Interconnection Feasibility Study Report
Request # BHCT-G3

200 MW Generator at Airport Tap in Pueblo, Colorado

Black Hills Corporation
Transmission Planning

July 7, 2009
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Executive Summary

Black Hills Corporation received an interconnection request (BHCT-G3) to install a 200 MW gas turbine generator facility near Pueblo, Colorado. The proposed project consists of two (2) 100 MW GE LMS100 gas turbines with a primary Point of Interconnection (POI) at Airport Tap. An alternate POI was requested on the existing Airport Memorial-DOT Tap 115 kV line to a new substation tentatively named Nyberg. The proposed interconnect in-service date is October 1, 2011.

The request was studied as a Network Resource interconnected at both POIs with the full 200 MW rated output with heavy summer loads for the year 2012. Steady-state analysis was performed to evaluate the potential impact of the proposed interconnection on the Black Hills Energy transmission system and identify upgrades required to mitigate any performance criteria violations.

Interconnection Requirements

Based on the results of this study, the proposed 200 MW facility can be interconnected to the 115kV transmission system at the Airport Tap POI with the following system additions and upgrades:

- Expansion of the Airport Tap 115 kV substation by one (1) position.
- Add a second 115 kV circuit on the proposed 115kV line from Airport Tap to West Station.
- Expansion of the West Station 115kV substation by one (1) positions.

These facilities are considered Network Upgrades with an estimated cost of **$6,100,000** and an expected in-service date of eighteen (18) months from the date of a signed interconnection agreement.

Interconnection Requirements – Alternate Location

The proposed 200 MW facility can be interconnected to the 115kV transmission at the alternate Nyberg POI with the following system additions and upgrades:

- A new six (6) position 115kV substation at the alternate POI.
- Build twenty (20) miles of double circuit 115kV line from the POI substation to West Station.
- Expansion the West Station 115kV substation by two (2) positions.

These facilities are considered Network Upgrades with an estimated cost of **$25,460,000** and an expected in-service date of eighteen (18) months from the date of a signed interconnection agreement.

Introduction

Black Hills Corporation received a Large Generator Interconnection request (BHCT-G3) to interconnect a 200 MW gas turbine generator facility near Pueblo, Colorado. The purpose of this Feasibility Study is to evaluate the potential impact on the Black Hills Energy transmission system and identify upgrades required to mitigate any performance criteria violations.

The proposed project consists of two (2) 100 MW GE LMS100 gas turbines with a primary Point of Interconnection (POI) at Airport Tap. An alternate POI, tentatively named Nyberg, was requested on the existing Airport Memorial – DOT Tap 115 kV line, approximately 6.5 miles west of DOT Tap.

Power Flow Study Models

Power flow studies for the proposed interconnection were performed using PSS/E simulation software, version 30.3.3. The base case originated from the WECC approved 13HS1AP base case. This case was updated to include 2012 heavy summer loading and projects with in-service dates prior to the facility in-service date. The included projects, which were determined to have an impact on system performance, included:

- Second Boone 230/115 kV transformer
- Comanche 230/115 kV transformer updates
- LaJunta Tie Project

A proposed new 115 kV line between a new Airport Tap 115 kV substation and the existing West Station 115 kV substation was not included in the base case. This project was not included to allow the study of the primary and alternate POI determine the need for this project.

The 200 MW of generation was dispatched by lowering the generation at Pawnee. The 200 MW facility was modeled as two (2) 100 MW generators. Each machine was modeled with its own 13.8 kV generator terminal bus and 13.8/115 kV step-up transformer with a maximum nameplate capacity of 125 MVA connected to the Airport Tap 115 kV bus. The estimated machine reactive capability curves provided with the application were used to set the reactive capability of each generator. When studying the alternate location, the two 13.8/115 kV step-up transformers connected the generator terminal buses to the Nyberg POI 115 kV substation bus.

Power Flow Analysis

Power flow analysis was used to determine the impacts, if any, of the proposed 200MW of generation on the Black Hills Energy transmission system. The voltage and thermal performance of the system was evaluated with and without the proposed project in-service. Table 1 displays the voltage criteria used in this power flow analysis. Thermal loading on all transmission lines were not allowed to exceed 100% of their normal rating, while thermal loading on transformers were allowed to overload up to 120% as shown in Table 2.

Table 1 Steady-State Voltage Criteria

BHCT-G3 Feasibility Study		
Steady-State Voltage Criteria		
	Acceptable Voltage Range	
Voltage Class	**Pre-Contingency**	**Post-Contingency**
69kV and Above	0.95 to 1.05 p.u.	0.90 to 1.10 p.u

Table 2 Maximum Transformer Overloads

BHCT-G3 Feasibility Study	
Maximum Transformer Overloads	
Maximum Hours at Overload	**Allowable Transformer Overload**
1/2 Hour	153%
1 Hour	135%
2 Hours	120%

The steady state analysis was performed with pre-contingency solution parameters that allowed adjustment of load tap-changing transformers, static VAR devices including switched shunt capacitors and reactors, and DC taps. Post-contingency solution parameters allowed for adjustment of DC taps only. Area interchange control was disabled and generator VAR limits were applied immediately for all solutions. A fixed-slope decoupled Newton solution method was implemented for all cases. Tables 3 and 4 list all of the prior outages and contingencies, respectively.

Table 3 Prior Outages Studied

BHCT-G3 Feasibility Study					
Prior Outages Studied					
PO#	**Prior Outage**	**PO#**	**Prior Outage**	**PO#**	**Prior Outage**
1	Burnt Mill - Freemary 115	16	W. Canon - Ponchbar 230	33	Comanche - Reader 115 #1
2	Burnt Mill - W. Station 115	17	Comanche - MidwayPS #1	34	MidwayPS - Northridge 115
3	Freemary - Reader 115	18	Comanche - Walsenburg 230	35	Boone 230/115 #T1
4	Overton - Apt Tap 115	19	Ftn Valley - Desert Cove 115	36	Comanche 230/115 #T1
5	Overton - Northridge 115	20	Ftn Valley - Midway BR 115	37	Comanche 345/230 #T3
6*	Apt Mem - DOT Tap 115	21	Hyde Park - Pueblo Plant 115	38	MidwayPS 230/115 #T1
6A*	Apt Mem - Nyberg 115	22	Hyde Park - W. Station 115	39	MidwayPS 345/230 #T2
6B*	Nyberg - DOT Tap 115	23	MidwayPS - W. Station 115 #1	40	W.Canon 230/115 #T1
7	Apt Park - Apt Tap 115	24	MidwayPS - MidwayBR 230	41	MidwayBR 230/115 #1
8	Apt Park - Apt Mem 115	25	Portland - Skala 115	42	Apt Gen 100MW #1
9	Boone - DOT Tap 115	26	Portland - W. Station 115	43	Comanche Gen #1
10	Boone - LaJunta W 115	27	Pueblo Plant - Reader 115	44	Comanche Gen #3
11	Boone - Comanche 230	28	Reader - Apt Mem 115	45	Lamar DC
12	Boone - Lamar CO 230 #1	29	Smelter - W. Canon 115	46**	W. Station - Apt Tap 115 #1
13	Boone - MidwayPS 230	30	Desert Cove - W. Station 115	46A**	W. Station - Nyberg 115 #1
14	Canon City - Skala 115	31	DanielPK - Comanche 345 #1		
15	Canon City - W. Canon 115	32	MidwayBR - W. Canon 230		

* PO# 6 was used for studying the system intact case and 200 MW interconnection at Airport Tap. 6A and 6B were used for studying the 200 MW interconnection at Nyberg.

** PO# 46 was used for studying the 200 MW interconnection at Airport Tap and 46A was used for studying the 200 MW interconnection at Nyberg.

Table 4 Contingencies Studied

BHCT-G3 Feasibility Study Contingencies Studied					
#	Contingency	#	Contingency	#	Contingency
1	DANIELPK 345.00-COMANCHE 345.00 #1	32	APT_PARK 115.00-APT_MEM 115.00 #1	63	MIDWAYPS 230.00-MIDWAYPS 345.00 #T2
2	DANIELPK 345.00-COMANCHE 345.00 #2	33	W STATION 115.00-APT TAP 115.00 #1	64	COMANCHE 115.00-COMANCHE 230.00 #T1
3	WALSENBG 230.00-STMBEACH 230.00 #1	34	W STATION 115.00-APT TAP 115.00 #2	65	COMANCHE 115.00-COMANCHE 230.00 #T2
4	BOONE 230.00-COMANCHE 230.00 #1	35	CANONCTY 115.00-SKALA 115.00 #1	66	MIDWAYPS 115.00-MIDWAYPS 230.00 #T1
5	BOONE 230.00-LAMAR_CO 230.00 #1	36	CANONCTY 115.00-W.CANON 115.00 #1	67	W.CANON 115.00-W CANON 230.00 #T1
6	BOONE 230.00-LAMAR_CO 230.00 #2	37	COMANCHE 115.00-READER 115.00 #1	68	BOONE 115.00-BOONE 230.00 #T1
7	BOONE 230.00-MIDWAYPS 230.00 #1	38	COMANCHE 115.00-READER 115.00 #2	69	BOONE 230.00-BOONE 115.00 #T2
8	BOONE 230.00-STMBEACH 230.00 #1	39	BOONE 115.00-LAJUNTAT 115.00 #1	70	WALSENBG 115.00-WALSENBG 230.00 #T2
9	COMANCHE 230.00-MIDWAYPS 230.00 #1	40	BOONE 115.00-LAJUNTAW 115.00 #1	71	WALSENBG 115.00-WALSENBG 230.00 #T3
10	COMANCHE 230.00-MIDWAYPS 230.00 #2	41	HYDEPARK 115.00-PUEBPLNT 115.00 #1	72	STMBEACH 115.00-STMBEACH 230.00 #T1
11	COMANCHE 230.00-WALSENBG 230.00 #1	42	HYDEPARK 115.00-W.STATON 115.00 #1	73	MIDWAYBR 115.00-MIDWAYBR 230.00 #1
12	VILAS 230.00-LAMAR_CO 230.00 #1	43	LAJUNTAT 115.00-LAJUNTAW 115.00 #1	74	RD_NIXON 115.00-RD_NIXON 230.00 #1
13	LAMAR_CO 230.00-LAMAR_DC 230.00 #1	44	LAJUNTAT 115.00-WILOW_CK 115.00 #1	75	LAMAR_CO 115.00-LAMAR_CO 230.00 #T1
14	LAMAR_CO 230.00-CO_GRN 230.00 #1	45	MIDWAYPS 115.00-W.STATON 115.00 #1	76	DESERTCOV - FTN VAL - MIDWAYBR 115.00
15	MIDWAYPS 230.00-MIDWAYBR 230.00 #1	46	PONCHA 115.00-SMELTER 115.00 #1	77	MIDWAYPS - NORTHRIDGE - OVERTON 115.00
16	MIDWAYPS 230.00-FULLER 230.00 #1	47	PONCHA 115.00-N.GUNNSN 115.00 #1	78	BOONE - APT MEM 115.00
17	SANLSVLY 230.00-WALSENBG 230.00 #1	48	PORTLAND 115.00-SKALA 115.00 #1	79	BOONE - NYBERG 115.00
18	SANLSVLY 230.00-PONCHABR 230.00 #1	49	PORTLAND 115.00-W.STATON 115.00 #1	80	NYBERG - APT MEM 115.00 #1
19	MIDWAYBR 230.00-RD_NIXON 230.00 #1	50	PUEB_W 115.00-PUEB_TP 115.00 #1	81	APT TAP - W. STATION 115.00 DOUBLE CIRCUIT
20	MIDWAYBR 230.00-W CANON 230.00 #1	51	PUEB_TP 115.00-STMBEACH 115.00 #1	82	NYBERG - W. STATION 115.00 DOUBLE CIRCUIT
21	RD_NIXON 230.00-KELKER S 230.00 #1	52	PUEB_TP 115.00-W.STATON 115.00 #1	83	NYBERG - W. STATION 115.00 #1
22	RD_NIXON 230.00-FULLER 230.00 #1	53	PUEBPLNT 115.00-READER 115.00 #1	84	NYBERG - W. STATION 115.00 #2
23	RD_NIXON 230.00-FRTRANGE 230.00 #1	54	READER 115.00-APT_MEM 115.00 #1	85	MIDWAY - W.STATION AND MIDWAY NORTHRIDGE 115
24	W CANON 230.00-PONCHABR 230.00 #1	55	AREQUGCH 115.00-W.CANON 115.00 #1	86	AIRPORT GEN #1 - 100MW
25	PONCHABR 230.00-PARLIN 230.00 #1	56	SMELTER 115.00-W.CANON 115.00 #1	87	AIRPORT GEN #2 - 100MW
26	LAMAR_CO 115.00-WILOW_CK 115.00 #1	57	STMBEACH 115.00-WALSENBG 115.00 #1	88	COMANCHE GEN #1
27	BURNTMIL 115.00-FREEMARY 115.00 #1	58	DESRTCOV 115.00-W.STATON 115.00 #1	89	COMANCHE GEN #2
28	BURNTMIL 115.00-W.STATON 115.00 #1	59	W.STATON 115.00-MIDWAYBR 115.00 #1	90	COMANCHE GEN #3
29	FREEMARY 115.00-READER 115.00 #1	60	MIDWAYBR 115.00-RD_NIXON 115.00 #1	91	LAMAR DC
30	OVERTON 115.00-APT_TAP 115.00 #1	61	COMANCHE 230.00-COMANCHE 345.00 #T3		
31	APT_PARK 115.00-APT_TAP 115.00 #1	62	COMANCHE 230.00-COMANCHE 345.00 #T4		

Power Flow Results

Category B and C outages were studied using the methods described above. Table 5 shows Category B violations for the system intact case, 200 MW interconnection at Airport Tap and 200 MW interconnection at Nyberg. Category C violations for the system intact case, 200 MW interconnection at Airport Tap and 200 MW interconnection at Nyberg have not been included in this report due to the large number of violations. Note that this table only shows thermal overloads as the simulations found no relevant voltage violations.

The Category B results showed that the limiting factors for the interconnection at Airport Tap were the Airport Tap – Midway and Airport Tap – Airport Memorial 115kV lines. The limiting factors for interconnecting at the alternate site of Nyberg were the Nyberg – Boone and Nyberg – Airport Memorial 115kV lines.

Based on the power flow results, it was determined that the optimal solution for the 200 MW interconnection at Airport Tap would be to build a new double circuit 115kV line from Airport Tap to West Station. Figure 1 shows the network diagram with the Airport Tap interconnection and the required double circuit 115kV line displayed in pink. With the addition of the 200 MW interconnection at Airport Tap and the Airport Tap – West Station 115kV double circuit line there were no Category B or C violations.

The optimal solution for the 200 MW interconnection at Nyberg would be to build a new double circuit 115kV line from Nyberg to West Station. Figure 2 shows the network diagram with the Nyberg interconnection and the required double circuit 115kV line displayed in pink. With the addition of the 200 MW interconnection at Nyberg and the Nyberg – West Station 115kV double circuit line there were no Category B or C violations.

Table 5 Category B Violations for System Intact and 200MW Interconnections at Airport Tap and Nyberg.

Category B Thermal Overloads - %Ratings					
Overloaded Element	**Rated MVA**	**Outage Description**	**System Intact**	**Airport Tap 200MW**	**Nyberg 200MW**
Hyde Park - Pueblo Plant 115	120	Burnt Mill - Freemary 115	101.1	110.1	109.3
Hyde Park - Pueblo Plant 115	120	Freemary - Reader 115	107.0	115.9	115.0
Hyde Park - Pueblo Plant 115	120	Burnt Mill - W. Station 115	-	104.6	103.8
Hyde Park - W. Station 115	120	Freemary - Reader 115	-	100.8	-
Reader - Pueblo Plant 115	159	Freemary - Reader 115	-	101.0	100.3
Freemary - Reader 115	122	Pueblo Plant - Reader 115	103.3	110.4	109.7
Freemary - Reader 115	122	Hyde Park - Pueblo Plant 115	-	103.5	102.8
Northridge - MidwayPS 115	122	Apt Park - Apt Tap 115	-	125.5	-
Northridge - MidwayPS 115	122	Apt Park - Apt Mem 115	-	105.4	-
Overton - Northridge 115	122	Apt Park - Apt Tap 115	-	153.9	-
Overton - Northridge 115	122	Apt Park - Apt Mem 115	-	133.3	-
Overton - Apt Tap 115	122	Apt Park - Apt Tap 115	-	162.3	-
Overton - Apt Tap 115	122	Apt Park - Apt Mem 115	-	141.7	-
Apt Park - Apt Tap 115	117	Overton - Apt Tap 115	-	171.3	-
Apt Park - Apt Tap 115	117	Overton - MidwayPS 115	-	162.4	-
Apt Park - Apt Tap 115	117	MidwayPS - W. Station 115	-	103.7	-
Apt Park - Apt Tap 115	117	Comanche 230/115 #T1	-	101.3	-
Apt Park - Apt Tap 115	117	Comanche 230/115 #T2	-	101.3	-
Apt Park - Apt Tap 115	117	MidwayPS 230/115	-	105.1	-
Apt Park - Apt Tap 115	117	Lamar DC Tie	-	101.3	-
Apt Park - Apt Tap 115	117	Comanche Gen #1	-	102.6	-
Apt Park - Apt Tap 115	117	Comanche Gen #2	-	102.7	-
Apt Park - Apt Tap 115	117	Comanche Gen #3	-	109.7	-
Apt Park - Apt Tap 115	117	MidwayPS - Midway BR 230	-	102.0	-
Apt Park - Apt Tap 115	117	MidwayBR - RD Nixon 230	-	100.7	-
Apt Park - Apt Mem 115	122	Overton - Apt Tap 115	-	144.7	-
Apt Park - Apt Mem 115	122	Overton - MidwayPS 115	-	136.2	-
Nyberg - Apt Mem 115	122	Boone - MidwayPS 230	-	-	102.8
Nyberg - Apt Mem 115	122	Boone - Stembeach 230	-	-	103.5
Nyberg - Apt Mem 115	122	Boone - Nyberg 115	-	-	164.7
Nyberg - Apt Mem 115	122	Comanche 230/115 #T1	-	-	101.8
Nyberg - Apt Mem 115	122	Comanche 230/115 #T2	-	-	101.8
Nyberg - DOT Tap	122	Nyberg - Apt Mem 115	-	-	166.6
Boone - DOT Tap 115	122	Nyberg - Apt Mem 115	-	-	151.1
Comanche 230/115 #T1	176	Comanche 230/115 #T2	101.1	-	-
Comanche 230/115 #T2	184	Comanche 230/115 #T1	101.1	-	-
Reader - Comanche 115 #1	300	Reader - Comanche #2	106.6	-	-
Reader - Comanche 115 #2	300	Reader - Comanche #1	106.6	-	-

Figure 1 Network Diagram for 200 MW Interconnection Upgrades at Airport Tap 115kV

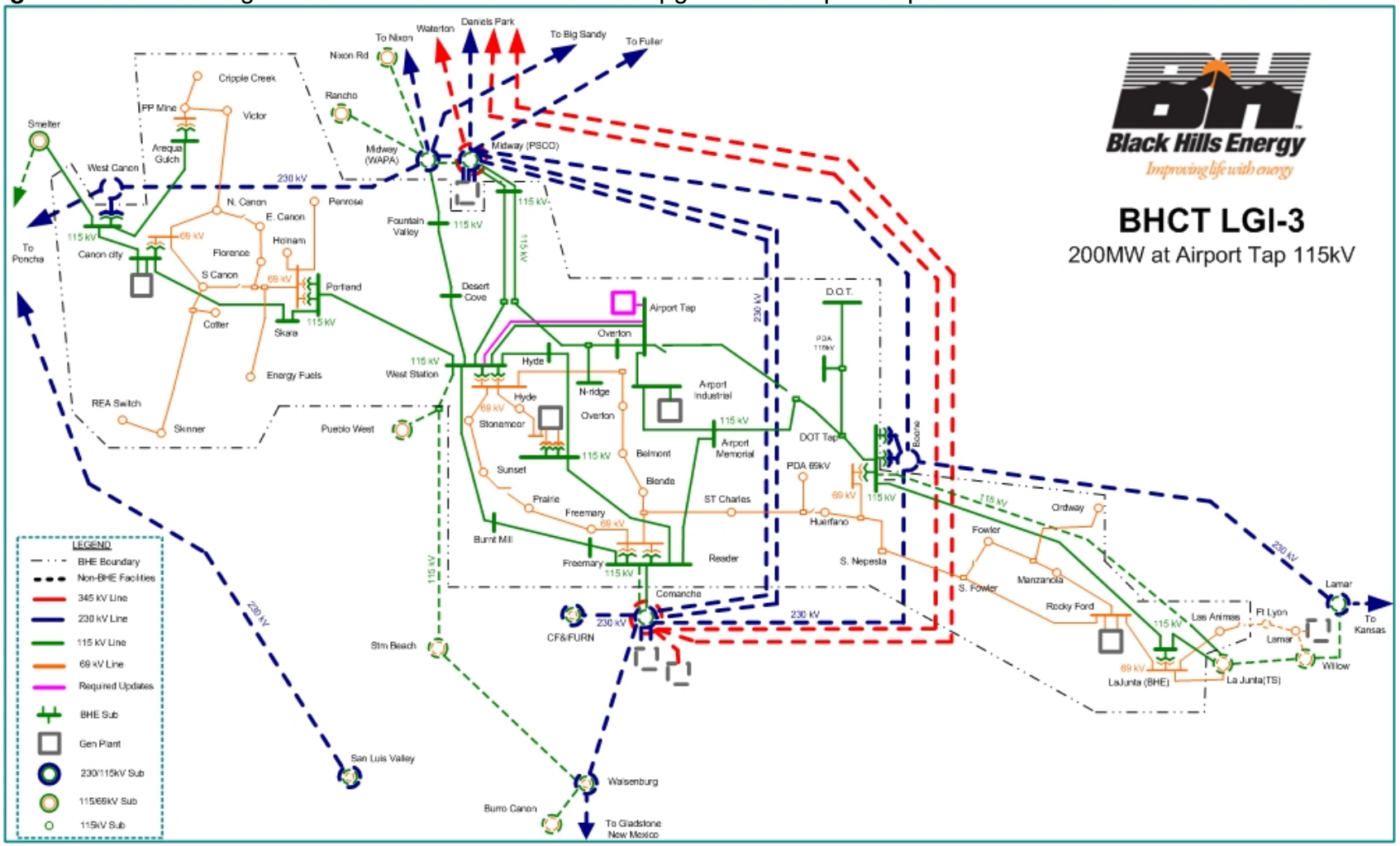
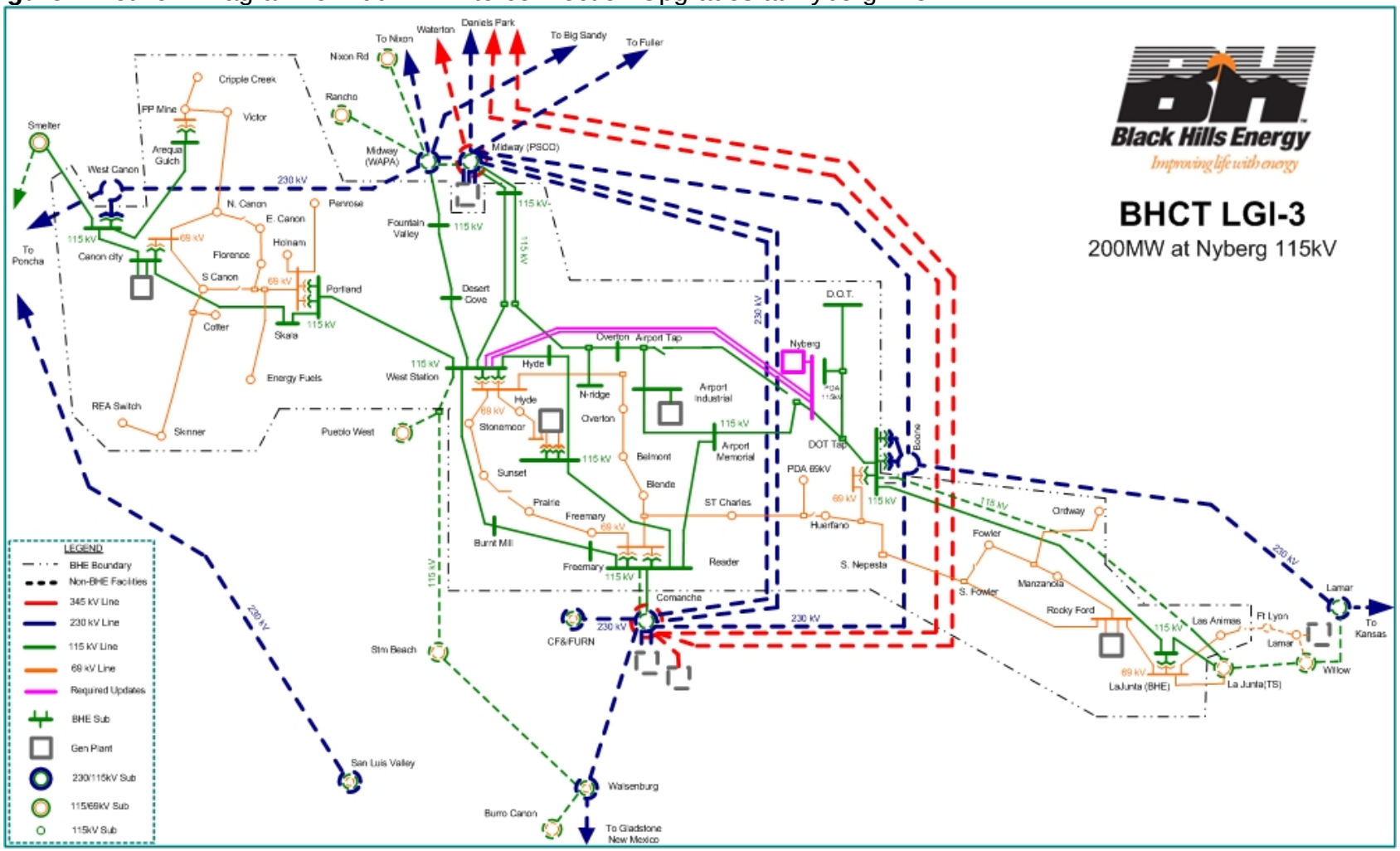


Figure 2 Network Diagram for 200 MW Interconnection Upgrades at Nyberg 115kV



Conclusions

This report describes the power flow studies performed to determine the impacts of interconnecting a 200 MW gas turbine generator facility near Pueblo, Colorado to the Black Hills Energy transmission system at Airport Tap 115kV, as well as the alternate location of Nyberg 115kV.

Based on the power flow simulations, the estimated total cost for the required interconnection at Airport Tap would be **$6,100,000.** These facilities are considered Network Upgrades with an expected in-service date of eighteen (18) months from the date of a signed interconnection agreement. Table 6 lists the required upgrades to accommodate the interconnection of 200MW at Airport Tap 115kV.

Table 6 Upgrade Costs for 200MW Interconnection at Airport Tap 115kV

BHCT-G3 Feasibility Study	
Upgrade Costs for 200MW at Airport Tap 115kV	
Cost in Millions	**Description**
$ 4.40	Add second circuit to the proposed 11 mile 115kV line between Airport Tap and West Station
$ 0.75	Expand Airport Tap 115kV substation (1 positions)
$ 0.95	Expand West Station 115kV substation (1 positions)
$ 6.1	**Total Upgrade Costs**

Based on the power flow simulations, the estimated total cost for the required interconnection at Nyberg would be **$25,460,000.** These facilities are considered Network Upgrades with an expected in-service date of eighteen (18) months from the date of a signed interconnection agreement. Table 7 lists the required upgrades to accommodate the interconnection of 200MW at Nyberg 115kV.

Table 7 Upgrade Costs for 200MW Interconnection at Nyberg 115kV

BHCT-G3 Feasibility Study	
Upgrade Costs for 200MW at Nyberg 115kV	
Cost in Millions	**Description**
$ 16.00	Build 20 miles of double circuit 115kV line from Nyberg to West Station
$ 7.56	New Nyberg 115kV substation (6 positions)
$ 1.90	Expand West Station 115kV substation (2 positions)
$ 25.46	**Total Upgrade Costs**