Interconnection Feasibility/System Impact Study Report
Request # GI-2008-03

250 MW Wind Farm, Near Genoa, Colorado

Public Service Company of Colorado
Transmission Planning
June 30, 2009

Executive Summary

Public Service Company of Colorado received an interconnection request (GI-2008-03) to install a 250.5 MW wind turbine generator facility near Genoa, Colorado. The proposed interconnection point is the planned new 230 kV switching station called Missile Site. This station is to be connected to the Pawnee-Daniels Park 230 kV line (see Figures 1 & 2 below). It is presently in PSCo's budget and scheduled to be in service in December 2010. The wind generating facilities are located 45 miles southeast of the interconnection point and would be connected via a developer owned radial 230 kV line. The requested in service date is December 2010 with a projected backfeed date of June 2010.

This request was studied as a Network Resource[1] at the full 250.5 MW rated output. The project's Energy Resource[2] status was also considered. These investigations included steady-state power flow, transient stability, and short circuit analyses. The request was studied as a stand-alone project only, with no evaluations made of other potential new generation requests that may exist in the Large Generator Interconnection Request (LGIR) queue, other than the generation projects that are already approved and planned to be in service by December 2010. The main purpose of this System Impact Study was to evaluate the potential impact on the PSCo transmission infrastructure as well as that of neighboring utilities when injecting the proposed 250 MW of generation at the interconnection point at the planned Missile Site Substation, and delivering the additional generation to native PSCo loads. The costs to

[1] **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.

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

interconnect the project with the transmission system were also evaluated by PSCo Engineering.

Network Resource

Based on the results of the study, the Network Resource analysis indicates that the developer can provide 250.5 MW if overloads on the following facilities are addressed:

- Beaver Creek 230/115 kV 224 MVA transformer T3 owned by Tri-State Generation & Transmission (TSG&T)
- Beaver Creek 115 kV TSG&T bus tie with Western Area Power Administration (WAPA)

Note – the Beaver Creek facilities are also benchmark overloaded.

The developer should contact TSG&T directly to review these results and determine the most appropriate way to address the reported overloads.

These results will be communicated to TSG&T, WAPA, and IREA.

Energy Resource

Interconnection as an Energy Resource will require the same Network Upgrades as are required for Network Resource status to deliver the requested generation level on a firm basis. Non-firm transmission capability may be available depending upon generation dispatch levels, demand levels, import path levels (TOT 3, etc.), and the operational status of transmission facilities.

Voltage Control at the Point of Interconnection

The Rocky Mountain Area Voltage Guidelines specify the ideal voltage range at 230 kV non-regulating buses in the Metro Denver-Boulder-Ft. Lupton Region 8 should be 1.00 – 1.03 per unit. To ensure reliable operation, the interconnecting generation should adhere to these guidelines. The proposed generation should be able to conform to this requirement when maintaining the power factor at the Missile Site POI near unity during peak system conditions.

However, the studies also show that wind plant operation can have a detrimental impact on the voltage regulating capability of the generating units connected at the Pawnee 230 kV substation. To mitigate this impact, the Developer will need to include reactive support within the wind farm. Our study shows that a 65 Mvar capacitor bank at the main 230/34.5 kV transformer low side bus will mitigate this problem. This will also bring the POI voltage to within the ideal voltage range for non-regulating buses. The Developer will need to perform additional detailed studies to determine the optimum types and locations for the reactive correction equipment.

Line charging from wind plant facilities is expected to be approximately 25 Mvar injected into the POI when the wind plant is off-line. This will also have an adverse impact on area generator reactive resources. Shunt reactors or other reactive compensation should be installed within the wind plant to mitigate the line charging.

The cost for the transmission interconnection (in 2009 dollars):

Transmission Proposal
The total estimated cost of the recommended system improvements to interconnect the project is approximately **$648,000** and includes:

- $ 0.642 million for PSCo-Owned, Developer-Funded Attachment Facilities
- $ 0.006 million for PSCo-Owned, PSCo-Funded Attachment Facilities
- $ 0.000 million for PSCo Network Upgrades for Delivery to PSCo Loads

This work can be completed in 12 months following receipt of authorization to proceed. However, the backfeed date of June 2010 cannot be met with this timeline.

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 250 MW operational capability of the facility to verify that the facility can safely and reliably operate within required power factor and voltage ranges.

3 A single point of contact needs to be provided to PSCo Operations to facilitate reliable management of the transmission system.

Figure 1 Network Diagram with Proposed POI at Missile Site

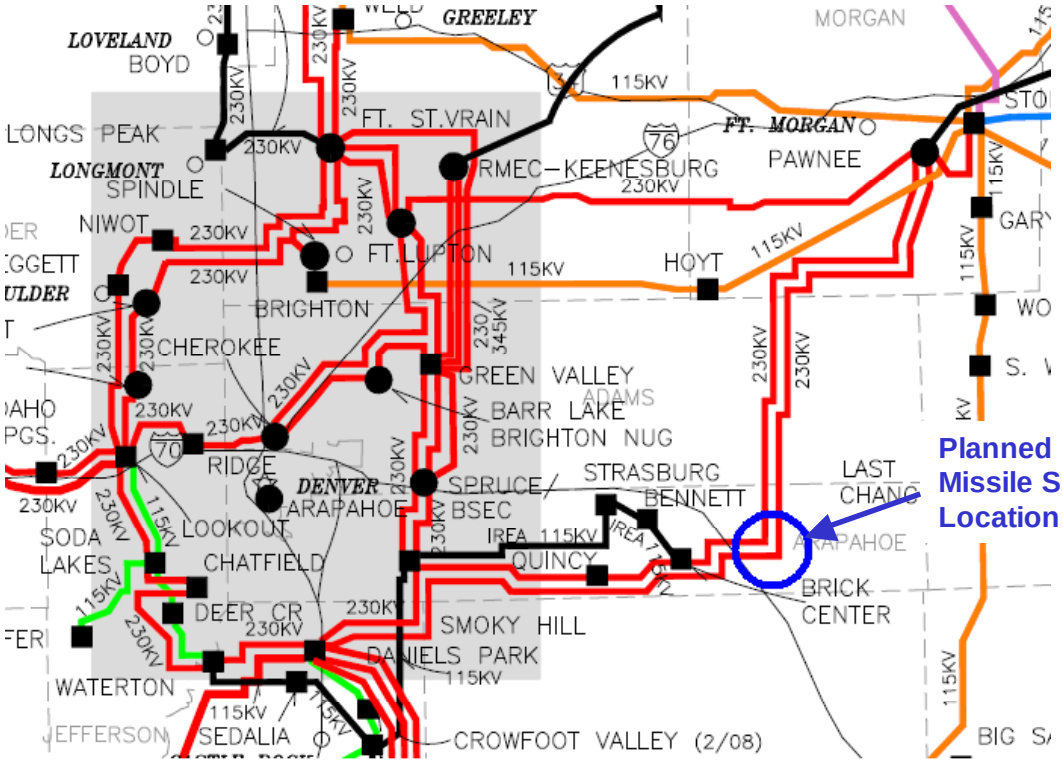
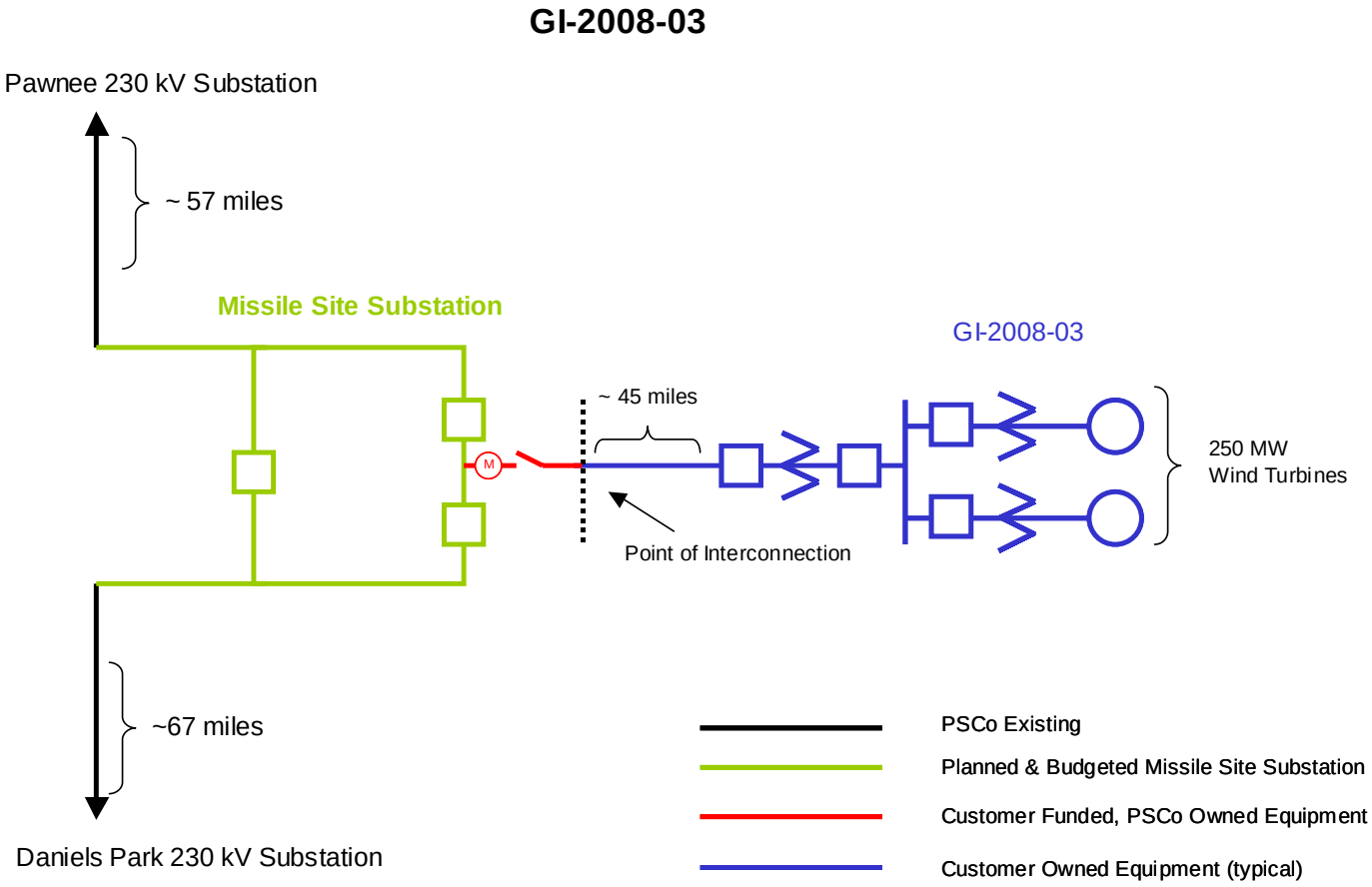


Figure 2 Proposed Interconnection Station One-Line Diagram



Introduction

Public Service Company of Colorado received a large generator interconnection request (GI-2008-03) to install a 250.5 MW generating facility near Genoa, Colorado. The project includes 167 GE 1.5 MW wind turbine generators (250.5 MW total). The proposed interconnection point is the planned new 230 kV switching station called Missile Site. This station is to be connected to the Pawnee-Daniels Park 230 kV line (see Figures 1 & 2). It is presently in PSCo's budget and scheduled to be in service in December 2010. The wind generating facilities are located 45 miles southeast of the interconnection point and would be connected via a developer owned radial 230 kV line. The requested in service date of the proposed generation is December 2010 with a projected backfeed date of June 2010.

This study examined the system reinforcements and associated costs required to facilitate the addition of the new generating plant to the transmission system as a Network Resource. The reinforcements include the direct connection of the generator to the system and any network upgrades required to maintain the reliability of the transmission system.

Study Scope and Analysis

The Feasibility/System Impact Study evaluated the transmission impacts associated with the proposed generating station. It consisted of power flow, dynamic & transient stability, and short circuit analyses. The power flow analysis identified any thermal or voltage limit violations resulting from the interconnection and an identification of network upgrades required to deliver the proposed generation to PSCo loads. The transient analysis identified any dynamic or transient stability problems associated with the new generation. The short circuit analysis identified short circuit levels and any circuit breakers that might exceed their fault interruption capability due to addition of the new generation.

PSCo adheres to NERC and 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 nominal, and steady-state power flows below the thermal ratings of all facilities. Per the Rocky Mountain Area Voltage Coordination Guidelines[2], PSCo tries to maintain a transmission system voltage profile ranging from 1.02 – 1.03 per unit at regulating buses and 1.0 – 1.03 per unit at non-regulating buses. Following a single contingency, transmission system steady state bus voltages must remain within 0.90 per unit to 1.10 per unit, and power flows within 100% of the facilities' continuous thermal ratings.

[2] The Voltage Coordination Guidelines Subcommittee of the Colorado Coordinated Planning Group developed these 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 involved in the development of these guidelines.

Transient stability criteria require that all generating machines remain in synchronism and all power swings should be well damped. Also, transient voltage performance should meet the following criteria:

- Following fault clearing for single contingencies, voltage may not dip more than 25% of the pre-fault voltage at load buses, more than 30% at non-load buses, or more than 20% for more than 20 cycles at any bus.
- Following fault clearing for double contingencies, voltage may not dip more than 30% of the pre-fault voltage at any bus or more than 20% for more than 40 cycles at any bus.

Wind plants are required to remain in service during a three-phase fault lasting up to 9 cycles. They should also remain in service following single line to ground faults with delayed clearing.

For this project, potential affected parties include the Intermountain Rural Electric Association (IREA), Tri-State Generation & Transmission (TSG&T), and Western Area Power Administration (WAPA).

Power Flow Study Models

The power flow studies were based on the WECC approved 11HS1BP base case. Load levels reflect 2011 heavy summer peak system conditions. The case was modified to update some facility ratings changes. The swing bus was also moved from Cherokee Unit 3 to Comanche Unit 1. In addition, the case was modified to reflect the delayed in service date of the Midway-Waterton 345 kV project. These facilities are presently scheduled to be in service in May 2011. The case was also modified to include the replacement of the Daniels Park 230/115 kV transformer with a 280 MVA unit.

Initially, studies were conducted including the new Beaver Creek-Hoyt 230 kV line that is in the case. However, comparison of results with those from a similar generation interconnection request prompted a review of the status of this line. Based on information received from the Western Area Power Administration, the new Beaver Creek-Hoyt 230 kV line in the case has been superceded by a new Story-Henry Lake-Sipres-Erie 230 kV circuit, which is planned to be in service in 2010. The case was subsequently modified to reflect this change.

Initially the studies were also performed with Peetz Logan at 12% output with a sensitivity case at 400 MW. However, subsequent to these studies, new 150 MW and 22.5 MW wind facilities at Peetz Logan signed power purchase agreements with PSCo. Therefore, the full 572.5 MW was subsequently included in the case. This is also consistent with other generation interconnection studies in the area. The case was also modified to include a new 200 Mvar capacitor bank on the Peetz Logan line near Pawnee. The new Peetz Logan facilities are due in service by the end of 2009.

The Project's wind turbine generators were modeled as an equivalent 250.5 MW machine connected to a 0.575 kV bus. The wind plant model includes an equivalent 34.5/0.575 kV generator step-up transformer and equivalent collector system impedance. It also includes two main 230/34.5 kV 140 MVA transformers modeled in parallel. This model is connected to the interconnection station through a 45-mile 230 kV overhead transmission line. The interconnection station is the planned Missile Site station connected to the Pawnee-Daniels Park 230 kV line. The reactive capability of the equivalent generator was based on values provided by the project developer and the generator scheduled voltage was set to 1.00 pu at the generator terminal.

Two main power flow case model generation dispatch scenarios were evaluated. One was created as a reference case and the other was created with the new generation modeled on the Pawnee-Daniels Park 230 kV line. To evaluate the capabilities of the existing transmission system and the potential reinforcements that would be required, the power flow models were modified to simulate a flow bias to the south. Generation that was redispatched to develop these dispatch scenarios included units at Pawnee, Peetz Logan, Comanche, and Squirrel. Besides the redispatch scenarios, the Squirrel generators were also switched off due to their cancellation since the load flow base case was developed. All of the generation at Pawnee, including Peetz Logan, was set to maximum output.

PSCo control area (Area 70) wind generation facilities, other than GI-2008-03 and Peetz Logan, were dispatched to approximately 12% of facility ratings, consistent with other similar planning study models.

Power Flow Study Process

Automated contingency power flow studies were completed on the reference model and the model with the proposed generation using PTI's PSS™MUST program, switching out single branches one at a time for all of the transmission facilities (lines and transformers) in control areas 70 (PSCo) and 73 (WAPA RM). Results from the two cases were compared and new overloads or overloads that increased by greater than 5% in the new generator case were noted.

Power Flow Results

A list of the transmission facilities that experienced new or significantly increased overloads in the case with the new generation as compared to the reference case can be found in Table 7 in the Appendix.

The Missile Site-Daniels Park 230 kV line was found to be overloaded at 109.4% of its 564 MVA rating versus 82.6% in the benchmark case. However, upgrades planned to be in service in the fourth quarter of 2009 will increase the rating to 734 MVA. This will relieve the overload. Therefore, no further upgrades are required.

The Cherokee-Silver Saddle 230 kV circuit was found to be overloaded at 100.3% of its 326 MVA rating in the case versus 98.8% in the benchmark case. However, review of the line rating determined that the rating in the case was incorrect. The correct rating is 365 MVA due to a line conductor limit. Therefore, this overload result is not a concern.

The Fort Lupton 230/115 kV transformer T3 was found to be overloaded at 101.5% of its 280 MVA normal rating versus 99.9% in the benchmark case. However, the emergency rating is 322 MVA. Therefore, an operating procedure can be used to relieve the overload of this facility. Further upgrades are not required.

The Fort Lupton-Pawnee 230 kV line was found to be overloaded at 125.0% of the 355 MVA rating in the case versus 108.0% in the benchmark case. However, review of this limit found it to be incorrect. The correct rating is 518 MVA due to the line conductor limit. With this revised limit, the overload no longer exists and, therefore, upgrades are not required.

The Fort Lupton-JL Green 230 kV circuit was found to be overloaded at 102.2% of the 495 MVA rating in the case versus 99.4% in the benchmark case. However, review of this limit found it to be incorrect. Based on information provided by TSG&T, the correct rating is 478 MVA due to a CT at TSG&T's JL Greene 230 kV substation. With this lower limit, the line is also overloaded in the benchmark case and the increase with the proposed generation is less than 5%. Therefore, upgrades due to the proposed generation are not required.

The Smoky Hill-Strasburg 115 kV circuit was found to be overloaded at 102.1% of its 144.6 MVA rating versus 95.1% in the benchmark case. This circuit is owned by IREA. IREA is aware of potential loading problems on this circuit and has a relay scheme or operating procedure to mitigate the issue.

The Smoky Hill-Peakview 115 kV circuit was found to be overloaded at 102.3% of the 186.6 MVA rating in the case versus 99.1% in the benchmark case. This circuit is owned by IREA. Based on information provided by IREA this circuit was upgraded earlier this year. The new rating is 241.6 MVA. Therefore, upgrades due to the proposed generation are not required.

The Brick Center 230/115 kV transformer T1 was found to be overloaded at 105.6% of the 168 MVA rating in the case versus 99.6% in the benchmark case. However, review of this rating determined it to be incorrect. The correct normal rating is 200 MVA. With the higher rating, the overload no longer exists. Therefore, upgrades are not required.

The Beaver Creek 230/115 kV 224 MVA transformer T3 was found to be overloaded at 118.9% of its 224 MVA rating versus 112.9% in the benchmark case. This facility is owned by TSG&T. The developer should contact TSG&T directly to review these results and determine the most appropriate way to address them.

The Beaver Creek TSG&T-WAPA 115 kV interconnection was found to be overloaded at 126.4% of its 200 MVA rating versus 119.9% in the benchmark case. This facility is owned by TSG&T. The developer should contact TSG&T directly to review these results and determine the most appropriate way to address them.

These results will be communicated to IREA, TSG&T, and WAPA.

Based on these results, the overloaded facilities that should be addressed are:

- Beaver Creek 230/115 kV 224 MVA transformer T3 owned by TSG&T
- Beaver Creek 115 kV bus tie owned by TSG&T.

The developer should contact TSG&T directly to review these results and determine the most appropriate way to address them.

Transient Stability Models

The dynamic and transient stability studies used the same base cases as were used in the load flow studies. Small changes in some remote generation levels were required to address model initialization problems. Please see the Power Flow Study Models section for more details.

Transient Stability Study Process

The transient stability studies were conducted using PTI's PSS/E Version 30.3.2 software. NERC Category B & C contingencies were considered as part of the analysis. The simulations considered three-phase faults with normal clearing and single line to ground faults with breaker failure & clearing by backup breakers. The analyses using three-phase faults assumed 5 cycle normal clearing time. The single line to ground breaker failure analyses used a backup clearing time of 17 cycles. The results were assessed for dynamic and transient stability performance, including wind turbine generator low voltage ride through. A listing of the buses that were monitored to evaluate transient voltage dip performance can be found in Table 8.

Transient Stability Study Results

The list of contingencies that were evaluated can be found in Table 9 in the Appendix. The range of contingencies evaluated was limited to that necessary to adequately assess the transient stability performance of the proposed wind turbine generator project. Plots of machine speed, power, terminal voltage, terminal frequency, and system voltages for each contingency were produced to perform the assessment.

The study shows that in one case that included a single line to ground fault at the Pawnee substation and breaker failure, case #211, the units at Pawnee went unstable.

However, a benchmark run without the proposed generation shows the same problem. Therefore, the wind farm is not responsible. This problem will be addressed through separate studies to investigate mitigating strategies.

Other than Case #211, the studies show that with the turbines specified, GE 1.5 MW (167 turbines), and operating using the WindCONTROL voltage and reactive control mode, the transmission system will be transiently stable and the wind farm will meet the low voltage ride through requirement with the following manufacturer recommended voltage trip levels and times:

Voltage at the terminal of the generator:
- 0.75 pu or lower for 1.9 seconds
- 0.50 pu or lower for 1.2 seconds
- 0.30 pu or lower for 0.70 second
- 0.15 pu or lower for 0.20 second
- 1.15 pu or higher for 0.10 second
- 1.30 pu or higher for 0.02 second

All transient voltage swings were within criteria. The maximum observed voltage dip was to 93.74%.

Network Resource (NR)

This Study has determined that the requested generation increase injected at the interconnection point at the planned Missile Site 230 kV substation causes overloads on the IREA and TSG&T systems. Therefore, the 250 MW Network Resource value requested will require these overloads to be addressed with the Affected Parties.

NR = 250 MW (with Affected Party overloads addressed)

Energy Resource (ER)

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.

Voltage Control at the Point of Interconnection

Wind developers are required to conform to NERC and WECC Reliability Criteria, Xcel Energy interconnection guidelines, and FERC Order 661-A, including:

- The wind plant shall maintain the power factor at the POI within the range of 0.95 leading to 0.95 lagging for the full MW operating range of the facility, if the System Impact Study demonstrates that this power factor requirement is necessary to ensure safety or reliability.
- During system intact conditions, criteria are to maintain transmission system bus voltages between 0.95 and 1.05 per unit of nominal. Following a single contingency, transmission system steady state bus voltages must remain within 0.90 per unit to 1.10 per unit.
- To ensure reliable operation, the interconnecting generation should adhere to the Rocky Mountain Area Voltage Coordination Guidelines for the Metro Denver-Boulder-Ft. Lupton Region 8; per the guidelines, PSCo tries to maintain an ideal transmission system voltage profile ranging from 1.02 – 1.03 per unit at regulating buses and 1.0 – 1.03 per unit at non-regulating buses.
- The impact of the wind generating facility on the reactive power schedules of nearby generating units may need to be mitigated by the developer if system studies demonstrate that the proposed wind generating facility causes nearby generating units to generate or absorb reactive power for voltage control[3]. It is understood that reactive power reserve must be maintained on generating units to allow them to dynamically regulate voltage for extreme system conditions.
- The wind plant is required to demonstrate to the satisfaction of PSCo System Operations prior to the commercial in-service date that it can safely and reliably operate within required power factor and voltage ranges.
- It is the responsibility of the project developer 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 to meet the power factor and voltage range standards.
- PSCo requires the Developer 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.

This study examined the ability of the proposed wind plant to adhere to the power factor and reactive power requirements of the interconnection guidelines. The results are in Table 1 below. Based on the results of the studies, the wind plant should be able to deliver the full 250.5 MW minus losses at the POI within the 0.95 leading to 0.95 lagging power factor criteria. Also, the proposed generation should be able to conform to the ideal voltage range for non-regulating buses when maintaining the power factor at the Missile Site POI near unity during peak system conditions.

[3] 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."

However, the studies also show that wind plant operation can have a detrimental impact on the voltage regulating capability of the generating units connected at the Pawnee 230 kV substation. Based on the study results, with the wind generators operating at maximum output and unity power factor, the Pawnee units would be required to increase their reactive output by 66 Mvars for an increase of 37% over the benchmark operating point. This is a significant reduction in generator reactive capability during peak system conditions. Therefore, to mitigate this impact, the Developer will need to add reactive support within the wind farm. Our study shows that a 65 Mvar capacitor bank at the main 230/34.5 kV transformer low side bus will mitigate this problem. This will also bring the POI voltage to within the ideal voltage range for non-regulating buses. The Developer will need to perform additional detailed studies to determine the optimum types and locations for the reactive correction equipment.

When the proposed wind plant is not generating, the facilities deliver approximately 25 Mvar at the POI due to line charging from the developer's 230 kV transmission line and 34.5 kV collector system. The voltage is within the ideal range, but the reactive output of the generating units changes by 16 Mvars. Therefore, reactive correction located within the wind plant will be required to mitigate the line charging.

Table 1 Voltage & Reactive Power at the Point of Interconnection

	Benchmark w/ POI, no generator – Peak Summer Conditions	Benchmark w/ POI & collector system, no generator – Peak Summer Conditions	GI 2008-03 @ 250 MW – Peak Summer Conditions Gen @ unity terminal PF 65 Mvar Cap Bank @ 34.5 kV transformer bus
Real Power Delivered at POI, MW	N/A	0	243.5
Reactive Power Delivered at POI, Mvar	N/A	25.2	17.0
Power Factor at POI	N/A	0.00	1.00
Voltage at the POI, pu	0.996	1.004	1.003
Voltage at Pawnee 230 kV bus, pu	1.030	1.030	1.030
Pawnee Unit 1 Reactive Output (P=530 MW), Mvar	101.3	92.2	101.3
Manchief Unit 1 Reactive Output (P=140 MW), Mvar	39.8	36.2	39.8
Manchief Unit 2 Reactive Output (P=140 MW), Mvar	39.8	36.2	39.8

Short Circuit Study Results

The Developer did not provide a short circuit model for the wind turbine generator. Therefore, an assumed model was used based on data from another study with similar generators. Based on the results of the short circuit studies, no new circuit breakers are expected to exceed their capabilities following installation of the new generation. The calculated short circuit parameters for the point of interconnection at Missile Site are shown in Tables 2a & 2b below.

Table 2a Short Circuit Parameters at the POI w/ Assumed WTG Model

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	Thevenin System Equivalent Impedance (R +j X) (ohms)
All Facilities in Service	7,789.80	5427.16	Z1(pos)= 1.75605 +j 16.9560 Z2(neg)= 1.76133 +j 16.9605 Z0(zero)= 8.99840 +j 37.7993
Pawnee Line Out	4,511.09	3443.28	Z1(pos)= 2.94877 +j 29.2884 Z2(neg)= 2.95780 +j 29.2851 Z0(zero)= 11.6297 +j 55.7853
Daniels Park Line Out	4,528.42	3,578.96	Z1(pos)= 2.72968 +j 29.1965 Z2(neg)= 2.73000 +j 29.2124 Z0(zero)= 10.6987 +j 51.7215

Table 2b Short Circuit Parameters at the POI w/o Assumed WTG Model

System Condition	Three-Phase Fault Level (Amps)	Single-Line-to-Ground Fault Level (Amps)	Thevenin System Equivalent Impedance (R +j X) (ohms)
All Facilities in Service	6632.50	4106.34	Z1(pos)= 2.27444 +j 19.8916 Z2(neg)= 2.28185 +j 19.8977 Z0(zero)= 14.0139 +j 55.4307
Pawnee Line Out	3350.77	2134.30	Z1(pos)= 4.75917 +j 39.3431 Z2(neg)= 4.77570 +j 39.3358 Z0(zero)= 22.0755 +j 105.277
Daniels Park Line Out	3370.47	2312.69	Z1(pos)= 4.35418 +j 39.1568 Z2(neg)= 4.35579 +j 39.1855 Z0(zero)= 18.9473 +j 91.6775

Costs Estimates and Assumptions

GI-2008-3 (Feasibility/System Impact Study Report)

The estimated total cost for the required upgrades for is **$648,000.**
The estimated costs shown are (+/-30%) estimates in 2009 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 siting, engineering, design, procurement and construction of these new Xcel Energy facilities. This estimate does 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 3 – PSCo Owned; Customer Funded Interconnection Facilities

Element	Description	Cost Est. Millions
PSCo's Missile 230kV Substation	Interconnect Customer at PSCo's Missile 230kV Substation. New 230kV equipment required for interconnection includes: • one 230kV, 2000 amp gang switch • 230kV bi-directional metering • relaying, communication and associated equipment • foundations and structures	**$0.434**
	Transmission tie line into substation.	**$0.070**
	Customer Load Frequency/Automated Generation Control and Generator Witness Testing.	**$0.128**
	Siting and Land Rights for required easements, reports, permits and licenses.	**$0.010**
	Total Cost Estimate for Customer Interconnection Facilities	**$0.642**
Time Frame	**To site, design, procure and construct**	**12 Months**

Table 4: PSCo Owned; PSCo Funded Interconnection Facilities

Element	Description	Cost
Daniels Park Substation	Relay setting changes	**$.003**
Pawnee Substation	Relay setting changes	**$.003**
	Total Cost Estimate for PSCo Interconnection Facilities	**$0.006**
Time Frame	**To design and schedule**	**1 Month**

Assumptions for Alternatives

- The cost estimates provided are "scoping estimates" with an accuracy of +/- 30%.
- Estimates are based on 2009 dollars (no escalation applied).
- There is no contingency added to the estimates.
- AFUDC is excluded from all cost estimate.
- 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 Generation Site is not in PSCo's service territory. The local utility will provide station service power to the generator.

Appendix

A. Generation Dispatch

Table 5 – Generation Dispatch in the GI-2008-03 Study New Generator Case

GI-2008-03 System Impact Study				
Generation Dispatch in New Generator Case				
Bus	Name	ID	Status	Pgen
90503	8-03_GEN 0.5750	1	1	250.5
70010	QF MNFRT 13.800	G1	0	0.0
70034	ARAP3 13.800	G3	1	44.0
70035	ARAP4 13.800	G4	1	115.0
70080	CAMEO1 13.800	G1	1	25.0
70081	CAMEO2 13.800	G2	1	44.0
70103	CHEROK1 15.500	G1	1	110.0
70104	CHEROK2 15.500	G2	1	110.0
70105	CHEROK3 20.000	G3	1	40.29
70106	CHEROK4 22.000	G4	1	380.0
70119	COMAN 1 24.000	G1	1	218.162
70120	COMAN 2 24.000	G2	1	320.0
70188	FTLUP1-2 13.800	1	0	0.0
70188	FTLUP1-2 13.800	2	0	0.0
70310	PAWNEE 22.000	G1	1	530.0
70314	MANCHEF1 16.000	G1	1	140.0
70315	MANCHEF2 16.000	G2	1	140.0
70406	ST.VR 2 18.000	G2	1	130.0
70407	ST.VR 3 18.000	G3	1	130.0
70408	ST.VR 4 18.000	G4	1	130.0
70409	ST.VRAIN 22.000	G1	1	342.0
70446	VALMONT 20.000	G5	1	188.0
70448	VALMONT6 13.800	G6	1	50.0
70478	ZUNI1 13.800	G1	0	0.0
70479	ZUNI2 13.800	G2	0	0.0
70498	QF BCP2T 13.800	G3	1	10.0
70498	QF BCP2T 13.800	S2	1	10.0
70499	QF B4-4T 13.800	G4	1	24.0
70499	QF B4-4T 13.800	G5	1	25.0

GI-2008-03 System Impact Study				
Generation Dispatch in New Generator Case				
Bus	Name	ID	Status	Pgen
70500	QF CPP1T 13.800	G1	1	20.0
70500	QF CPP1T 13.800	G2	1	20.0
70501	QF CPP3T 13.800	S1	1	27.0
70502	QF UNC 13.800	G1	1	29.0
70502	QF UNC 13.800	G2	1	29.0
70502	QF UNC 13.800	G3	1	17.0
70553	ARAP5-6 13.800	G5	1	37.0
70553	ARAP5-6 13.800	G6	1	37.0
70554	ARAP7 13.800	G7	1	45.0
70556	QF B4D4T 12.500	S3	1	70.0
70557	VALMNT7 13.800	G7	1	36.0
70558	VALMNT8 13.800	G8	1	36.0
70562	SPRUCE1 18.000	G1	1	140.0
70563	SPRUCE2 18.000	G2	1	140.0
70565	BRTNNUG1 13.800	G1	1	64.0
70566	BRTNNUG2 13.800	G2	1	64.0
70588	RMEC1 15.000	G1	1	140.0
70589	RMEC2 15.000	G2	1	140.0
70591	RMEC3 23.000	G3	1	322.0
70593	SPNDLE1 18.000	1	1	134.0
70594	SPNDLE2 18.000	2	1	134.0
70631	SQRRL01 24.000	1	0	0.0
70632	SQRRL02 24.000	1	0	0.0
70633	SQRRL03 24.000	1	0	0.0
70777	COMAN 3 24.000	1	1	499.5
70822	CEDARCK1 34.500	1	1	15.0
70823	CEDARCK2 34.500	1	1	15.0
71005	GI-2006-2-1 0.6900	1	1	149.5
71006	GI-2006-2-2 0.5750	1	1	22.5
72001	PTZ LGN S WG0.5750	1	1	94.5
72002	PTZ LGN S WG0.5750	1	1	105.0
72003	PTZ TBL 2 WG0.5750	1	1	97.5
72004	PTZ TBL 1 WG0.5750	1	1	102.0
			(1=on)	

Table 6 – Generation Dispatch in the GI-2008-03 Study Benchmark Case

GI-2008-03 System Impact Study				
Generation Dispatch in Benchmark Case				
Bus	Name	ID	Status	Pgen
70010	QF MNFRT 13.800	G1	0	0.0
70034	ARAP3 13.800	G3	1	44.0
70035	ARAP4 13.800	G4	1	115.0
70080	CAMEO1 13.800	G1	1	25.0
70081	CAMEO2 13.800	G2	1	44.0
70103	CHEROK1 15.500	G1	1	110.0
70104	CHEROK2 15.500	G2	1	110.0
70105	CHEROK3 20.000	G3	1	40.29
70106	CHEROK4 22.000	G4	1	380.0
70119	COMAN 1 24.000	G1	1	315.4924
70120	COMAN 2 24.000	G2	1	200.0
70188	FTLUP1-2 13.800	1	0	0.0
70188	FTLUP1-2 13.800	2	0	0.0
70310	PAWNEE 22.000	G1	1	530.0
70314	MANCHEF1 16.000	G1	1	140.0
70315	MANCHEF2 16.000	G2	1	140.0
70406	ST.VR 2 18.000	G2	1	130.0
70407	ST.VR 3 18.000	G3	1	130.0
70408	ST.VR 4 18.000	G4	1	130.0
70409	ST.VRAIN 22.000	G1	1	342.0
70446	VALMONT 20.000	G5	1	188.0
70448	VALMONT6 13.800	G6	1	50.0
70478	ZUNI1 13.800	G1	0	0.0
70479	ZUNI2 13.800	G2	0	0.0
70498	QF BCP2T 13.800	G3	1	10.0
70498	QF BCP2T 13.800	S2	1	10.0
70499	QF B4-4T 13.800	G4	1	24.0
70499	QF B4-4T 13.800	G5	1	25.0
70500	QF CPP1T 13.800	G1	1	20.0
70500	QF CPP1T 13.800	G2	1	20.0
70501	QF CPP3T 13.800	S1	1	27.0
70502	QF UNC 13.800	G1	1	29.0
70502	QF UNC 13.800	G2	1	29.0
70502	QF UNC 13.800	G3	1	17.0
70553	ARAP5-6 13.800	G5	1	37.0

GI-2008-03 System Impact Study				
Generation Dispatch in Benchmark Case				
Bus	Name	ID	Status	Pgen
70553	ARAP5-6 13.800	G6	1	37.0
70554	ARAP7 13.800	G7	1	45.0
70556	QF B4D4T 12.500	S3	1	70.0
70557	VALMNT7 13.800	G7	1	36.0
70558	VALMNT8 13.800	G8	1	36.0
70562	SPRUCE1 18.000	G1	1	140.0
70563	SPRUCE2 18.000	G2	1	140.0
70565	BRTNNUG1 13.800	G1	1	64.0
70566	BRTNNUG2 13.800	G2	1	64.0
70588	RMEC1 15.000	G1	1	140.0
70589	RMEC2 15.000	G2	1	140.0
70591	RMEC3 23.000	G3	1	322.0
70593	SPNDLE1 18.000	1	1	134.0
70594	SPNDLE2 18.000	2	1	134.0
70631	SQRRL01 24.000	1	0	0.0
70632	SQRRL02 24.000	1	0	0.0
70633	SQRRL03 24.000	1	0	0.0
70777	COMAN 3 24.000	1	1	750.0
70822	CEDARCK1 34.500	1	1	15.0
70823	CEDARCK2 34.500	1	1	15.0
71005	GI-2006-2-1 0.6900	1	1	149.5
71006	GI-2006-2-2 0.5750	1	1	22.5
72001	PTZ LGN S WG0.5750	1	1	94.5
72002	PTZ LGN S WG0.5750	1	1	105.0
72003	PTZ TBL 2 WG0.5750	1	1	97.5
72004	PTZ TBL 1 WG0.5750	1	1	102.0
			(1=on)	

Appendix

B. Power Flow Contingency Results

The results of the power flow studies are summarized in Table 7 below. The facilities identified in this study report as overloaded in the contingency analysis are limited to new or significantly increased overloads and do not address all of the facilities that may have been flagged as overloaded in the contingency runs. The other facilities that may be overloaded, independent of the new 250 MW generation injection at Missile Site substation, will be addressed through other separate Transmission Planning project proposals or by other affected utilities.

Table 7 – Summary Listing of Differentially Overloaded Facilities[4]

				Branch N-1 Loading Without GI-2008-03			Branch N-1 Loading With GI-2008-03			
Monitored Facility (Line or Transformer) From Bus To Bus	**Type**	**Line Owner**	**Branch Rating MVA**	**N-1 Flow in MVA**	**N-1 Flow in % of Rating**	**Total # of Violations**	**N-1 Flow in MVA**	**N-1 Flow in % of Rating**	**Total # of Violations**	**N-1 Contingency Outage From Bus To Bus**
500 MISSILE 230 70139 DANIELPK 230 1	LN	PSCo	564	465.9	82.6	0	616.8	109.4	5	70311 PAWNEE 230 70545 BRICKCTR 230 1
70107 CHEROKEE 230 70609 SILVSADL 230 1	LN	PSCo	326	321.9	98.8	0	327.0	100.3	1	70192 FTLUPTON 230 70529 JLGREEN 230 1
70191 FTLUPTON 115 70192 FTLUPTON 230 T3	TR	PSCo	280	279.6	99.9	1	284.1	101.5	3	70192 FTLUPTON 230 70529 JLGREEN 230 1
70192 FTLUPTON 230 70311 PAWNEE 230 1	LN	PSCo	355	383.5	108.0	8	443.6	125.0	8	500 MISSILE 230 70139 DANIELPK 230 1
70192 FTLUPTON 230 70529 JLGREEN 230 1	LN	PSCo/TSG &T	495	492.1	99.4	1	505.9	102.2	2	70107 CHEROKEE 230 70362 RIVERDAL 230 1
70395 SMOKYHIL 115 70416 STRASBRG 115 1	LN	IREA	144.6	137.5	95.1	0	147.6	102.1	2	70343 QUINCY 230 70545 BRICKCTR 230 1

[4] **Newly overloaded elements, or delta overloads > 5% of rating, due to proposed 250 MW generation injection at POI.**

				Branch N-1 Loading Without GI-2008-03			Branch N-1 Loading With GI-2008-03			
Monitored Facility (Line or Transformer) From Bus To Bus	**Type**	**Line Owner**	**Branch Rating MVA**	**N-1 Flow in MVA**	**N-1 Flow in % of Rating**	**Total # of Violations**	**N-1 Flow in MVA**	**N-1 Flow in % of Rating**	**Total # of Violations**	**N-1 Contingency Outage From Bus To Bus**
70395 SMOKYHIL 115 70521 PEAKVIEW 115 1	LN	IREA	186.6	184.9	99.1	2	190.9	102.3	3	70513 HOMESTEA 230 70524 SULPHUR 230 1
70545 BRICKCTR 230 70546 BRICKCTR 115 T1	TR	PSCo	168	167.3	99.6	0	177.5	105.6	2	70343 QUINCY 230 70545 BRICKCTR 230 1
73015 B.CK TRI 115 73016 B.CK TRI 230 1	TR	TSG&T	224	253.0	112.9	1	266.3	118.9	1	70397 B.CK PS 115 73020 BEAVERCK 115 1
73015 B.CK TRI 115 73020 BEAVERCK 115 1	LN	TSG&T	200	239.9	119.9	1	252.8	126.4	1	70397 B.CK PS 115 73020 BEAVERCK 115 1

C. Dynamic and Transient Stability Study Data & Results

Table 8 – Monitored Buses for Transient Voltage Dip Evaluation

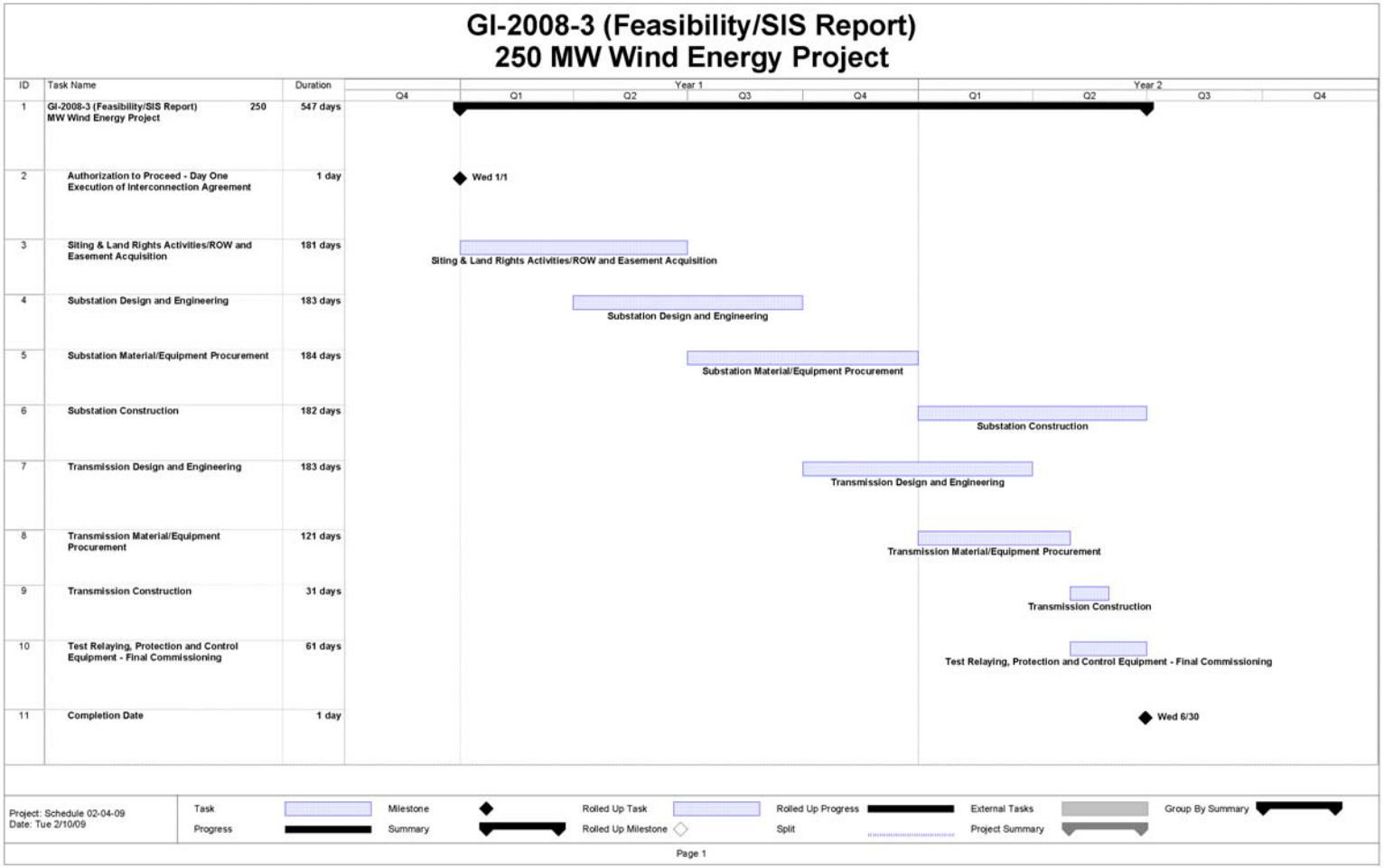
Bus #	Bus Name	Nominal Bus Voltage	Bus #	Bus Name	Nominal Bus Voltage
500	MISSILE	230.0	70311	PAWNEE	230.0
70192	FTLUPTON	230.0	70545	BRICKCTR	230.0
70546	BRICKCTR	115.0	70547	BENNET	115.0
70416	STRASBRG	115.0	70343	QUINCY	230.0
70396	SMOKYHIL	230.0	70046	BUCKLY34	230.0
70491	TOLGATE	230.0	70239	JEWELL2	230.0
70260	LEETSDAL	230.0	70067	BUCKLY12	230.0
70512	JEWELL1	230.0	70417	SULLIVN	230.0
70528	SPRUCE	230.0	70532	POWHATON	230.0
70283	MEADOWHL	230.0	70395	SMOKYHIL	115.0
70162	EAST	115.0	70537	FITZSMNS	115.0
70538	CHAM48TH	115.0	70521	PEAKVIEW	115.0
70515	DAVIDSON	115.0	70516	PONDERSA	115.0
70581	GRNDVIEW	115.0	70517	PARKERPS	115.0
70518	BAYOU	115.0	70523	SULPHUR	115.0
70551	MURPHY	230.0	70513	HOMESTEA	230.0
70524	SULPHUR	230.0	70533	LEMON	230.0
70284	SURREYRG	230.0	70139	DANIELPK	230.0
70138	DANIELPK	115.0	70278	MARCY	230.0
70323	PRAIRIE2	230.0	70331	PRAIRIE	230.0
70427	TARRYALL	230.0	70601	DANIELPK	345.0
70527	SANTEFE	230.0	70115	HPCYN	115.0
70117	CROWFOOT	115.0	73192	STORY	230.0

Table 9 – Summary Listing of Dynamic & Transient Stability Study Contingencies & Results

Case #	Fault Type	Fault Location	Tripped Facility	Additional Tripped Facility	Stability Results	Transient Voltage Dip Criteria	
						Bus	Lowest Transient Voltage Dip (pu)
100	3ph	Missile Site 230 kV	Missile Site-Daniels Park 230kV	N/A	Stable	BRICKCTR 230 kV	0.9491
101	3ph	Missile Site 230 kV	Missile Site-Pawnee 230 kV	N/A	Stable	MISSILE 230 kV	0.9572
102	3ph	Missile Site 230 kV	Missile Site-GI-2008-03 230 kV	NA	Stable	SULPHER 230 kV	0.9758
110	3ph	Pawnee 230 kV	Pawnee-Missile Site 230 kV	N/A	Stable	MISSILE 230 kV	0.9682
111	3ph	Pawnee 230 kV	Pawnee-Story 230 kV	N/A	Stable	SULPHER 230 kV	0.9715
112	3ph	Pawnee 230 kV	Pawnee-Peetz Logan 230 kV	N/A	Stable	SULPHER 230 kV	0.9698
113	3ph	Pawnee 230 kV	Pawnee Unit 1 GSU	N/A	Stable	TARRYALL 230 kV	0.9612
114	3ph	Pawnee 230 kV	Pawnee-Manchief 230 kV	N/A	Stable	SULPHER 230 kV	0.9679
210	slg w/ BF	Pawnee 230 kV	Pawnee-Manchief 230 kV	Pawnee-Brick Center 230 kV	Stable	MISSILE 230 kV	0.9374
211	slg w/ BF	Pawnee 230 kV	Pawnee-Story 230 kV	Pawnee-Missile Site 230 kV	Unstable	N/A	N/A
211_BM*	slg w/ BF	Pawnee 230 kV	Pawnee-Story 230 kV	Pawnee-Missile Site 230 kV	Unstable	N/A	N/A

*Benchmark Case

C. Project Schedule



D. Proposed Interconnection Station One-line