Interconnection System Impact Study Report
Request # NQ-2014-1
Final Draft

50 MW Solar Photovoltaic Generating Facility
Various Locations, Colorado

Public Service Company of Colorado
Transmission Planning
May 1, 2015

Executive Summary

Public Service Company of Colorado (PSCO) signed a System Impact Study Agreement for a 50 MW solar photovoltaic location study on February 18, 2014 that was assigned NQ-2014-1 as the study number. The objective of the study was to determine the impact of a proposed 50 MW solar generator on the transmission system at several locations on the PSCO transmission system. The expected in-service date (ISD) for NQ-2014-1 is within the 2015-2016 timeframe.

This request was studied as a stand-alone generator interconnection project that excluded any other new generation requests in the PSCO Generator Interconnection Request queue (excluding generator interconnection projects with planned in-service dates by the summer of 2014). The main purpose of this System Impact Study was to evaluate the potential impact on PSCO's interconnected transmission system and its neighboring utilities (the affected parties) due to an additional 50 MW of generation injected into the system. In addition, a sensitivity study was conducted assuming a 30 MW generation injection. It should be noted that PSCO evaluated the capacity adequacy of the transmission system only up to the Point of Interconnection (POI). The study assumed that the Interconnection Customer is responsible for ensuring that the interconnecting line from the generator to the POI is adequately rated for the proposed 50 MW generation. The nine generation locations included in the study are listed below:

Location	Voltage (kV)
Comanche	230
San Luis Valley	115
Hartsel	230
Cameo	230
Rifle	230
Unitah	230
Collbran	138
Poncha	230
Hayden	230

The study results indicate that five of the nine generation locations have negligible system impact with the injection levels of 50 MW or 30 MW. The remaining four locations (Poncha, Comanche, San Luis Valley, and Hayden) have an appreciable system impact with the 50 MW injection level while Hayden also has an appreciable system impact at the 30 MW injection level – thus each of them may need some mitigation. The system impacts associated with these four locations could be mitigated with planned transmission project(s) or by utilizing operating procedure(s). Therefore, based on both the results of this study and the distance to PSCO load centers, the following generation injection locations are recommended for further consideration. Once an individual location has been determined a subsequent generator interconnection study will be required.

1. **Hartsel 230 kV**
2. **Cameo 230 kV**
3. **Rifle 230 kV**
4. **Uintah 230 kV**
5. **Collbran 138 kV**

In 2016 when transmission could be complete, this study recommends the remaining generating injection locations for further consideration:

6. **Poncha 230 kV**
7. **Comanche 230 kV**
8. **San Luis Valley 115 kV**
9. **Hayden 230 kV**

It should be noted that previous interconnection studies focused entirely at San Luis Valley have resulted in lesser injection capabilities than shown in this report. For example, the Feasibility Study Report for GI-2014-11 has shown that 50 MW rated output at San Luis Valley 230 kV bus does not qualify for Network Resource Interconnection Service (NRIS). The difference in study results can be attributed to GI-2014-11 including Light Spring sensitivity cases which is outside the scope of this NQ-2014-1 study. The Feasibility Study Report for GI-2014-11 is posted on PSCo's OASIS website[1] and should be reviewed before pursuing a solar PV generator at San Luis Valley.

It should also be noted that, due to its interconnected nature, a generation injection at one location on the transmission system generally changes the injection capability at other locations. The generation injection capability results provided in this report are based on stand-alone transmission studies. Therefore, the generation injection capability values can and will change when Public Service Company of Colorado

[1] http://www.rmao.com/wtpp/PSCO_Transmission_Studies.html

(PSCO) performs additional specific resource portfolio studies or generator interconnection studies pursuant to the Open Access Transmission Tariff (OATT).

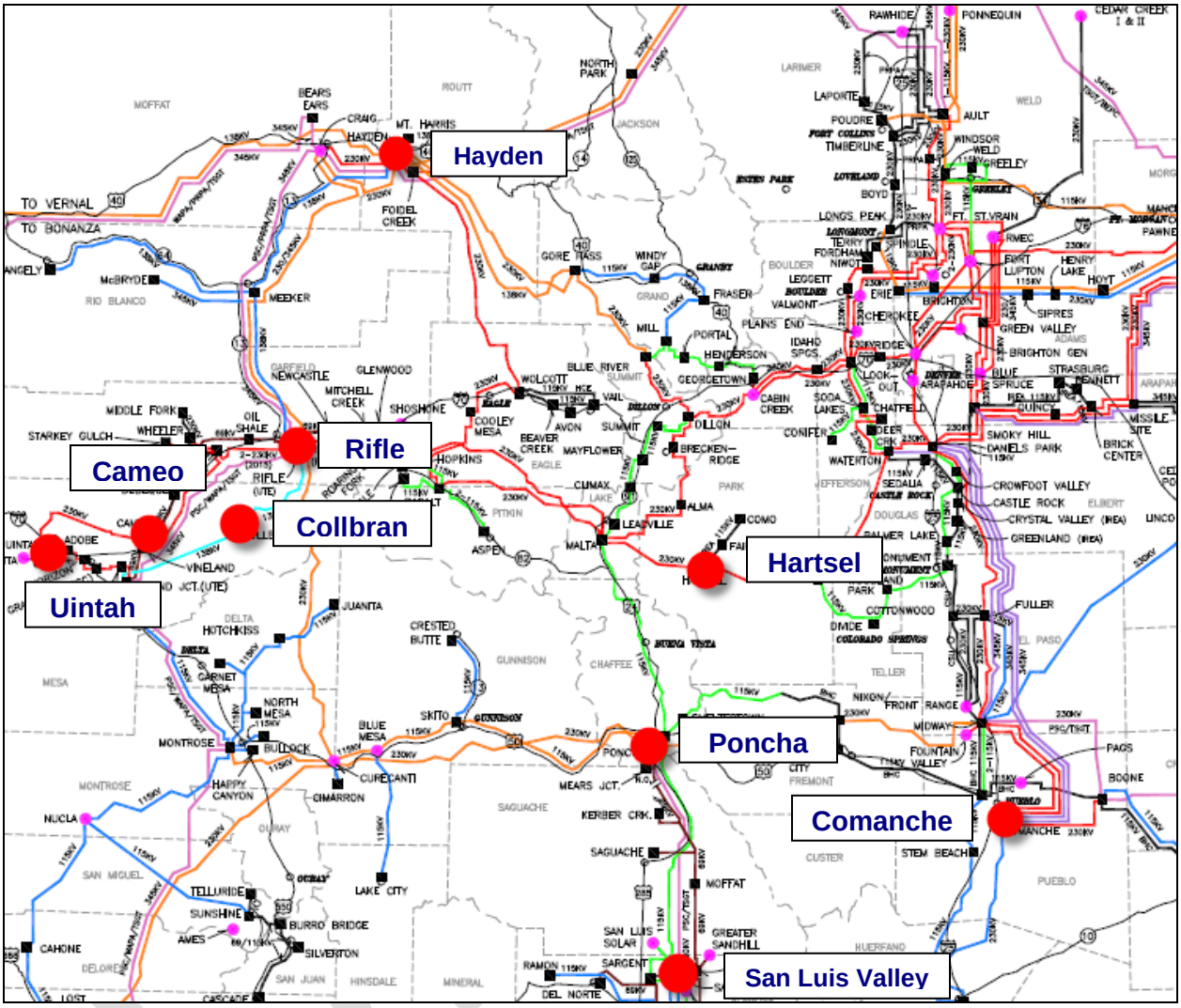

Figure 1: Solar Injection Locations

Introduction

Public Service Company of Colorado (PSCO) signed a System Impact Study Agreement for a 50 MW solar photovoltaic location study on February 18, 2014 that was assigned NQ-2014-1 as the study number. The objective of the study was to determine the impact of a proposed 50 MW solar generator on the transmission system at several locations on the PSCO transmission system. The expected in-service date (ISD) for NQ-2014-1 is within the 2015-2016 timeframe.

Study Scope and Analysis

The System Impact Study evaluated the transmission impacts associated with the proposed solar generation facility. The study consisted of a single contingency (N-1) power flow analysis. The power flow analysis identified thermal and voltage limit violations resulting from the installation of the proposed generation.

PSCO adheres to NERC & WECC Reliability Criteria, as well as internal company criteria for planning studies. During system intact conditions, PSCO's 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. Operationally, PSCO attempts to maintain a transmission system voltage profile ranging from 1.02 per unit or higher at regulating (generation) buses to 1.0 per unit or higher at transmission load buses. Following a single contingency, transmission system steady state bus voltages must remain within 0.90 per unit to 1.05 per unit, and power flows within 100% of the facilities' continuous thermal ratings. Also, voltage deviations should not exceed 5%.

Devices that can automatically adjust in response to contingency events were allowed to adjust during outage simulations. These may include automatic shunt capacitors or reactors, phase shifting transformers and load tap changing (LTC) transformers. Manual system adjustments such as generation dispatch levels were not allowed. Area interchange adjustments were also not allowed.

The substation locations that were analyzed to accommodate up to 50 MW of new generation are on the PSCO transmission system in Colorado, and listed below.

Location	Voltage (kV)
Comanche	230
San Luis Valley	115
Hartsel	230
Cameo	230
Rifle	230
Unitah	230
Collbran	138
Poncha	230
Hayden	230

The System Impact Study results indicate that there are affected parties due to the system impact of NQ-2014-1. Affected parties include Tri-State Generation & Transmission (TSGT) and Colorado Springs Utilities (CSU).

Power Flow Study Models

The NQ-2014-1 System Impact Study Agreement stated the study will use a WECC approved 2014 heavy summer operating case and the base case will be modified to accommodate a 50 MW injection at various locations by sinking load in the Denver Metro area. However, the customer later requested a later year base case which included planned projects and generation in the Comanche and San Luis Valley area. Therefore, the power flow study was based on the WECC approved 17HS1AP_r32 case. PSCo loads in the case were adjusted to reflect the most recent (April 2013) PSCo load forecast. IREA load was also adjusted to reflect IREA's latest load forecast (November 2013). The topology was also updated to reflect current project plans. Updates were included for the PSCo, IREA, CSU, TSG&T, WAPA, PRPA, BHE, and BEPC systems.

The base case assumes a TOT-5 major path flow (west-east) of 650 MW. To assess impact of generation addition to the Pueblo area system generation dispatch was adjusted to create a south to north flow on the transmission system south of Denver Metro. The base case was modified to accommodate 50 MW injections at various locations by sinking to load in the Denver Metro area. The study includes steady state power flow analyses for the benchmark case (before NQ-2014-1) and the study cases (after the NQ-2014-1 generator injections are included).

Generator and DC tie levels were assumed as follows:

Generator or DC tie	Capacity (MW)	Net output (MW)
Comanche Units 1-2	725	660
Comanche Unit 3	804	766
Comanche PV	120	120
Fountain Valley Units 1-6	240	240
Jackson Fuller Units 1-2	250	200
San Luis Valley Unit 1	50	50
Limon I, II, & III	600	137
CO Green & Twin Buttes Units	97	75
Lamar DC tie	200	25
Manchief Units 1-2	280	0
Spruce Units 1-2	280	0
Plains End Units 0-9	55	0
Ft. St. Vrain Units 5-7	555	0
Valmont Units 6-8	127	0
Craig Units 1-3	1,374	1,355
Hayden Units 1-2	98	498

Power Flow Study Process

Contingency power flow studies were completed on the reference models and the models with the proposed new generation using Siemens PTI PSSE Ver. 33.4 software program. Results from each of the cases were compared and new overloads or overloads that increased significantly in the new generation case were noted. Voltage criteria violations were also recorded. PSSE's ACCC analysis module was used to perform the power flow contingency analysis. Area 70 (PSCO) and Area 73 (WAPA R.M.) were used for contingency files (single branches and tie-lines). Monitored elements included branches and ties in Areas 70 and 73.

Power Flow Results

The results in Table 1 show the percent loading of lines following various contingencies for the projected 2017 on-peak summer system[2] or "status quo" as well as the projected system after the individual addition of the nine 50 MW injection points. Table 2 shows similar loading with a reduced injection of 30 MW at each location. The results show both pre-existing and post-injection overloaded elements. For easier viewing, some cells are highlighted in yellow. Yellow cells indicate differential percent loading greater than one percent. Cells with no highlight indicate a differential loading less than one percent which is assumed within the tolerance of the study and has little to no effect on the element.

The results listed in Table 1 indicate that the largest differential impact is due to a 50 MW injection at Hayden 230 kV substation. The injection creates an overload on the Meeker-Ute Rifle 138 kV line following the loss of the Craig-Meeker 345 kV line. The rating of the Meeker-Ute Rifle 138 kV line is limited by substation equipment at Ute Rifle. PSCO is planning a project to remove the limiting elements on this line but an in-service date has not been set at this time.

Differential impacts are also shown due to the 50 MW injection at Poncha 230 kV, San Luis Valley 115 kV, and Comanche 230 kV substations. These injection points create an overload on the Cottonwood-Briargate and Cottonwood-Kettle Creek 115 kV lines following the loss of the other line. PSCO has identified mitigation options plans to address these potential overloads. Therefore, the implemented mitigation option may even be adequate for a solar generator of 50 MW installed at Poncha, San Luis Valley, and Comanche– however, this may need to be further evaluated for the proposed generation's in-service date. .

The locations that cause no differential impact greater than one percent are Hartsel 230 kV, Cameo 230 kV, Rifle 230 kV, Uintah 230 kV, and Collbran 138 kV substations.

[2] The study results are presumed valid for the 2014 heavy summer on-peak period as represented in the WECC "14hs4a" power flow operating case at a TOT5 major path flow (west-east) of 530 MW.

A sensitivity study was conducted that considered injecting 30 MW of solar generation at each location to determine the impact of a reduced solar injection level. The results of the 30 MW injection study are shown in Table 2. The overloaded contingency flows near Kettle Creek that result from injecting generation at Poncha, San Luis Valley, and Comanche at 50 MW have been removed by reducing the generation to 30 MW. Loading concerns remain on TSGT's Meeker-Ute Rifle 138kV line following the loss of the Craig-Meeker 345 kV line. There are no other locations that cause differential contingency loading greater than one percent.

No new violations of the voltage limit criteria (0.90 p.u. - 1.05 p.u.) or the voltage deviation criteria (< 5%) were caused in PSCO's interconnected transmission system due to the addition of NQ-2014-1 generating facilities. Based on the results of the 50 and 30 MW injection analyses, Hartsel**,** Cameo, Rifle Ute, Uintah, and Collbran are desirable locations due to causing negligible system impact on the existing transmission system for either injection level. Poncha, Comanche, and San Luis Valley are also desirable locations at the lower 30 MW injection level or at the 50 MW level once the mitigation identified for overloads inthe Colorado Springs Utilities system is in-service. Hayden substation may also be desirable at both 50 MW and 30 MW injection levels once limiting substation equipment has been removed at Rifle Ute.

Based on both the results of the study and the distance to PSCO load centers, the following generation injection locations are recommended for further consideration. Once an individual location has been determined a subsequent generator interconnection study will be required.

10. **Hartsel 230 kV**
11. **Cameo 230 kV**
12. **Rifle 230 kV**
13. **Uintah 230 kV**
14. **Collbran 138 kV**

In 2016 when transmission could be complete, this study recommends the remaining generating injection locations for further consideration:

15. **Poncha**
16. **Comanche**
17. **San Luis Valley**
18. **Hayden**

It should be noted that previous interconnection studies focused entirely at San Luis Valley have resulted in lesser injection capabilities than shown in this report. For example, the Feasibility Study Report for GI-2014-11 has shown that 50 MW rated output at San Luis Valley 230 kV bus does not qualify for Network Resource Interconnection Service (NRIS). The difference in study results can be attributed to GI-2014-11 including Light Spring sensitivity cases which is outside the scope of this NQ-2014-1 study. The Feasibility Study Report for GI-2014-11 is posted on PSCo's OASIS

website[3] and should be reviewed before pursuing a solar PV generator at San Luis Valley.

It should also be noted that, due to its interconnected nature, a generation injection at one location on the transmission system generally changes the injection capability at other locations. The generation injection capability results provided in this report are based on stand-alone transmission studies. Therefore, the generation injection capability values can and will change when Public Service Company of Colorado (PSCO) performs additional specific resource portfolio studies or generator interconnection studies pursuant to the Open Access Transmission Tariff (OATT).

[3] http://www.rmao.com/wtpp/PSCO_Transmission_Studies.html

Xcel Energy

Power Flow N-1 Contingency Analysis Results

Table 1: Power flow results with 50 MW injection

Monitored Facility (Line or Transformer)	Owner	Summer Normal (Continuous) Facility Rating MVA	N-1 Percent Loading of Summer Normal Rating										N-1 Contingency Outage
			Status Quo	Hartsel	Cameo	Rifle Ute	Uintah	Collbran	Hayden	Poncha	Comanche	San Luis Valley	
Meeker - Ute Rifle 138 kV Line	TSGT	126	106.5%	105.7%	101.7%	102.0%	102.0%	97.0%	108.2%	104.9%	106.1%	104.9%	Craig-Meeker 345 kV Line
Cottonwood-Briargate 115 kV Line	CSU	162	114.1%	113.3%	114.2%	114.2%	114.3%	114.3%	114.1%	115.1%	115.5%	115.1%	Cottonwood-Kettle Creek 115 kV Line
Cottonwood-Kettle Creek 115 kV Line	CSU	150	113.4%	112.6%	113.6%	113.6%	113.6%	113.6%	113.5%	114.5%	114.9%	114.5%	Cottonwood-Briargate 115 kV Line

Table 2: Power flow results with 30 MW injection

Monitored Facility (Line or Transformer)	Owner	Summer Normal (Continuous) Facility Rating MVA	N-1 Percent Loading of Summer Normal Rating										N-1 Contingency Outage
			Status Quo	Hartsel	Cameo	Rifle Ute	Uintah	Collbran	Hayden	Poncha	Comanche	San Luis Valley	
Meeker - Ute Rifle 138 kV Line	TSGT	126	106.5%	106.0%	103.6%	103.8%	103.8%	100.7%	107.6%	105.6%	106.3%	105.6%	Craig-Meeker 345 kV Line
Cottonwood-Briargate 115 kV Line	CSU	162	114.1%	113.6%	114.2%	114.2%	114.2%	114.2%	114.1%	114.7%	114.9%	114.7%	Cottonwood-Kettle Creek 115 kV Line
Cottonwood-Kettle Creek 115 kV Line	CSU	150	113.4%	112.9%	113.5%	113.5%	113.6%	113.6%	113.5%	114.1%	114.3%	114.1%	Cottonwood-Briargate 115 kV Line