

# **Interconnection System Impact Study Report Request # GI-2006-3**

## **600 MW Coal Fired Facility in Morgan County, Colorado**

Xcel Energy Transmission Planning  
April 9, 2007

### **Executive Summary**

PSCo Transmission received a generation request to determine the feasibility and system impact of interconnecting 600 MW of new Customer coal fired generation into the PSCo transmission system at the Pawnee Station 230 kV bus. The Customer proposed commercial operation date is May 31, 2013 with an assumed back feed date of May 31, 2011. This request was studied as both an Energy Resource (ER)<sup>1</sup> and a Network Resource (NR)<sup>2</sup>. The request was studied as a stand-alone project and considering other projects in the PSCo Generation Request queue<sup>3</sup> specifically, GI-2006-1 and GI-2006-2.

### **Stand Alone Results**

#### **Energy Resource:**

The ER portion of this study determined that the Customer could not provide any firm energy without the construction of network reinforcements. This determination is based on existing limitations due to the limitation on the lines out of Pawnee. Non-firm transmission capability may be available depending on marketing activities, dispatch patterns, demand levels and the status of transmission facilities.

#### **Network Resource:**

As a NR request, PSCo evaluated the network to determine the upgrades required to deliver the full 600 MW of the coal-fired facility to PSCo native load customers. Two alternatives have been recommended.

### **Alternative 1**

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<sup>1</sup> **Energy Resource Interconnection Service (ER Interconnection Service)** shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or nonfirm capacity of the Transmission Provider's Transmission System on an as available basis. Energy Resource Interconnection Service in and of itself does not convey transmission service.

<sup>2</sup> **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.

<sup>3</sup> [http://www.rmao.com/wtpp/psco\\_studies.html](http://www.rmao.com/wtpp/psco_studies.html)



The total estimated cost of the recommended system upgrades to accommodate the project for Alternative 1 is approximately **\$88.12** million and includes:

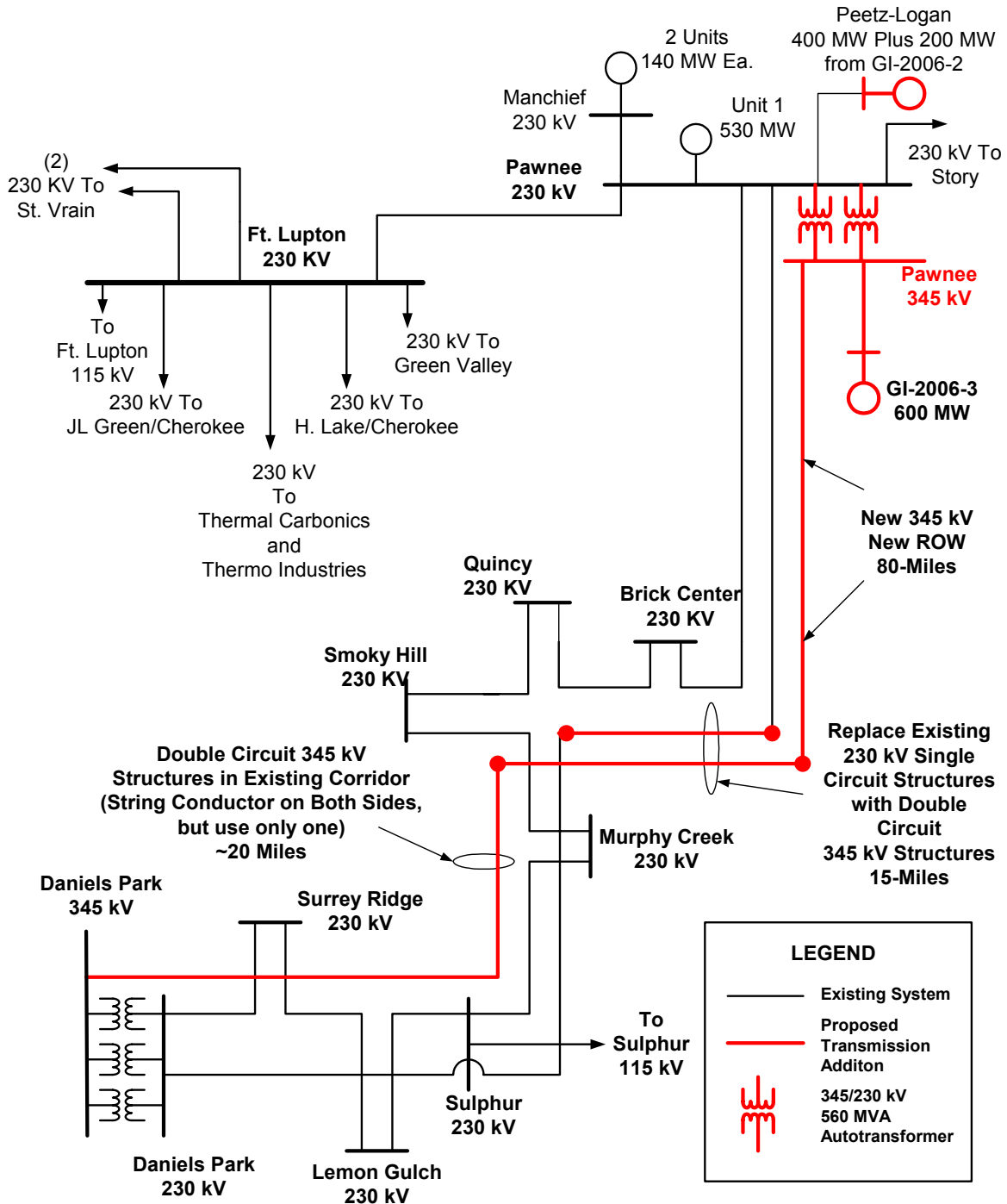
- \$ 0.80 million for PSCo-Owned, Customer Funded Interconnection Facilities
- \$7.58 million for PSCo Network Upgrades for Interconnection
- \$79.74 million for PSCo Network Upgrades for Delivery

These basic upgrades including interconnection as shown in Figure 1 would consist of:

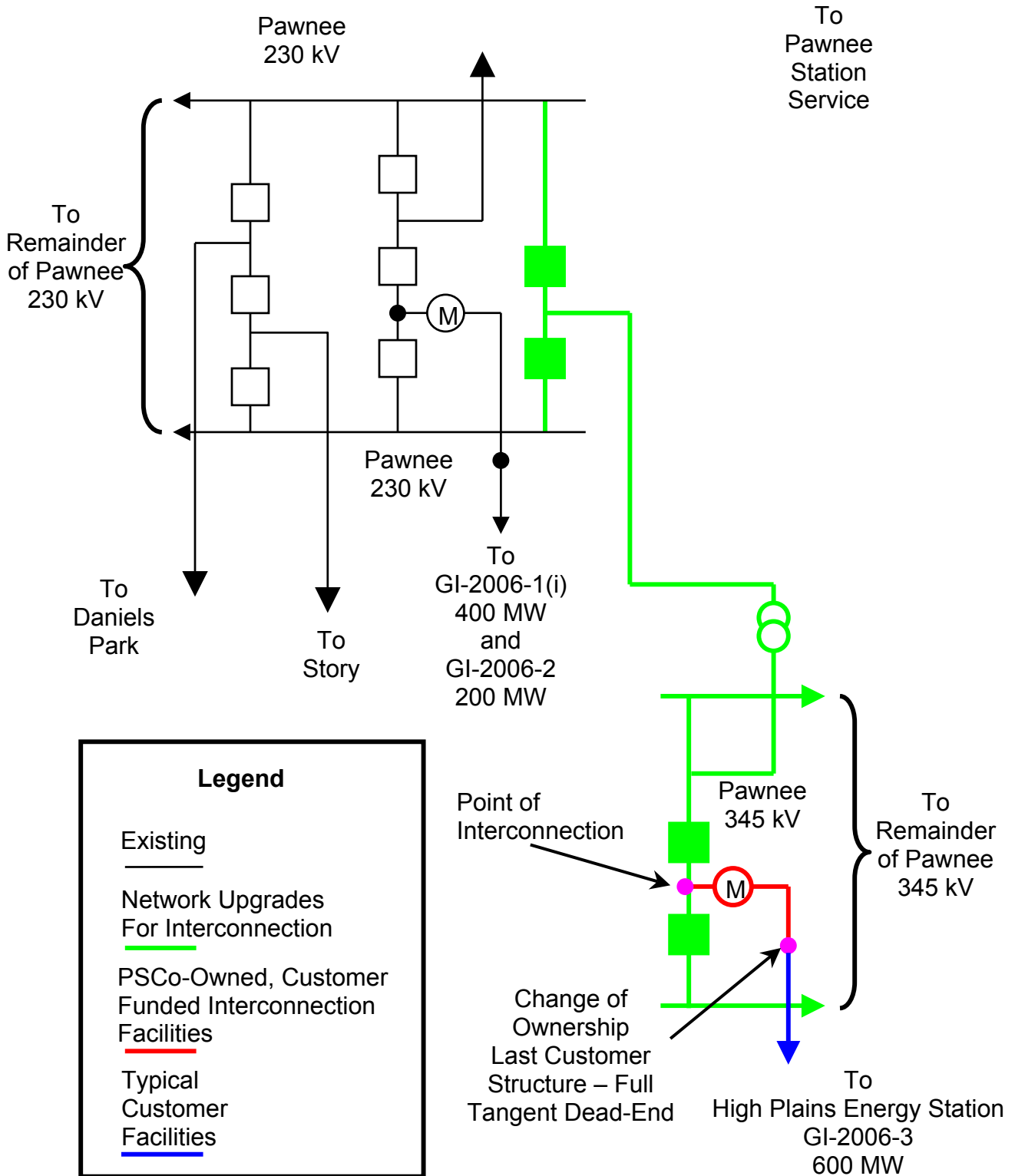
- Constructing a new 115-mile 345 kV line from Pawnee to Daniels Park Substation. The new transmission can be described in three sections:
  - The first section consists of 80-miles of new 345 kV single circuit steel structures in new right of way from Pawnee and then join the existing PSCo transmission corridor near Brick Center Substation
  - Replace 15-miles of an existing single circuit line between Brick Center and Smoky Hill (part of the Pawnee-Daniels Park 230 kV line) with double circuit 345 kV capable structures. One side will operate at 230 kV to maintain the existing circuit. The other side will operate at 345 kV and make up the second section.
  - The final (third) section consists of constructing 20 miles of new 345 kV transmission from Smoky Hill to Daniels Park.
- Two 345/230 kV autotransformers at Pawnee
- One new 345 kV line termination at Daniels Park

A partial one-line of Pawnee Station detailing the Interconnection is shown in Figure 2.

**Figure 1- Alternative 1 Transmission Network with Recommended Upgrades for Delivery**



**Figure 2: Pawnee Station One-line with Interconnection of GI-2006-3**



The estimated time required to engineer, permit, and construct all the required PSCo facilities for interconnection is estimated to be at least 36 months. The estimated time required to engineer, permit, and construct the Network Upgrade facilities for delivery is at least 60 months. According to the interconnection request, the Customer will engineer, permit, construct, and finance the 20-mile 345 kV transmission line to Pawnee Station.

### **Alternative 2**

The total estimated cost of the recommended system upgrades to accommodate the project for Alternative 2 is approximately **\$111.41** million and includes:

- \$ 0.80 million for PSCo-Owned, Customer Funded Interconnection Facilities
- \$7.58 million for PSCo Network Upgrades for Interconnection
- \$103.03 million for PSCo Network Upgrades for Delivery

These basic upgrades including interconnection as shown in Figure 3 would consist of:

- Converting the existing 115-mile 230 kV line from Pawnee to Daniel Park Substation from 230 kV operation to 345 kV operation and converting the existing 80-mile 230 kV line from Pawnee to Brick Center Substation from 230 kV operation to 345 kV operation. This can be described in four sections:
  - The first section would re-insulate and reconductor 80 miles of the existing Pawnee to Brick Center 230 kV line and the parallel Pawnee to Daniels Park 230 kV line for 345 kV operation.
  - The second section would require rebuilding 15-miles of single circuit wood structures with double circuit 345 kV structures from Brick Center to just outside of Smoky Hill that currently make up the a portion of the Pawnee-Daniels Park 230 kV line.
  - The third section would require rebuilding 15-miles of single circuit wood structures and rebuild with double circuit 345 kV structures operated at 230 kV from Brick Center to just outside of Smoky Hill that currently make up the a portion of the Brick Center to Quincy/Smoky Hill 230 kV line. One circuit to continue on to Smoky Hill and the other to connect to the current double circuit structure that hold the existing Pawnee-Daniels Park 230 kV line making a Brick Center to Daniels Park 230 kV line
  - The fourth and final section requires constructing 20 miles of new double circuit 345 kV structures from just outside of Smoky Hill to Daniels Park utilizing the existing vacant corridor.
- Three 345/230 kV autotransformers at Pawnee
- Two 345/230 kV autotransformers at Brick Center and associated 230 kV yard expansion.
- Two 345 kV line terminations at Brick Center
- One New 230 kV line termination at Brick Center
- Two New 345 kV line terminations at Daniels Park

The Interconnection requirements for Alternate 2 would be the same as Figure 2.



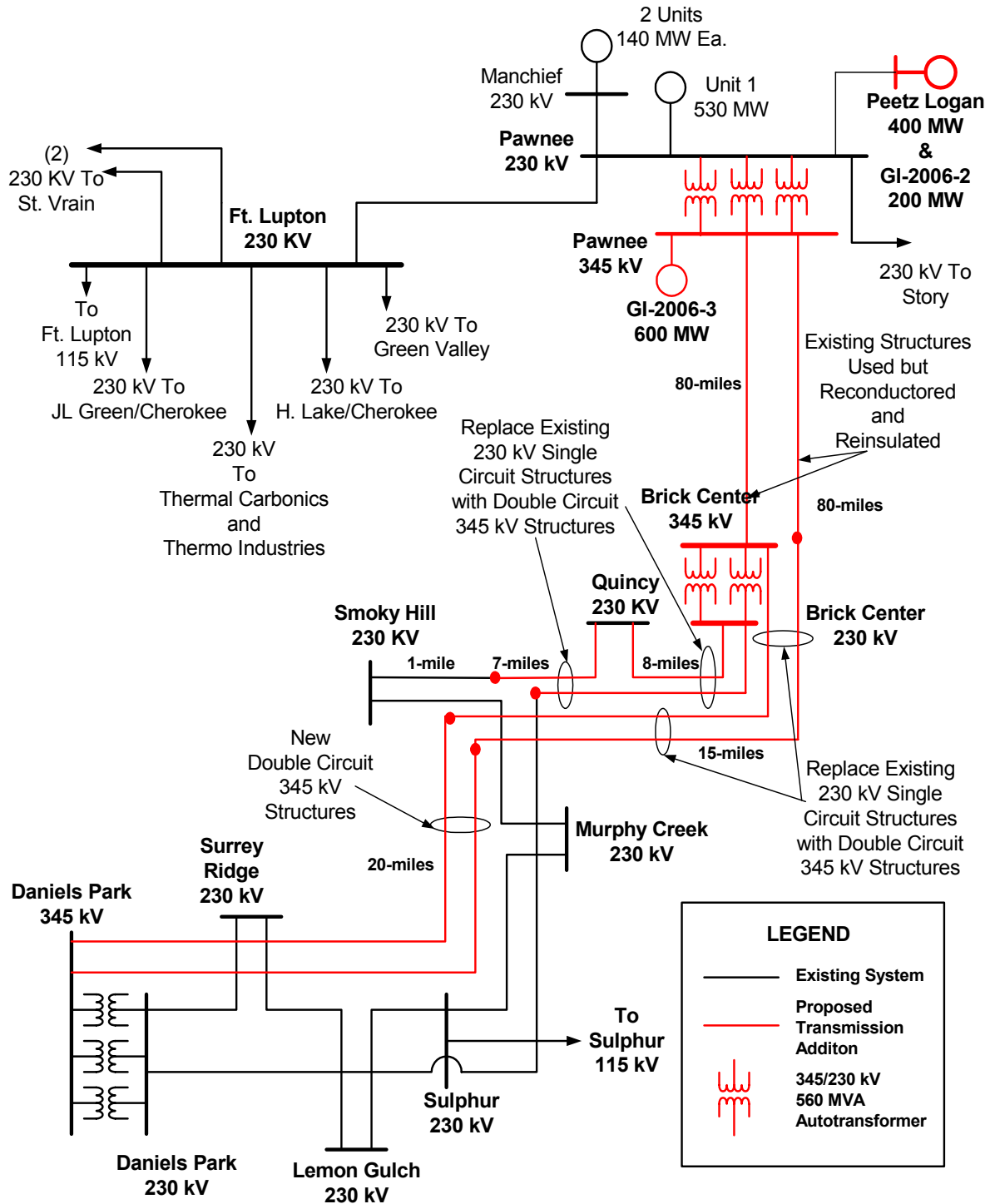
The estimated time required to engineer, permit, and construct all the required PSCo facilities for interconnection is estimated to be at least 36 months. The estimated time required to engineer, permit, and construct the Network Upgrade facilities for delivery is at least 60 months. According to the interconnection request, the Customer will engineer, permit, construct, and finance the 20-mile 345 kV transmission line to Pawnee Station.

### **Considering Other Requests**

The PSCo system can accept the full output of GI-2006-3. When considering other requests in the PSCo Generation Interconnection Request Queue specifically GI-2006-1 and GI-2006-2, and the Network Upgrades required for full delivery of these projects, no additional upgrades are required.

Additional details of the studies can be found under the Power Flow and Stability Study sections.

**Figure 3 Alternative 2 Transmission Network with Recommended Upgrades for Delivery**



## **Study Scope and Analysis**

The Interconnection System Impact Study evaluated the transmission requirements associated with the proposed interconnection to the PSCo Transmission System. It consisted of power flow, short circuit, and dynamic stability analyses. The power flow analysis provided a preliminary identification of any thermal or voltage limit violations resulting for the interconnection, and for a NR request, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified any circuit breaker short circuit capability limits exceeded as a result of the Interconnection and for a NR request, the delivery of the proposed generation to PSCo loads. The dynamic stability analysis identified any limitations due to angular instability of the system for regional disturbances

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 nominal / 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 1.03 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 to 1.10 per-unit, and power flows within 1.0 per-unit of the elements continuous thermal ratings.

## **Study Models**

The power flow studies were based on a 2013 power flow case that was developed from the approved Western Electricity Coordinating Council (WECC) 2011 heavy summer base model. The loads were adjusted in the Rocky Mountain Region for the 2013 summer time frame. The Customer's 600 MW coal-fired unit was modeled with Customer provided details and a +/-0.95 per unit (p.u.) power factor capability to simulate required VAR output. The project generation was dispatched to replace southern PSCo generation.

The Point of Interconnection (POI) between the Customer and PSCo is assumed to be the point at which the 20-mile transmission line meets the Pawnee Substation bus. The 20-mile line was modeled using typical PSCo 345 kV steel pole construction. with a two conductor bundled 954 ASCR conductor per phase. For the 345 kV interconnection, typical GSU transformer impedances were used for the Customer's equipment.

To evaluate the capabilities and system requirements for firm transfer levels, the power flow model was modified to simulate high TOT 3 path flows. Efforts were made to include in the models all transmission projects expected to be in service for the 2013 heavy summer season. The studies assumed 2013 peak summer demand conditions in the PSCo system and in other utility systems.

## **Power Flow Study Results and Conclusions**

### **Energy Resource (ER) Study Results**

The results of the ER study indicate that there is no available delivery capacity from Pawnee Station; therefore the ER is zero MW. Non-firm transmission capability may be available depending on marketing activities, dispatch patterns, demand levels, and the status of transmission facilities.

### **Network Resource (NR) Study Results**

The NR study determined the network upgrades that would be required to accept the full 600 MW from the proposed generating plant for the conditions studied. At 600 MW of generation from the Customer, there were a number of contingency overloads. Appendix A shows the most significant contingencies and the associated overloads along with results from the benchmark case and with the Network Upgrades.

Studies indicated that if either of the proposed alternatives for Network Upgrades for Delivery are implemented for this project, there are no significant impacts to the neighboring utilities or to the TOT 3 transmission path.

### **Short Circuit Study Results**

Once the Customer's generator is installed along with the network upgrades for delivery fault studies were performed.

#### **Alternative 1**

The fault current at the Pawnee 345 kV bus is 9 kA for a single line to ground (SLG) fault and 8.6 kA for a 3-phase fault. At the 230 kV bus, the fault current is 20 kA for a SLG fault and 19.2 kA for a 3-phase fault.

These values are within all circuit breaker interrupting ratings.

#### **Alternative #2**

The fault current at the Pawnee 345 kV bus is 13.5 kA for SLG faults and 13.7 kA for 3-phase faults. At the 230 kV bus, the fault current is 21.9 kA for a SLG fault and 20.9 kA for a 3-phase fault.

The fault study also examined faults at Brick Center and Daniels Park, which determined that all values are within all circuit breaker interrupting ratings.

### **Dynamic Stability Analysis**

Transient stability analyses were performed by modeling three-phase fault contingencies in the region of study. Dynamic models for the proposed project were prepared using Customer supplied data. The analysis indicated the system is stable before, during, and after contingencies once network upgrades were implemented.



The GI-2006-3 machine models for the dynamics analysis used the Customer provided data, except for the Power System Stabilizer (PSS), which was disabled for the analysis. Using the PSS information as provided resulted in undamped oscillations of power and voltage on numerous PSCo generators as well as the Customer's generator. Should the Customer proceed with the interconnection process, further studies with the PSS will be required to fine-tune the PSS to prevent the undamped oscillations.

The results show that the transient stability of the region is not affected by proposed project.

Tables showing the results can be found in Appendix B.

### **Costs Estimates and Assumptions**

#### **Alternative 1**

The estimated total cost for the required upgrades for Alternative 1 is **\$88,120,000**.

The estimated costs shown are "indicative", or "scoping" (+/-30%) estimates in 2007 dollars and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the engineering, design, and construction of these new PSCo facilities. This estimate does not include any costs for any Customer-owned, supplied, and installed equipment and associated design and engineering. This estimate also does not include any costs that may be required for other entities' systems. 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.

The estimated costs for interconnection are detailed in Tables 1 and Table 2. The customer is responsible for the construction of the 20-mile transmission line from the generating station location to the point of interconnection at Pawnee Station. PSCo has not estimated this cost. Table 3 shows the detailed costs for Network Upgrades required for Firm Delivery.

**Table 1 – PSCo Owned Customer Funded Interconnection Facilities**

Element	Description	Cost Est. Millions
<b>Pawnee Station</b>	Interconnect Customer to tap PSCo's new 345 kV bus. The new equipment includes 345 kV bi-directional metering, relaying and associated equipment and material.	<b>\$0.43</b>
	Transmission tie line into Pawnee Station.	<b>\$0.21</b>
	Customer Generator Communication to Lookout	<b>\$0.12</b>
	Customer Generator Witness Testing	<b>\$0.02</b>
	Siting and Land Rights for required easements, reports, permits and licenses.	<b>\$0.02</b>
<b>Total Cost Estimate for Customer Interconnection Facilities</b>		<b>\$0.80</b>

**Table 2 – PSCo Network Upgrades for Interconnection**

Element	Description	Cost Est. Millions
<b>Pawnee Station</b>	Interconnect Customer's 345 kV line into new 345 kV Yard and tying the 345 kV yard into the existing 230 kV yard. The new equipment required includes: <ul style="list-style-type: none"> <li>• Two new 345 kV 2000 A, 40 kA circuit breakers</li> <li>• Two 230 kV 3000 A, 40 kA, circuit breakers</li> <li>• One 345/230 kV 560 MVA autotransformer</li> <li>• Eight 345 kV switches</li> <li>• Four 230 kV switches</li> <li>• transmission line relaying and testing</li> <li>• required steel supporting structures and foundations</li> </ul>	<b>\$7.49</b>
<b>Lookout Center</b>	Communications with Plant	<b>\$0.09</b>
<b>Total Cost Estimate for PSCo Network Upgrades for Interconnection</b>		<b>\$7.58</b>
<b>Time Frame</b>		<b>36 Months</b>

**Table 3 – PSCo Network Upgrades for Delivery – Alternative 1**

Element	Description	Cost Est. Millions
<b>Pawnee Station</b>	New 345 kV Line terminal to Daniels Park requiring the following equipment: <ul style="list-style-type: none"> <li>• One 345 kV, 2000 Amp, 40 kA circuit breaker</li> <li>• One 345/230 kV 560 MVA autotransformer</li> <li>• Two 345 kV 2000 Amp gang switches</li> <li>• Two 230 kV 3000 Amp, 50 kA circuit breakers</li> <li>• Four 230 kV 3000 Amp gang switches</li> <li>• required steel and foundations</li> <li>• electrical bus work</li> <li>• metering, control, relaying and testing</li> </ul>	<b>\$5.92</b>

<b>Element</b>	<b>Description</b>	<b>Cost Est. Millions</b>
<b>Daniels Park</b>	New 345 kV Line Terminal to Pawnee. The following equipment will be required: <ul style="list-style-type: none"> <li>• Two 345 kV 3000 Amp 50 kA circuit breakers</li> <li>• Six 345 kV 2000 Amp gang switches</li> <li>• required supporting steel and foundations</li> <li>• electrical bus work</li> <li>• metering, control, relaying, and testing</li> </ul>	<b>\$1.76</b>
<b>Transmission</b>	Add a new single circuit 345 kV line from Pawnee -Daniels Park. This includes: <ul style="list-style-type: none"> <li>• Single Circuit 345 kV from Pawnee to just outside of Brick Center Switching Station including new ROW (80 -Miles).</li> <li>• Rebuild existing Pawnee-Daniels Park single circuit 230 kV line from Brick Center to outside of Smoky Hill (15-miles) to double circuit 345 kV line One side operated at 345 and the other operated at 230 kV for the Pawnee-Daniels Park line.</li> <li>• Construct new double circuit 345 kV line from just outside of Smoky Hill to Daniels Park utilizing existing ROW (20-miles). String both sides of double circuit tower.</li> </ul>	<b>\$66.49</b>
<b>Siting and Permitting</b>	Obtain necessary siting, permits, and ROW as required	<b>\$5.57</b>
	<b>Total Cost Estimate for PSCo Network Upgrades for Delivery</b>	<b>\$79.74</b>
	<b>Total Cost of Project</b>	<b>\$88.12</b>
<b>Time Frame</b>		<b>60 Months</b>

## Alternative 2

The estimated total cost for the required upgrades for Alternative 2 is **\$111,410, 000**.

The estimated costs shown are “indicative”, or “scoping” (+/-30%) estimates in 2007 dollars and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the engineering, design, and construction of these new PSCo facilities. This estimate does not include any costs for any Customer-owned, supplied, and installed equipment and associated design and engineering. This estimate also does not include any costs that may be required for other entities’ systems. 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.

The estimated costs for interconnection are detailed in Table 4 and Table 5. The customer is responsible for the construction of the 20-mile transmission line from the generating station location to the point of interconnection at Pawnee Station. PSCo

has not estimated this cost. Table 6 shows the detailed costs for Network Upgrades required for Firm Delivery.

**Table 4 – Customer Interconnection Facilities**

Element	Description	Cost Est. Millions
<b>Pawnee Station</b>	Interconnect Customer to tap PSCo's new 345 kV bus. The new equipment includes 345 kV bi-directional metering, relaying and associated equipment and material.	<b>\$0.43</b>
	Customer Generator Communication to Lookout	<b>\$0.21</b>
	Customer Generator Witness Testing	<b>\$0.12</b>
	Generator Testing	<b>\$0.02</b>
	Siting and Land Rights for required easements, reports, permits and licenses.	<b>\$0.02</b>
	<b>Total Cost Estimate for Customer Interconnection Facilities</b>	<b>\$0.80</b>

**Table 5 – PSCo Network Upgrades for Interconnection**

Element	Description	Cost Est. Millions
<b>Pawnee Station</b>	Interconnect Customer's 345 kV line into new 345 kV Yard and tying the 345 kV yard into the existing 230 kV yard. The new equipment required includes: <ul style="list-style-type: none"> <li>• Two new 345 kV 2000 A, 40 kA circuit breakers</li> <li>• Two 230 kV 3000 A, 40 kA, circuit breakers</li> <li>• One 345/230 kV 560 MVA autotransformer</li> <li>• Eight 345 kV 2000 Amp gang switches</li> <li>• Four 230 kV 3000 Amp gang switches</li> <li>• transmission line relaying and testing</li> <li>• required steel supporting structures and foundations</li> </ul>	<b>\$7.49</b>
<b>Lookout Center</b>		<b>\$0.09</b>
	<b>Total Cost Estimate for PSCo Network Upgrades for Interconnection</b>	<b>\$7.58</b>
<b>Time Frame</b>		<b>36 Months</b>

**Table 6 – PSCo Network Upgrades for Delivery – Alternative 2**

Element	Description	Cost Est. Millions
<b>Pawnee Station</b>	New 345 kV Line terminals to Daniels Park and Brick Center requiring the following equipment: <ul style="list-style-type: none"> <li>• Six 345 kV, 2000 Amp, 40 kA circuit breakers</li> <li>• Two 345/230 kV 560 MVA autotransformers</li> <li>• Eight 345 kV 2000 Amp gang switches</li> <li>• required steel and foundations</li> <li>• electrical bus work</li> <li>• metering, control, relaying and testing</li> </ul>	<b>\$13.47</b>

Element	Description	Cost Est. Millions
<b>Daniels Park</b>	New 345 kV Line Terminal to Pawnee. The following equipment will be required: <ul style="list-style-type: none"> <li>• Three 345 kV 3000 Amp 50 kA circuit breakers</li> <li>• Six 345 kV 2000 Amp gang switches</li> <li>• misc. supporting steel and foundations</li> <li>• electrical bus work</li> <li>• associated metering control, relaying and testing</li> </ul>	<b>\$2.51</b>
<b>Brick Center Substation</b>	New 345 kV Yard with 230 kV yard expansion including two line terminals, one each to Daniels Park and Pawnee. This includes the following equipment: <ul style="list-style-type: none"> <li>• Six 345 kV 3000 Amp 50 kA circuit breakers</li> <li>• Two 345/230 kV 560 MVA autotransformers</li> <li>• Fourteen 345 kV 2000 Amp, gang switches</li> <li>• Five 230 kV 3000 Amp, 50 kA circuit breakers</li> <li>• Eleven 230 kV gang switches</li> <li>• associated steel and foundations</li> <li>• associated metering, control, relaying and testing</li> <li>• electrical bus work</li> </ul>	<b>\$18.82</b>
<b>Transmission</b>	Converting the existing 115-mile 230 kV line from Pawnee to Daniel Park Substation from 230 kV operation to 345 kV operation and converting the existing 80-mile 230 kV line from Pawnee to Brick Center Substation from 230 kV operation to 345 kV operation by reinsulating and reconductoring 80 miles of the existing Pawnee to Brick Center 230 kV line and the parallel Pawnee to Daniels Park 230 kV line for 345 kV operation.	<b>\$21.68</b>
	Rebuild 15-miles of single circuit wood structures with double circuit 345 kV structures from Brick Center to just outside of Smoky Hill that currently make up the a portion of the Pawnee-Daniels Park 230 kV line and continue for 20 additional miles on existing corridor to Daniels Park for a total of 35 miles of new 345 kV double circuit towers.	<b>\$27.33</b>
	Rebuild 15-miles of single circuit wood structures with double circuit 345 kV structures operated at 230 kV from Brick Center to just outside of Smoky Hill that currently make up the a portion of the Brick Center to Quincy/Smoky Hill 230 kV line. One circuit to continue on to Smoky Hill and the other to connect to the current double circuit structure that hold the existing Pawnee-Daniels Park 230 kV line making a Brick Center to Daniels Park 230 kV line	<b>\$14.88</b>
<b>Siting and Permitting</b>	Obtain necessary siting, permits, and ROW as required	<b>\$4.34</b>
	<b>Total Cost Estimate for PSCo Network Upgrades for Delivery</b>	<b>\$103.03</b>
	<b>Total Cost of Project</b>	<b>\$111.41</b>
<b>Time Frame</b>		<b>60 Months</b>

### **Assumptions for Alternatives**

- The cost estimates provided are “scoping estimates” with an accuracy of +/- 30%.
- Estimates are based on **2007** dollars.
- PSCo (or it’s Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- The estimated time for design and construction of PSCo network upgrades for interconnection at the Pawnee Station is at least 60 months, and is completely independent of other queued projects and their respective ISD’s.
- It is anticipated that in order to construct the PSCo network upgrades for delivery, a Certificate of Public Convenience and Necessity (CPCN) will be required by the Colorado Public Utilities Commission (CPUC). The application for a CPCN will not be submitted until the Interconnection Agreement is fully executed. The estimated time frame for the CPCN process, siting, permitting, easement and right-of-way acquisition, design and construction for the PSCo network upgrades is at least 28 months from the time the Interconnection Agreement is fully executed. This time frame is also based on other identified assumptions for Siting and Land Rights, Substation Engineering and Transmission Engineering as listed below.
- Implementation of the recommended infrastructure for delivery will require that existing facilities be taken out of service for sustained periods. In most cases, these outages cannot be taken during peak load periods due to operational constraints. As a result, the estimated time frame for implementation could be increased by 3-6 months.
- The Customer will be responsible for funding and constructing approximately 20 miles of transmission line from the proposed generating station to the point of interconnection (Pawnee Station).
- The last span into Pawnee Station from the Customer owned 345 kV line will be a slack span between the PSCo substation dead-end and the Customer’s last structure, which is assumed to be a dead-end tangent structure.
- A siting study will be required if network upgrades for delivery. Extensive public involvement is anticipated. Permit applications and possible minor right-of-way acquisition will be required. Land use permits will be required from multiple local jurisdictions.

# Appendix A

## Contingency Results

**Table 7: Contingency Analysis Details**

	ALTERNATIVE #		1	2	Contingency
	Rating	w/o HPEC	Pawnee - Daniels Park, Pawnee-Smoky Hills	Pawnee - Daniels Park, Pawnee-DP, Pawnee-Brick- DP	
Overloaded Branches					
California - North 542 115	137.0	85.2			Cherokee - Lacombe 230
Cherokee - Conoco 115	134.8	89.6			Cherokee - Lacombe 230
Daniel Park 230/115	150.0	97.9	112.4	115.8	Parker PS - Bayou 115
Denver Terminal - Elati 230	440.0				Pawnee - Brick Center 230
Ft Lupton 230/115	280.0	99.7			Valmont - Spindle 230
Ft Lupton - JL Green 230	495.0	96.4	102.9		Ft Lupton - Henry Lake 230
Pawnee - Keenesberg 345	960.0				Pawnee - Brick Center 230
Smoky Hill - Peakview 115	186.6	90.7	102.1	101.6	Smoky Hills - Murphy 230
Smoky Hill - Murphy 230	340.0	79.0			Smoky Hills - Peakview 115
Washington - JL Green 230	495.0	92.6			Ft Lupton - Henry Lake 230
Homestead - Sulphur 230	340.0	71.2			Smoky Hills - Peakview 115
Homestead - Murphy 230	340.0	78.2			Smoky Hills - Peakview 115
Brick Center 345/230	560.0	n/a		128.4	Brick Center - Smoky Hill 345
Brick Center 230/115	200.0	114.5			Quincy - Brick Center 231
Pawnee - Brick Center 345	1200.0	n/a		106.4	Daniels Park - Pawnee 345
Silver Saddle - Reunion 230	326.0	102.4			Ft Lupton-JL Green 230
Archer - Cheyenne 115	80.0				Ft Lupton - Pawnee 230
Archer - Stegall 230	442.0	109.4	113.9	113.7	Ault - LRS 345

Note: Peetz Logan total generation at 600 MW

With added Story - Beaver Creek 230 kV line plus Kiowa, Outback and Canterbury 230 kV

With Peetz Logan - Pawnee impedance data revised

## **Appendix B**

### **Dynamic Stability Results**

**Table 8: Transient Stability Results – Bench Mark Case before GI-2006-3**

	<b>Fault Location</b>	<b>Action</b>	<b>Result</b>
1	3PH at Pawnee 230 kV bus; 4 cycles	Trip Pawnee-Daniels Park 230 kV line	System Stable
2	3PH at Daniels Park 230 kV bus, 4 cycles	Trip Pawnee-Daniels Park 230 kV line	System Stable
3	3PH at Pawnee 230 kV bus; 4 cycles	Trip Pawnee–Brick Center 230 kV line	System Stable
4	3PH at Brick Center 230 kV bus, 4 cycles	Trip Pawnee – Brick Center 230 kV line	System Stable
5	3PH at Pawnee 230 kV bus; 4 cycles	Trip Pawnee–Ft. Lupton 230 kV line	System Stable
6	3PH at Ft. Lupton 230 kV bus, 4 cycles	Trip Pawnee – Ft. Lupton 230 kV line	System Stable
7	3PH at Pawnee 230 kV bus; 4 cycles	Trip Pawnee–Story 230 kV line	System Stable
8	3PH at Story 230 kV bus; 4 cycles	Trip Pawnee–Story 230 kV line	System Stable
9	3PH at Story 230 kV bus; 4 cycles	Trip Story 345/230 kV transformer	System Stable
10	3PH at Daniels Park 345 kV bus; 3 cycles	Trip Daniels Park - Comanche 345 kV line	System Stable
11	3PH at LRS 345 kV bus; 3 cycles	Trip LRS–Story 345 kV line	System Stable
12	3PH at LRS 345 kV bus; 3 cycles	Trip LRS–Ault 345 kV line	System Stable

**Table 2: Transient Stability Results – Case with GI-2006-2 and GI-2006-3 and Alternative #1 and Alternative #2 Network Upgrades for Delivery**

<b>#</b>	<b>Fault Location</b>	<b>Action</b>	<b>Result Alternative #1</b>	<b>Result Alternative #2</b>
1	3PH at Pawnee 230 kV bus; 4 cycles	Trip Pawnee-Daniels Park 230 kV line	System Stable	System Stable
2	3PH at Daniels Park 230 kV bus, 4 cycles	Trip Pawnee-Daniels Park 230 kV line	System Stable	System Stable
3	3PH at Pawnee 230 kV bus; 4 cycles	Trip Pawnee–Brick Center 230 kV line	System Stable	System Stable
4	3PH at Brick Center 230 kV bus, 4 cycles	Trip Pawnee – Brick Center 230 kV line	System Stable	System Stable
5	3PH at Pawnee 230 kV bus; 4 cycles	Trip Pawnee–Ft. Lupton 230 kV line	System Stable	System Stable
6	3PH at Ft. Lupton 230 kV bus, 4 cycles	Trip Pawnee – Ft. Lupton 230 kV line	System Stable	System Stable
7	3PH at Pawnee 230 kV bus; 4 cycles	Trip Pawnee–Story 230 kV line	System Stable	System Stable
8	3PH at Story 230 kV bus; 4 cycles	Trip Pawnee–Story 230 kV line	System Stable	System Stable
9	3PH at Story 230 kV bus; 4 cycles	Trip Story 345/230 kV transformer	System Stable	System Stable
10	3PH at Daniels Park	Trip Daniels Park -	System Stable	System Stable

#	Fault Location	Action	Result Alternative #1	Result Alternative #2
	345 kV bus; 3 cycles	Comanche 345 kV line		
11	3PH at LRS 345 kV bus; 3 cycles	Trip LRS–Story 345 kV line	System Stable	System Stable
12	3PH at LRS 345 kV bus; 3 cycles	Trip LRS–Ault 345 kV line	System Stable	System Stable
13	3PH at Pawnee 345 kV bus; 3 cycles	Trip Pawnee-Daniels Park 345 kV line	System Stable	System Stable
14	3PH at Daniels Park 345 kV bus, 3 cycles	Trip Pawnee-Daniels Park 345 kV line	System Stable	System Stable
15	3PH at Pawnee 345 kV bus; 3 cycles	Trip Pawnee 345/230 kV transformer	System Stable	System Stable
16	3PH at Pawnee 230 kV bus; 3 cycles	Trip Pawnee 345/230 kV transformer	System Stable	System Stable
17	3PH at Pawnee 345 kV bus; 3 cycles	Trip Pawnee – Brick Center 345 kV line	NA	System Stable
18	3PH at Brick Center 345 kV bus; 3 cycles	Trip Brick Center – Daniels Park 345 kV line	NA	System Stable