar	Lamar - Colorado Green 230 kV	70254	70700
	GCON12	Lamar	Lamar - Lamar DC	70254	70801
	GCON13	Story	Story - LRS 345 kV	73193	73108
	GCON14	LRS 345 kV	LRS 345/230 kV Transformer	73108	73107
	GCON15	LRS	LRS - Ault 345 kV	73108	73012
	GCON16	Ault	Ault - Craig 345 kV	73012	79014
	GCON17	Ault	Ault - Windsor 230 kV	73011	70474
	GCON18	Ault	Ault - Weld 230 kV	73011	73212
W009 Contingencies					
	PCON1	Pawnee	Pawnee - Ft. Lupton 230 kV	70311	70192
	PCON2	Pawnee	Pawnee - Quincy 230 kV	70311	70343
	PCON3	Pawnee	Pawnee - Story 230 kV	70311	73192
*	PCON4	Pawnee	Pawnee - W009 230 kV	70311	70902
	PCON5	Pawnee 230 kV	Pawnee 230/22.1 kV Transformer	70311	70310
	PCON6	Pawnee	Pawnee - Daniels Park 230 kV	70311	70139
*	PCON7	W009 230 kV	W009 230/34.5 kV transformer	70542	70815
W022 Contingencies					
*	RCON1	W022 Tap	W022 Tap - W022 230 kV	70545	70546
*	RCON2	W022 Tap	W022 Tap - Green Valley 230 kV	70545	70048
*	RCON3	W022 Tap	W022 Tap - RMEC 230 kV	70545	70590
*	RCON4	W022 230 kV	W022 230/34.5 kV transformer	70546	70823
*	RCON5	RMEC	RMEC - W022 Tap 230 kV	70590	70545
	RCON6	RMEC	RMEC - Green Valley 230kV	70590	70048
G025 Contingencies					
	SCON1	Spruce	Spruce - Picadilly 230 kV	70528	70530
	SCON2	Spruce	Spruce - Chambers 230 kV	70528	70539
	SCON3	Spruce	Spruce - Smoky Hill 230 kV	70528	70396
	SCON4	Spruce	Spruce - Sky Ranch 230 kV	70528	70392
	SCON5	Spruce	Spruce - Green Valley 230 kV	70528	70048
	SCON6	Spruce 230 kV	Spruce 230/18 kV Transformer	70528	70562
*	SCON7	Spruce 230 kV	Spruce/G025 230/18 kV Transformer	70528	70571
G029 Contingencies					
*	FSVCON1	G029	G029 - Ft. St. Vrain 230 kV	70592	70410
*	FSVCON2	G029	G029 - Isabelle 230 kV	70592	70544
*	FSVCON3	G029 230 kV	G029 230/18 kV transformer	70592	70593
	FSVCON4	Ft. St. Vrain	Ft. St. Vrain - Ft. Lupton 230 kV	70410	70192
*	FSVCON5	Ft. St. Vrain	Ft. St. Vrain - G029 230 kV	70410	70592
	FSVCON6	Ft. St. Vrain	Ft. St. Vrain - Isabelle 230 kV	70410	70544
	FSVCON7	Ft. St. Vrain	Ft. St. Vrain - Longs Peak 230 kV	70410	73116
	FSVCON8	Ft. St. Vrain	Ft. St. Vrain - Fordham 230 kV	70410	73562
	FSVCON9	Ft. St. Vrain	Ft. St. Vrain - Windsor 230 kV	70410	70474
	FSVCON10	Ft. St. Vrain	Ft. St. Vrain - Weld PS 230 kV	70410	70471
	FSVCON11	Ft. St. Vrain	Ft. St. Vrain - Valmont 230 kV	70410	70447
	FSVCON12	Ft. St. Vrain	Ft. St. Vrain - Green Valley 230 kV	70410	70048
	FSVCON13	Ft. St. Vrain 230 kV	Ft. St. Vrain 230/22 kV transformer	70410	70409
*= Not in benchmark cases					

Appendix B

Table B- 2 Minimum Load Stability Disturbance List

		Faulted End	Circuit Faulted	From Bus No	To Bus No
General Contingencies					
	GCON1	Comanche	Comanche - Midway 230 kV	70122	70286
	GCON2	Comanche	Comanche - Fuller 230 kV	70122	73477
	GCON3	Daniels Park	Daniels Park - Midway PS 230 kV	70139	70286
	GCON4	Midway PS	Midway PS - Daniels Park 230 kV	70286	70139
	GCON5	Lookout	Lookout - Cabin Creek 230 kV	70266	70072
	GCON6	Lookout	Lookout - West PS 230 kV	70266	70480
	GCON7	Cherokee	Cherokee - Lacombe 230 kV	70107	70324
	GCON8	Boone	Boone - Midway PS 230 kV	70061	70286
	GCON9	Boone	Boone - Lamar 230 kV	70061	70254
	GCON10	Boone	Boone - Comanche 230 kV	70061	70122
	GCON11	Lamar	Lamar - Colorado Green 230 kV	70254	70700
	GCON12	Lamar	Lamar - Lamar DC	70254	70801
	GCON13	Story	Story - LRS	73193	73108
	GCON14	LRS 345 kV	LRS 345/230 kV Transformer	73108	73107
	GCON15	LRS	LRS - Ault 345 kV	73107	73012
	GCON16	Ault	Ault - Craig 345 kV	73012	79014
	GCON17	Ault	Ault - Windsor 230 kV	73011	70474
	GCON18	Ault	Ault - Weld 230 kV	73011	73212
W009 Contingencies					
	PCON1	Pawnee	Pawnee - Ft. Lupton 230 kV	70311	70192
	PCON2	Pawnee	Pawnee - Quincy 230 kV	70311	70343
	PCON3	Pawnee	Pawnee - Story 230 kV	70311	73192
	PCON4	Pawnee	Pawnee - W009 230 kV	70311	70542
	PCON5	Pawnee 230 kV	Pawnee 230/22.1 kV Transformer	70311	70310
	PCON6	Pawnee	Pawnee - Daniels Park 230 kV	70311	70139
	PCON7	W009 230 kV	W009 230/34.5 kV transformer	70542	70815
	PCON8	No Fault	Drop Pawnee 1		
W022 Contingencies					
	RCON1	W022 Tap	W022 Tap - W022 230 kV	70545	70546
	RCON2	W022 Tap	W022 Tap - Green Valley 230 kV	70545	70048
	RCON3	W022 Tap	W022 Tap - RMEC 230 kV	70545	70590
	RCON4	W022 230 kV	W022 230/34.5 kV transformer	70546	70823
	RCON5	RMEC	RMEC - W022 Tap 230 kV	70590	70545
G025 Contingencies					
	SCON1	Spruce	Spruce - Picadilly 230 kV	70528	70530
	SCON2	Spruce	Spruce - Chambers 230 kV	70528	70539
	SCON3	Spruce	Spruce - Smoky Hill 230 kV	70528	70396
	SCON4	Spruce	Spruce - Sky Ranch 230 kV	70528	70392
	SCON5	Spruce	Spruce - Green Valley 230 kV	70528	70048
G029 Contingencies					
	FSVCON4	Ft. St. Vrain	Ft. St. Vrain - Ft. Lupton 230 kV	70410	70192
	FSVCON6	Ft. St. Vrain	Ft. St. Vrain - Isabelle 230 kV	70410	70544
	FSVCON7	Ft. St. Vrain	Ft. St. Vrain - Longs Peak 230 kV	70410	73116
	FSVCON8	Ft. St. Vrain	Ft. St. Vrain - Fordham 230 kV	70410	73562
	FSVCON9	Ft. St. Vrain	Ft. St. Vrain - Windsor 230 kV	70410	70474
	FSVCON10	Ft. St. Vrain	Ft. St. Vrain - Weld PS 230 kV	70410	70471
	FSVCON11	Ft. St. Vrain	Ft. St. Vrain - Valmont 230 kV	70410	70447
	FSVCON12	Ft. St. Vrain	Ft. St. Vrain - Green Valley 230 kV	70410	70048
Ridge Crest Contingencies					
	RCCON1	Peetz 115 kV	Peetz-Sterling 115 kV	73150	73191
	RCCON2	Peetz 115 kV	Peetz-Sidney 115 kV	73150	73179
Ponnequin Contingencies					
	QCON1	Ponnequin 115 kV	Ponnequin - Cheyenne 115 kV	73504	73043
	QCON2	Ponnequin 115 kV	Ponnequin - Rockport Tap 115 kV	73504	73172
Spring Canyon Contingencies					
	SPCCON1	Spring Canyon 230 kV	Spring Canyon - Sidney 230 kV	73579	73180
	SPCCON2	Spring Canyon 230 kV	Spring Canyon - N. Yuma 230 kV	73579	73143
*= No. of cases					49

Appendix C

Table C- 1 Peak Load Stability Results

	Meets Criteria? Y/N	Bus With Maximum Transient Volt Dev.	Maximum Transient Voltage Deviation-%	Short-Term[1] Post-Transient Voltage Deviation-%
General Contingencies				
GCON1	Y	WILOW CK	7.83%	0.02%
GCON2	Y	WILOW CK	7.78%	0.00%
GCON3	Y	PAWNEE 2	1.26%	0.07%
GCON4	Y	CLR 1 0.	1.37%	0.00%
GCON5	Y	CLR 1 0.	1.28%	0.01%
GCON6	Y	WESTPS 2	1.50%	1.19%
GCON7	Y	CLR 1 0.	1.47%	0.12%
GCON8	Y	LAMAR CO	4.68%	0.03%
GCON9	N	LAMAR CO		
GCON10	Y	LAMAR CO	3.71%	0.02%
GCON11	Y	LAMAR CO	8.75%	0.02%
GCON12	Y	CLR 1 0.	1.92%	0.82%
GCON13	Y	SPRNGCAN	2.18%	1.57%
GCON14	Y	LAR.RIVR	2.22%	1.52%
GCON15	Y	CLR 1 0.	10.66%	5.95%
GCON16	Y	CLR 1 0.	2.46%	0.61%
GCON17	Y	CLR 1 0.	2.13%	0.02%
GCON18	Y	CLR 1 0.	2.01%	0.04%
Pawnee Contingencies				
PCON1	Y	PAWNEE 2	1.37%	0.27%
PCON2	Y	CLR 1 0.	1.38%	0.62%
PCON3	Y	PAWNEE 2	1.24%	0.07%
PCON4	Y	CLR 1 0.	2.16%	0.74%
PCON5	Y	PAWNEE 2	1.52%	1.29%
PCON6	Y	QUINCY 2	1.45%	0.92%
PCON7	Y	CLR 1 0.	5.91%	0.00%
RMEC Contingencies				
RCON1	Y	CLR 1 0.	1.99%	1.03%
RCON2	Y	CLR 1 0.	0.42%	0.03%
RCON3	Y	CLR 1 0.	0.41%	0.05%
RCON4	Y	CLR 1 0.	0.55%	0.44%
RCON5	Y	CLR 1 0.	0.37%	0.04%
Spruce Contingencies				
SCON1	Y	CLR 1 0.	1.29%	0.05%
SCON2	Y	CLR 1 0.	1.29%	0.05%
SCON3	Y	CLR 1 0.	1.23%	0.11%
SCON4	Y	CLR 1 0.	1.27%	0.07%
SCON5	Y	CLR 1 0.	1.27%	0.07%
SCON6	Y	CLR 1 0.	2.02%	0.44%
SCON7	Y	CLR 1 0.	1.95%	0.41%
Ft St Vrain Contingencies				
FSVCON1	Y	CLR 1 0.	0.36%	0.09%
FSVCON2	N	ISABELLE	5.70%	5.51%
FSVCON3	Y	CLR 1 0.	1.00%	0.49%
FSVCON4	Y	CLR 1 0.	1.53%	0.20%
FSVCON5	Y	CLR 1 0.	1.70%	0.09%
FSVCON7	Y	CLR 1 0.	1.99%	0.17%
FSVCON8	Y	CLR 1 0.	1.75%	0.00%
FSVCON9	Y	CLR 1 0.	1.97%	0.11%
FSVCON10	Y	CLR 1 0.	2.01%	0.14%
FSVCON11	Y	CLR 1 0.	1.45%	0.24%
FSVCON12	Y	CLR 1 0.	1.65%	0.16%
FSVCON13	Y	CLR 1 0.	4.09%	1.48%

Note:

1. At 10 seconds.

Appendix D

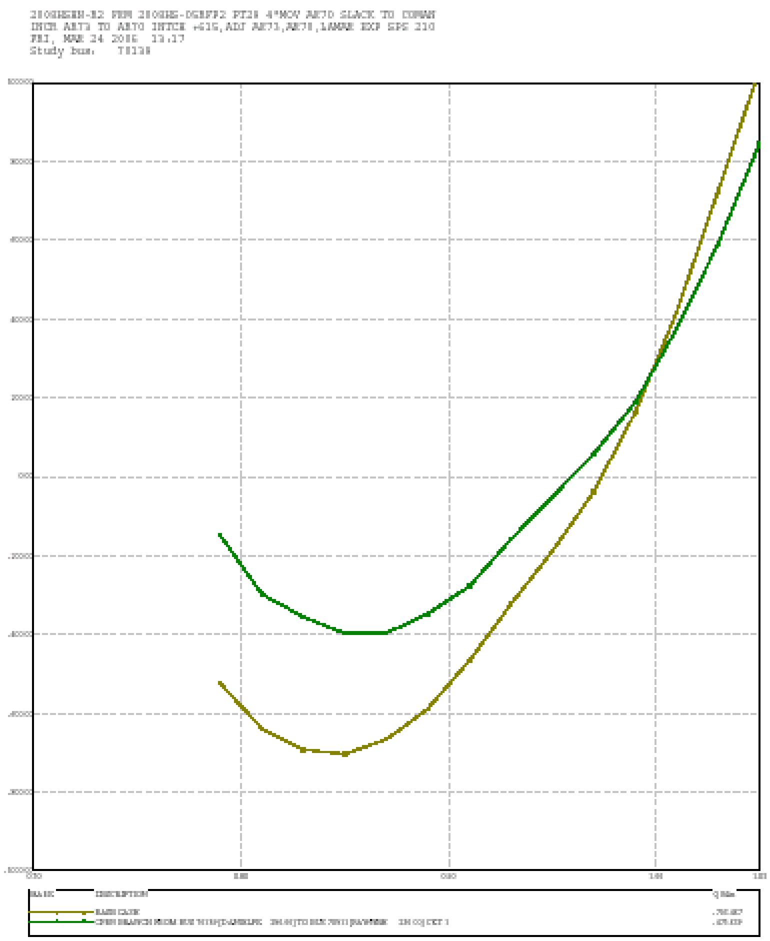

Figure D- 1 QV Results for Benchmark Case

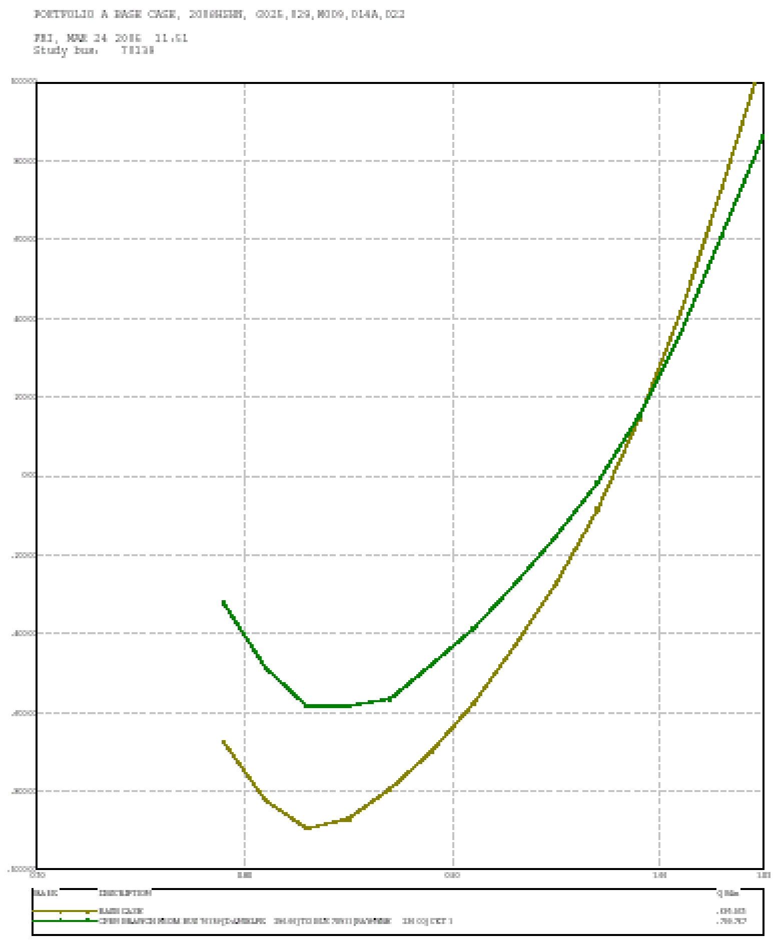

Figure D- 2 QV Results with Additional Wind Generation