Interconnection System Impact Study Report
Request # GI-2006-2 - Third Restudy

175 MW Wind Expansion of Peetz Logan, near Peetz, Colorado

Public Service Company of Colorado
Transmission Planning
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Executive Summary

PSCo transmission finalized the System Impact Study (SIS) for request GI-2006-4 for a total of 800 MW at Peetz- Logan on February 5th, 2008. In the process of conducting that SIS for GI-2006-4 (200 MW) at Peetz Logan for a total of 800 MW it was determined that the original GI-2006-2 SIS dated April 2007 would need to be reevaluated. Transmission Planning studies for GI-2006-4 indicated that the proposed 200 MW Developer's Large Generation Facility expansion does not meet the FERC Order 661-A guidelines for Low Voltage Ride Through (LVRT)[1] and therefore it is not feasible to expand the Developer's Large Generation Facility to a total of 800 MW. In addition, during the evaluation of the LVRT requirements in this present study GI-2006-2, it was determined that the Developer does not meet the FERC Order 661-A guidelines for Low Voltage Ride Through (LVRT) for a previous request evaluated in GI-2006-2[2]. PSCo Transmission Planning and the Developer agreed to a restudy of the GI-2006-2 system impact study based on a more detailed representation of the wind collector system. The results of that restudy were presented in a report issued June 25, 2008. (Restudy system impact study #1) Subsequently, discussions with the developer concerning that report, a request was received by PSCo concerning a change in turbine provider(Siemens 2.3 MW) and a reduction in the size of the GI-2006-2 request to 175 MW. Additionally, the developer submitted a detailed steady state and dynamics report to PSCo in January 2009 for their evaluation of the revised GI-2006-2 project. PSCo has reviewed that January 2009 report and has issued this restudy system impact study dated February 2009. (Restudy System Impact study #2-175 MW)
Public Service Company of Colorado (PSCo) received a request in May 2009 to modify the wind turbine generators at the wind generation facility at Peetz Logan. This request was not to materially increase the size above the 575 MW nameplate capacity currently proposed, but to replace 11 Siemens 2.3 MW wind turbines with 17 GE 1.5 MW units. The original facility, which can produce 400 MW, consists solely of GE (General Electric) 1.5 MW wind turbines. The additional capacity to be provided under GI-2006-2 and reflecting 65 Siemens SWT 2.3 MW turbines and 17 GE 1.5 MW turbines will generate the latest change (Restudy System Impact #3). Considering transmission

[1] **http://www.ferc.gov**
[2] The System Impact Study GI-2006-2 was issued to the Customer on April 4, 2007. The Facility Study GI-2006-2 was issued to the Customer on December 19, 2007.

system losses, about 540 MW of energy would be delivered from the overall Peetz Logan facility to the Point of Interconnection (POI) at the Pawnee 230-kV bus.

The results of this restudy concluded that based upon the information provided by the developer, the addition of a reduced GI-2006-2 project to 175 MW along with the installation of 200 MVAR capacitors would not adversely impact the PSCo transmission system. With the nameplate capability of the entire Peetz Logan wind facility totaling 575 MW and the use of 65 Siemens SWT 2.3 MW turbines and 17 GE 1.5 MW turbines for the 175 MW GI-2006-2, the low-voltage ride-through criteria will be met.

Power Flow Case Set-up

The power flow cases used in this re-study started from the 2012 HS2A Approved Case modified for 2010, i.e., the 2010HS Budget case. From this case, two cases were developed, one with generation at the Peetz Logan wind farm increased to 400 MW (benchmark case), and a second case with that 400 MW plus an additional 175 MW for the reduced GI-2006-2 project. This generation was assumed to displace power from resources in southeastern Colorado, resulting in a stressed system near the point of interconnection (POI.)

The wind farm was modeled in significant detail, based upon the 34.5-kV collector system data provided by the developer, for both the initial 400 MW as well as the proposed 175 MW expansion as GI-2006-2. Each individual wind turbine generator was modeled with voltage schedules and with individual step-up transformers, along with the full power flow representation of the 34.5 kV collector system, the four 230/34.5 kV transformers and the 230-kV line from the wind farm to Pawnee. This detail was provided by the developer for the entire 575-MW facility and has been used as presented. With the change in the number and size of the wind turbines (May 2009), a revised collector system was provided for the study. Therefore, this study evaluated the overall wind farm generation facilities at Peetz Logan in the same level of detail as in the previous updated study, at the individual wind turbine generator level.

The capability of the overall project is essentially unchanged and the replacement wind turbines can provide similar levels of reactive support as in the previous re-study. Therefore, there was no reason to perform any steady state analysis, as the same thermal and voltage issues would be flagged. It should be noted that the prior report for the 575-MW Peetz Logan facility indicated a need for the addition of shunt capacitors, and indicated that if those capacitors were located near the POI, about 200 MVAR of switched shunt capacitors would be needed. These capacitors are in the process of being installed with the 200 MVAR capacitor project estimated to be in service Sept 25th, 2009.

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Steady State Results: Reactive Power Requirements

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

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

2 PSCo will require testing of the full range of 0 MW to 575 MW operational capability of the facility. These tests will include, but not be limited to, power factor control, and VAR control as measured at the Pawnee 230 kV bus POI for various generation output levels (0 to 575 MW) of the Customer's wind generation facility.

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

Voltage Protection Relay Thresholds and Durations

The existing GE wind turbines use the LVRT II package provided by the manufacturer. The previous stability analyses for Peetz Logan used the typical values as documented in the manufacturer's documentation. As part of the analysis that was performed for the developer, GI-2006-2, the voltage protection settings for the existing 400 MW of GE wind turbines were field-checked to establish the proper values for the stability analysis. The actual field settings for the existing GE wind turbines allow a longer period of operation under extreme voltage conditions than the typical values. This will reduce the possibility of wind turbines being tripped during severe system disturbances on the PSCO system.

Voltage – Percent of Nominal	Maximum Time (seconds)
0 - 15	0.020
15 - 35	0.625
35 - 55	0.783
55 -75	0.941
75 - 85	10
85 - 90	600
90 -110	Continuous
110 -115	1.000
115 - 130	0.100
>130	0.020

For the new Siemens units and the new GE units(175 MW for GI-2006-2), the data used for the protective relays are the typical data as described in the appropriate manufacturer's documentation.

Stability Analysis Results

The normal voltage control scheme in the power flow cases for the Manchief and Pawnee generators generally results in the Pawnee 230-kV bus voltage being within the 1.024 to 1.030 pu range during peak load conditions with all facilities in service. With the Peetz Logan facility operating at full capability (575 MW) and delivering about 534 MW to the POI and with the 200 MVAR capacitor bank near the POI in service, the Pawnee voltage is 1.024 pu. With this system configuration, the stability analysis was performed, with various contingencies close to the POI and the generating facility studied. The following contingencies were considered:

No	Faulted End	From Bus	To Bus	Fault time period
1	Pawnee	Pawnee 230 kV	Ft. Lupton 230 kV	5 cycles
2	Pawnee	Pawnee 230 kV	Brick Center 230 kV	5 cycles
3	Pawnee	Pawnee 230 kV	Story 230 kV	5 cycles
4	Pawnee	Pawnee 230 kV	Peetz Logan 230 kV	5 cycles
5	Pawnee	Pawnee 230 kV	Daniels Park 230 kV	5 cycles
6	Peetz Northern Sub 34.5 kV	Peetz Northern Sub 34.5 kV	Feeder 34.5 kV	5 cycles

The analysis was performed with and without the 345-kV line from Pawnee to Smoky Hill. For the contingencies 1, 2, 3, 5 and 6 listed above, with the 345-kV line; all machines in the PSCO system remained in synchronism, all oscillations positively damped, and the system was stable. All WECC criteria for voltage recovery and frequency deviation are met at buses in the PSCO system for those contingencies. Also, none of the wind turbines at Peetz Logan tripped due to low voltage. When Contingency 4 was simulated, the network calculation does not converge if the Siemens turbines are isolated from the PSCO system without tripping them offline first. This issue is directly related to the SMK203 machine model for the Siemens Wind turbines. If the Siemens turbines are tripped offline, the results show the system is stable and all relevant criteria are met.

Based on the 2010HS power flow model, if the GI-2006-2 project's 200 MVAR of switched capacitors are not online when the wind farm is at full output, the voltage at the Pawnee 230-kV bus under N-0 conditions will be about 1.014. From the developer's report, there was an indication that low starting voltage levels at the Pawnee 230-kV bus could result in WECC criteria not being met. To evaluate this issue, several possible scenarios were considered that could lead to low voltage at Pawnee.

1. These included the non-operation of generation at Pawnee. With Manchief 1&2 out of service potentially due to economic dispatch, the voltage was 1.022 pu under N-0. With Pawnee unit out, for extended maintenance, the voltage was 1.026 pu on the 230-kV bus.
2. Increasing overall TOT3 flows to the 1,600 MW level (from the base case level of 1,319 MW) would lower the Pawnee 230 kV bus voltage to about 1.019.pu.
3. Lighter loads within the PSCO system should tend to increase voltage, while higher loads would tend to depress voltages. This study used heavy summer load conditions.
4. Finally, the non-existence of capacitors on the developer's facilities during peak load conditions and peak wind generation resulted in voltage levels of 1.014 under N-0.

For this last condition, and without the 345-kV line, stability analysis was run for the same 6 fault scenarios previously described. The results indicate that if the voltage at Pawnee is about 1.014 per unit, the voltage after initial recovery dips below 0.75% of initial value after a three-phase fault on the Pawnee – Story 230-kV line is cleared. This violates WECC voltage recovery criteria. **Therefore, it is necessary to maintain the voltage at the Pawnee 230-kV bus above 1.02 per unit under system intact conditions. This will require that the developer's capacitors installed near Pawnee on the Pawnee – Peetz Logan 230 kV circuit must be switched on during periods of high wind generation.** No voltage recovery or frequency deviation violations are observed at any bus in the PSCO system for any of the other contingencies.