GENERATOR INTERCONNECTION REQUEST

BHCT-G11
Interconnection System Impact Restudy

PREPARED BY
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TRANSMISSION PLANNING

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Executive Summary

Black Hills Corporation (BHC) conducted a System Impact Study (SIS) in response to the request to provide interconnection service for the proposed generation facility under the guidance of the Black Hills Colorado Transmission (BHCT) Open Access Transmission Tariff Large Generator Interconnection Procedures (LGIP). This section summarizes the SIS results for the BHCT-G11 interconnection request.

Disclaimer

The results of this SIS are highly dependent on the assumed system topology and the timing of projects in the vicinity of the proposed interconnection, which are subject to change. Interconnection Service in and of itself does not convey any right to receive transmission service to any specific customer or Point of Delivery. It should be noted that carrying out the system upgrades identified in this report does not guarantee transmission service for the customer. Transmission Service should be requested through the BHCT OASIS and the request will be granted on a first-come, first serve basis.

Background

A valid interconnection request for the 29 MW project was received from the interconnection customer (IC) on May 25, 2012. The IC elected to forgo the Feasibility Study and proceed with the SIS phase of the LGIP. The proposed project consists of sixteen (16) Vestas V100 wind turbine generators (WTG), and will connect to the Black Hills Colorado Electric (BHCE) 115 kV transmission system at the Rattlesnake Butte substation located at the wind project site in Huerfano County, Colorado. The BHCT-G11 interconnection request represents Phase III of a wind project; (BHCT-G8) was recently put into service for the same IC. The point of interconnection for the BHCT-G8, G10, and G11 interconnection requests will be the 115 kV Rattlesnake Butte substation. The IC requested that the project be evaluated as a Network Resource (NR) as well as an Energy Resource (ER) on the BHCT system. The requested commercial operation date of the project is December 31, 2016.

The study considered the impacts of the interconnection request by reanalyzing the transmission system before and after the interconnection of the proposed project with the recently signed Power Purchase Agreements (PPAs) with PSCo that were not included in the original SIS. The study included steady state and transient stability analysis for the 2016 peak summer with the project evaluated as an ER for a worst case scenario. The study also provided a cost estimate and implementation schedule for suggested system upgrades, if applicable, to accommodate the proposed project.

The criteria applied in this study are consistent with NERC/WECC Reliability Criteria. For more detailed information on the criteria used for each analysis, refer to Section 2.2.

Results

No detrimental impacts to the BHCE and surrounding transmission system were identified as a result of the interconnection of the BHCT-G11 wind generation project.

Conclusions

The 29-MW injection from BHCT-G11 (ER or NR) could be accommodated at the POI with the following required network upgrades:

- New 115 kV terminal position at the BHCE 115 kV Rattlesnake Butte substation

The new 115 kV circuit breaker required for this new terminal will convert the bus configuration from a three breaker ring bus to a four breaker ring bus. In addition to the network upgrades mentioned above, a 5 MVAR shunt reactor at the POI substation will be required of the Interconnection Customer. This requirement is independent and in addition to that required for BHCT-G11 as shown in Figure 3.

The estimated cost of the system upgrades is $1,499,602. The estimated completion time for the system upgrades is approximately 12 months (engineering design/materials procurement/construction & commissioning).

There were transmission loading concerns encountered in the BHCT-G11 analyses that were previously identified and not directly attributed to the BHCT-G11 project. Black Hills is currently developing a plan to address thermal loading issues on the following transmission lines:

- Hyde Park-West Station 115 kV line
- Reader-Pueblo 115 kV line
- Desert Cove-Fountain Valley-Midway 115 kV line

To ensure the BHCT-G11 project can be operated at the requested capacity of 29 MW, the aforementioned projects should be completed to prevent the thermal ratings from being exceeded under contingency conditions. If the previously identified upgrades cannot be completed by the ISD of the BHCT-G11 project, generation curtailments for the proposed project or other operational measures may have to be implemented under planned outage scenarios until the upgrades are complete.

1. Introduction

Black Hills Colorado Electric owns certain transmission facilities with transmission service pursuant to a FERC-approved Open Access Transmission Tariff ("OATT"). A valid request was received from the Interconnection Customer (IC) on May 25, 2012 to provide interconnection service for the proposed generation facility under the guidance of the Black Hills Colorado Transmission OATT Large Generator Interconnection Procedures. The IC elected to forgo the Feasibility Study and proceed with the SIS phase of the LGIP. The proposed project consists of sixteen (16) Vestas V100 wind turbine generators nominally rated at 1.8 MW each, and will connect to the BHCT 115 kV system at the Rattlesnake Butte substation in Huerfano County, Colorado. The IC requested that the project be evaluated as a Network Resource (NR) and an Energy Resource (ER) on the BHCT system. The requested commercial operation date of the project is December 31, 2016.

1.1. Study Scope

The study considered the impacts of the interconnection request by reanalyzing the transmission system before and after the interconnection of the proposed project, assuming planned PSCo generation additions that were not included in the original SIS. The study included steady state and transient stability analysis for the 2016 peak summer with the project evaluated as an ER for a worst case scenario. The study also provided a cost estimate and implementation schedule for suggested system upgrades, if applicable, to accommodate the proposed project.

1.2. Study Area

The study area included all BHCE transmission equipment as well as neighboring transmission system elements roughly bound by Poncha to the west, Walsenburg to the south, Lamar to the east, and Daniels Park to the north. A diagram of the study area is shown in Figure 1. Points of interconnection between BHCE and neighboring utilities are shown in Table 1.

Table 1: BHCE Transmission System Interconnection Points

Interconnection Name	Interconnecting Utility[1]
Midway (PSCo)	PSCo
Midway (WAPA)	WAPA, CSU, TSG&T
Boone	PSCo, TSG&T
Reader	PSCo
Cañon West	WAPA, PSCo
West Station	TSG&T

[1] CSU means Colorado Springs Utilities; WAPA means Western Area Power Administration, PSCo means Public Service Company of Colorado and TSG&T means Tri-State Generation and Transmission Association, Inc.

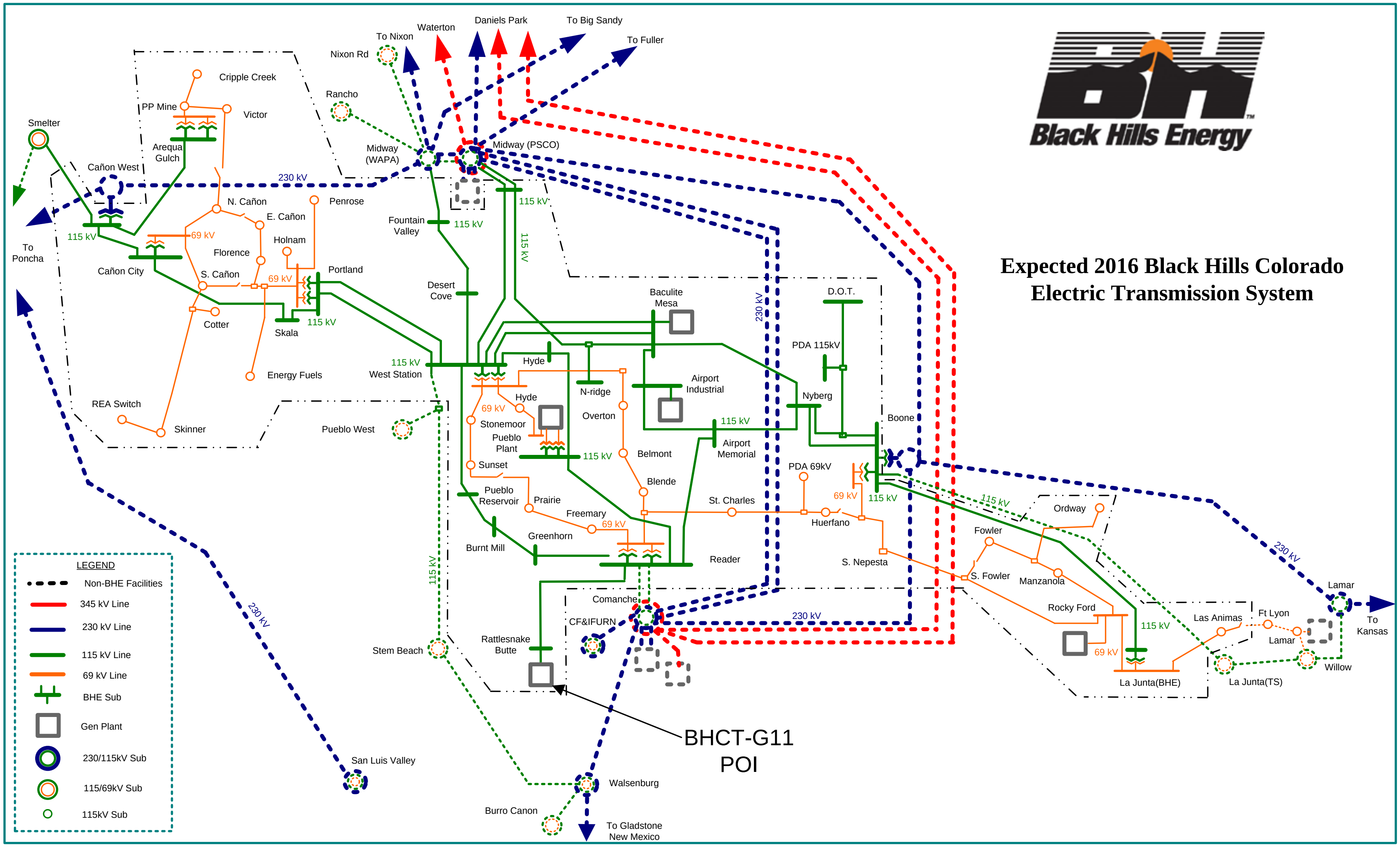

Figure 1: BHCT-G11 SIS Study Area Map

1.3. Benchmark Cases

The 2016 heavy summer study scenario was built from a 15HS case utilized by Tri-State for interconnection studies. The 2015HS case originated from WECC's 15HS3S base case.

Significant changes to the existing Black Hills transmission system to create the 2016 model included projects planned for completion this year and all budgeted projects listed in the most recent version of the BHCE Strategic Plan.

- Baculite Mesa-Overton-Northridge 115 kV rebuild transmission line (ISD 2016)
- Boone-Nyberg 115kV Project (ISD 2015)
- West Station-Desert Cove 115kV Line Rebuild (ISD 2015)
- Portland 115/69kV Transformer Replacement (ISD 2016)

A 90 MW natural-gas-fired turbine was modeled as a sensitivity at PAGS in the 2016 study case to represent the G6 signed interconnection with an in-service date of 2017.

1.4. Project Model

The proposed projects, Phase I (BHCT-G8), Phase II (BHCT-G10) and Phase III (BHCT-G11) were represented in the power flow model as three equivalent WTGs rated at 28.8 MW each, operated with +9.36/-13.07 MVAR capability. Each generator step-up (GSU) transformer increased the voltage from 0.69 kV to 34.5 kV, with an equivalent impedance value of 9.00% with a 10.98 X/R ratio. The high side of each GSU will interconnect to an underground collector system with assumed equivalent impedance of 0.017 + j0.014 per unit, and a susceptance of 0.030 per unit. The equivalent network impedance based upon "WECC Wind Power Plant Power Flow Modeling Guide, May 2008, Table 1 Sample Equivalent Collector System Parameters" was modeled in the absence of design data. A single 115:34.5 kV station transformer rated at 35 MVA was modeled with an impedance value of 7.00% with a 29.52 X/R ratio. This was based upon transformer information supplied by the Consulting Engineers.

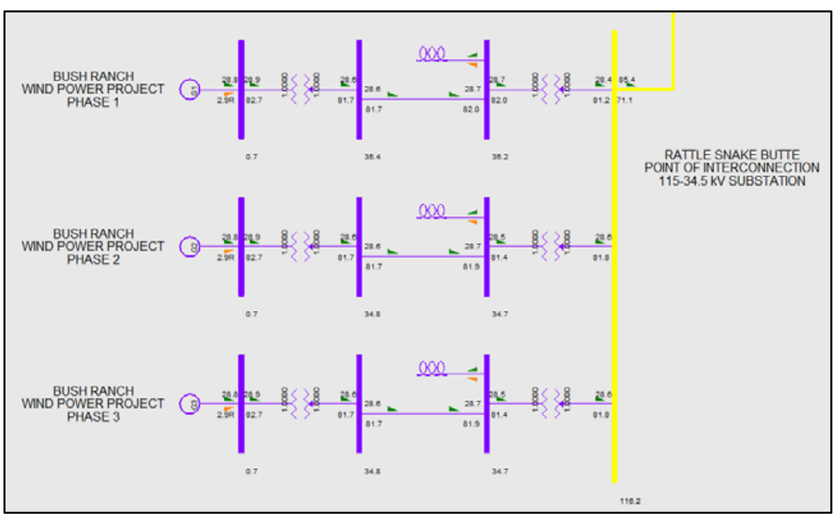

Figure 2: BHCT-G11 Equivalent One-Line Diagram

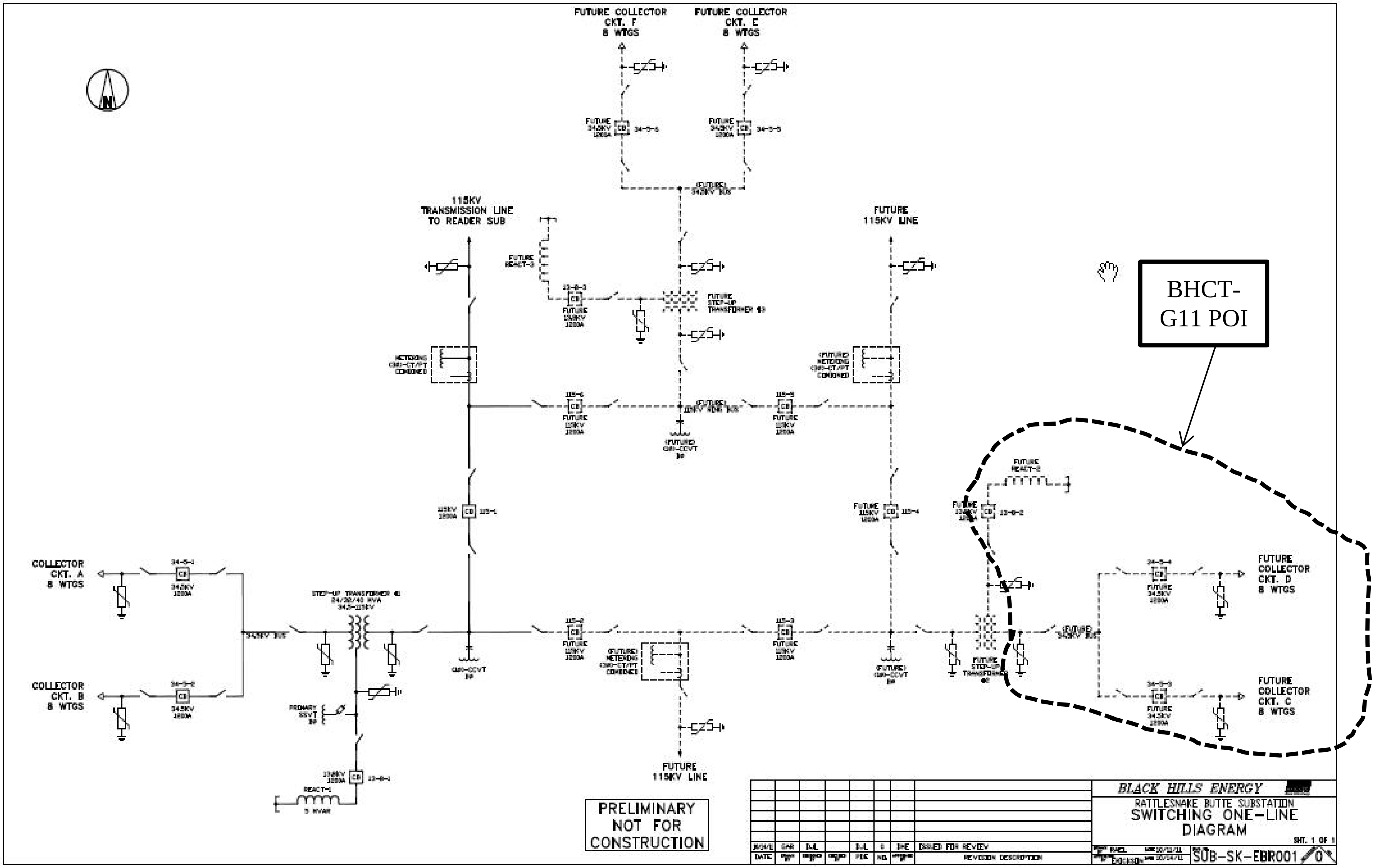

Figure 3: BHCT-G11 POI Substation One-Line Diagram

The transient stability model utilized was PSS/E's generic type 3 model used to represent the proposed project.

1.5. Network Facility Alternatives

No alternative transmission options were evaluated. The BHCT-G11 point of interconnection is located at the new facility constructed for BHCT-G8 and the proposed BHCT-G10.

1.6. Interconnection Requirements

1.6.1. Reactive Power Requirements

The proposed project shall maintain a composite power delivery at continuous rated power output at the POI at a power factor within the range of 0.95 leading to 0.95 lagging, across the range of near 0% to 100% of facility MW rating, with the magnitude of reactive power calculated on the basis of nominal POI voltage (1.0 p.u. V). The design shall consider the effects of step-up transformer reactance and voltage taps/turns ratios, and bus-fed auxiliary load. Based on the plant data supplied by the IC and the results of the SIS, the proposed project may need supplemental reactive voltage support equipment to meet these requirements. It is assumed that these requirements are independent and in addition to those required for BHCT-G8 and G10 as shown in Figure 3.

If BHC requires additional reactive power support or voltage regulation to mitigate known system weaknesses, BHC will negotiate with the generator owner for any additional capability beyond the minimum requirements stated above.

Refer to BHC's *Facility Connection Requirements* document for details on excitation systems, voltage regulation, governor requirements, etc.

2. Study Methodology

This section summarizes the methods used to derive the power flow and transient stability results.

2.1. Assumptions

The SIS was performed with the following assumptions:

- All existing and planned facilities and the effects of control devices and protection systems were accurately represented in the system model.
- Projected firm transfers were represented per load and resource updates.
- Existing and planned reactive power resources were modeled to ensure adequate system performance.
- BHCT-G8 and BHCT-G10 are in service and generating at full output (29 MW each).
- There were no specific planned outages identified for the 2016 study period. The list of the evaluated prior and forced outages used to simulate NERC TPL Reliability Standard Category A, B & C contingencies is included in Appendix B.
- PSCo's 250MW wind resource at the 230kV Jackson Fuller substation and the 120MW solar project at Comanche 230kV substation should be on at 100% of nameplate capacity.

The power flow analysis was performed with pre-contingency solution parameters that allowed adjustment of load tap-changing (LTC) transformers, static VAR devices including switched shunt capacitors and reactors, and DC taps. Post-contingency solution parameters allowed adjustment of DC taps and adjustment of switched shunt elements outside the study area. Area interchange control was disabled and generator VAR limits were applied automatically for all solutions. The solution method implemented for all cases was a fixed-slope decoupled Newton solution.

2.2. Reliability Criteria

The criteria described in this section are consistent with the NERC TPL Reliability Standards, the WECC System Performance Regional Criterion (TPL-001-WECC-CRT-2) and Colorado Coordinated Planning Group's Voltage Coordination Guide.

2.2.1. Steady State Voltage Criteria

Under system intact conditions, steady state bus voltages must remain between 0.95 and 1.05 per unit. Following a Category B or C contingency, bus voltages must remain between 0.90 and 1.10 per unit. Pre-existing voltage violations outside the localized study area were ignored during the evaluation.

2.2.2. Steady State Thermal Criteria

All line and transformer loading must be less than 100% of their established continuous rating for system normal conditions (NERC/WECC Category A). All line and transformer loadings must be less than 100% of their established continuous or emergency rating under outage conditions (NERC/WECC Category B and C).

2.2.3. Transient Voltage and Frequency Criteria

NERC Standards require that the system remain stable and within applicable thermal ratings and voltage limits for Category A, B, and C disturbances. The *WECC Disturbance – Performance Table of Allowable Effects on Other Systems* states the following requirements:

- Category B: Any transient voltage dip must not exceed 25% at load buses or 30% at non-load buses. The dip also must not exceed 20% for more than 20 cycles at load buses. Frequency must not drop below 59.6 Hz for 6 or more cycles at a load bus.
- Category C: Any transient voltage dip must not exceed 30% at load buses or 30% at non-load buses. The dip also must not exceed 20% for more than 40 cycles at load buses. Frequency must not drop below 59.0 Hz for 6 or more cycles at a load bus.

2.3. Power Flow Analysis

All power flow analysis was conducted with version 33.5 of PTI's PSS/e software. Power flow results were monitored and reported for transmission system elements in the study area described in Section 1.2. Power flow analysis was used to evaluate the thermal and voltage performance of the system under Category A, B, and C disturbance conditions. Refer to Appendix B for a complete list of simulated prior and forced outages.

Thermal loading was reported when a modeled transmission element was loaded over 98% of its appropriate MVA rating modeled in the power flow database and when the incremental increase in loading from Pre-Project to Post-Project exceeded 2%. Transmission voltage violations were reported when the criteria described in Section 2.2.1 were not met.

The proposed project was evaluated as a 29 MW ER, dispatched against the Pawnee Generating Station in northern Colorado. Also the Lamar DC tie was dispatched at 200MW E-W.

Table 2 lists the generation dispatch used for each of the aforementioned resource designations for the heavy summer scenario, respectively.

Table 2: Generation Dispatch Scenarios

SCENARIO	CANON_55 70083	CANON_59 70084	E_CANON 70160	PP_MINE 70306	PUB_DSLS 70334	PUEBPLNT G1 70337	PUEBPLNT G2 70337	R.F.DSLS 70344	APT_DSLS 70548	BAC_MSA_GEN1 71001	BAC_MSA_GEN2 71002	BAC_MSA_GEN3-S1 71003	BAC_MSA_GEN3-G1 71003	BAC_MSA_GEN3-G2 71003	BAC_MSA_GEN4-S1 71004	BAC_MSA_GEN4-G1 71004	BAC_MSA_GEN4-G2 71004	BAC_MSA_GEN5-G1 71005	PAWNEE 70310	BHCT-G8 71009	BHCT-G10 71012	BHCT-G11 71015
2018HS BENCHMARK	0	0	0	0	0	0	0	0	0	90	90	20	40	40	20	40	40	0	505	29	29	0
2018HS Scenario 1	0	0	0	0	0	0	0	0	0	90	90	20	40	40	20	40	40	40	476	29	29	29
2018HS Scenario 2	0	0	0	0	0	0	0	0	0	90	90	20	40	40	20	40	40	90	476	29	29	29

2.4. Transient Stability Analysis

The objective of the transient stability analysis is to determine the ability of generators to remain in synchronism with one another by surviving the first swing of a disturbance such as a ground fault and subsequent breaker action on the transmission system. Transient stability also simulates the ability of the system as a whole to return to a given steady-state equilibrium after being moved away from it by a small perturbation.

Transient analysis was performed to evaluate the dynamic characteristics of the transmission system in proximity to the BHCE footprint following various disturbances. System loads were modeled using the WECC generic motor load penetration of 20 percent, with the under voltage load shedding function disabled to provide a worst-case representation of system performance. The transient stability contingencies were simulated out to 10 seconds to ensure a damped system response. The disturbances evaluated in the transient analysis were selected based on significance with respect to proximity to local generation. The 3-phase faults listed in Table 4 were simulated for the 2016 peak scenario.

Table 3: Simulated Transient Stability Disturbances

Disturbance Description	3Φ Faulted Bus	Cleared Element	Fault Duration (cycles)
System Intact	None	No Fault	NA
Baculite Mesa-Airport Memorial 115	Bac. Mesa 115 kV	Baculite Mesa-Airport Memorial 115 line	5
Baculite Mesa-Nyberg 115	Bac. Mesa 115 kV	Baculite Mesa-Nyberg 115 line	5
Baculite-Overton 115	Bac. Mesa 115 kV	Baculite Mesa-Overton 115 line	5
Baculite-West Station 115	Bac. Mesa 115 kV	Baculite Mesa-West Station 115 line	5
Baculite-West Station 1 & 2 115	Bac. Mesa 115 kV	Baculite Mesa-West Station 1 & 2 115 lines	5
Reader-Airport Memorial	Reader 115 kV	Reader-Airport Memorial 115 line	5
Reader-Comanche 115	Reader 115 kV	Reader-Comanche 115 line	5
Reader-Comanche 1 & 2 115	Reader 115 kV	Reader-Comanche 1 & 2 115 lines	5
Reader-Greenhorn 115	Reader 115 kV	Reader-Greenhorn 115 line	5
Reader-Pueblo 115	Reader 115 kV	Reader-Pueblo 115 line	5
Boone-LaJuntaW 115	LaJuntaW 115 kV	Boone-LaJunta 115 line	5
LaJuntaW-LaJuntaT 115	LaJuntaW 115 kV	LaJuntaW-LaJuntaT 115 line	5
West Canon-Canon City 115	Canon City 115kV	West Canon-Canon City 115 line	5
Portland-West Station 115	West Station 115	Portland-West Station 115 line	5
Portland-West Station 1 & 2 115	West Station 115	Portland-West Station 1 & 2 115 lines	5
Comanche-MidwayPS 230	Comanche 230 kV	Comanche-MidwayPS 230 line	5
Comanche-Boone 230	Comanche 230 kV	Comanche-Boone 230 kV line	5
Comanche-Dan. Park 345	Comanche 345 kV	Comanche-Daniels Park 345 kV line	4
Midway-West Canon 230	Midway 230 kV	Midway-West Canon 230 line	5
Portland-Skala 115	West Station 115	Portland-Skala 115 line	5
Reader-Rattlesnake Butte 115	Reader 115 kV	Reader-Rattlesnake Butte 115 line	5

The following parameters were monitored in the 2016HS scenario to evaluate system stability performance.

- Rotor angle plots provide a measure for determining how the proposed generation unit would swing with respect to other generating units in the area. This information is used to determine if a machine would remain in synchronism or go out-of-step from the rest of the system following a disturbance.
- Bus voltage plots, in conjunction with the relative rotor angle plots, provide a means of detecting out-of-step conditions. The bus voltage plots are useful in assessing the magnitude and duration of post-disturbance voltage dips and peak-to-peak voltage oscillations. Bus voltage plots also give an indication of system damping and the level to which voltages are expected to recover in the steady state conditions.
- Bus frequency plots provide information on magnitude and duration of post-fault frequency swings with the new project in service. These plots indicate the extent of possible over-frequency or under-frequency excursions, which can occur due to an area's imbalance between load and generation.

Other parameters plotted for the 2016HS scenario included generator field and terminal voltage, generator rotor speed, and real and reactive power output.

3. Results

The objective of this study was to assess the reliability impacts of the proposed project on the transmission system. This study was not intended to examine pre-existing problems unrelated to the proposed plant, but rather to determine whether the transmission system meets BHCE's performance criteria when the plant is in-service. Under that assumption, a number of pre-existing criteria violations were identified during the analysis that were not included in the results section of the report. The following issues were omitted from the report:

- Operational issues on the 69 kV system related to load service
- Pre-existing issues identified in the benchmark pre-project case

3.1. Power Flow Analysis

There were some adverse impacts to the BHCE and surrounding transmission system identified in the 2016HS power flow analysis as a result of the interconnection of the BHCT-G11 project. The 2016HS powerflow results are summarized in Table 5 below. The results assume the PAGS Unit #5 generator is dispatched at 90MW for all overloads except the Midway transformer overload which assumes PAGS #5 is at 40MW and Pueblo Plant-Reader which assumes PAGS #5 is at 0MW. These variations in PAGS #5 output were included to demonstrate that the overload exists even at reduced PAGS #5 output.

Table 4: 2016HS Powerflow Results

Overloaded element	Loading (%)	Loading (MVA)	rating (MVA)	outage	prior outage	Project Contribution Loading (%)
FTN_VLY 115.00-DESRTCOV 115.00 #1	111	128	115	133_MIDWAYPS 230.-FULLER 230. #1 LINE	MIDWAYPS230-MIDWAYBR230	3
FTN_VLY 115.00-MIDWAYBR 115.00 #1	110	127	115	143_MIDWAYBR 230.-MIDWAYPS 230. #1 LINE	MIDWAYPS-FULLER230	3
HYDEPARK 115.00-W.STATON 115.00 #1	109	130	119	106_BAC-WST1&2	SYSTEM INTACT	3
MIDWAYPS 115.00-MIDWAYPS 230.00 #T1	121	118	97	139_DANIELPK 345.-COMANCHE 345. #2 LINE	DANIELPK-COMANCHE345-1	4
PUEBPLNT 115.00-READER 115.00 #1	103	164	160	139_DANIELPK 345.-COMANCHE 345. #2 LINE	DANIELPK-COMANCHE345-1	3

PSCo's Midway 230/115kV transformer has been identified in PSCo/BHE planning and LGIR studies and PSCo is aware of the issue and it is on their watch list. The Hyde Park-West Station and Pueblo Plant-Reader 115kV line overloads are due to terminal limitations at West Station and Pueblo Plant which also have been identified in BHE TCPC studies and will be upgraded. The Desert Cove-Fountain Valley-Midway(WAPA) 115kV line overload, which also has been identified in BHE TCPC studies, should be rebuilt. If the previously identified upgrades cannot be completed by the ISD of the BHCT-G11 project, generation curtailments for the proposed project or other operational measures may have to be implemented under planned outage scenarios until the upgrades are complete.

3.2. Transient Stability Analysis

The transient stability study results of the BHCT-G11 project modeled were negligible. There were no post-contingent voltage violations or additional frequency criteria violations, and all system oscillations were adequately damped. Due to the large size of plot files created in this analysis, plots were not included in the study report, but are available on request.

3.3. Reactive Power Analysis

Similar to the BHCT-G8 and G10 projects, the BHCT-G11 project produced a 4 MVAR injection at the POI substation when the WTGs were offline due to the charging effects of the collector system. The reactive power injection did not result in system voltages outside the allowable range. However, the resulting power factor measured at the POI was outside the 0.95 lead/lag requirement due to the purely reactive injection of the project at zero real power output. The project is nearly 'VAR neutral,' but shunt reactive support will be required at the interconnection substation to meet the reactive power requirements specified in Section 1.6.1. Also, the Reader-Rattlesnake Butte line consumes 14 MVAR when all three phases of Busch Ranch are on with a combined output of 84MW. Figure 4 shows the VAR consumption of the line as a result of varying levels of all three phases of Busch Ranch. The VAR consumption of the Reader-Rattlesnake Butte 115kV line, which currently is not in violation, should continue to be monitored in future Rattlesnake Butte generator interconnection studies.

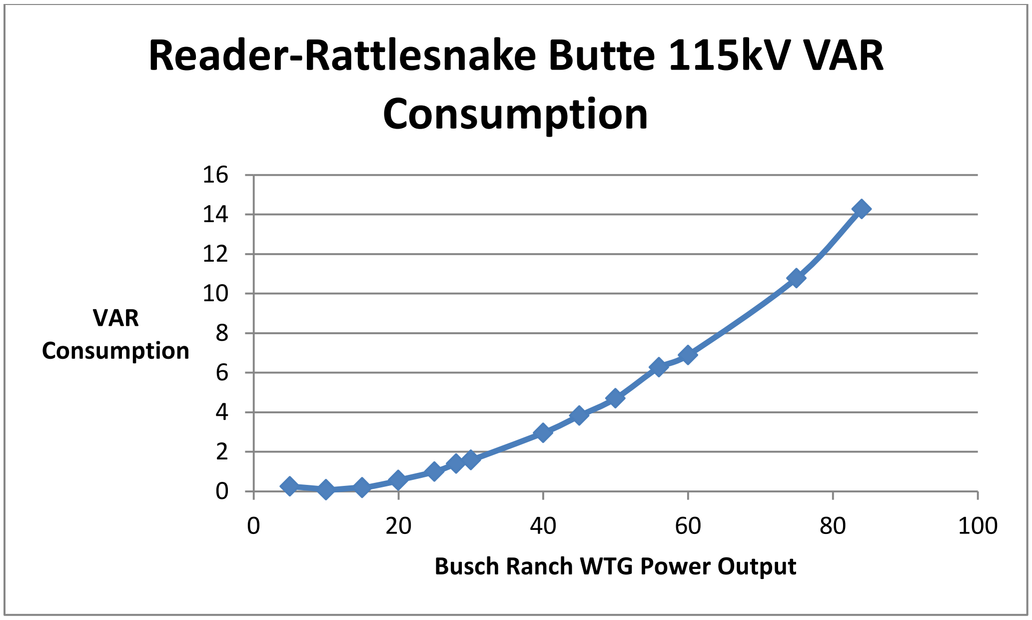

Figure 4: Reader-Rattlesnake Butte 115kV VAR Consumption

3.4. Results Summary

Based on the results of the SIS as described in Section 3, the BHCE transmission system cannot reliably accommodate a 29-MW injection from the BHCT-G11 project as an Energy or Network Resource without previously identified network upgrades. In order to accommodate the full 29 MW project, the following system upgrades are needed:

- Upgrade Hyde Park-West Station 115 kV line continuous rating to at least 700 amps.
- Upgrade Reader-Pueblo 115 kV line continuous rating to at least 900 amps.
- Upgrade Desert Cove-Fountain Valley-Midway 115 kV line continuous rating to at least 800 amps.

Direct assigned upgrades associated with the requested generation facility include:

- 5 MVARs of reactive voltage support to offset the effects of collector system charging under low generation output conditions.
- Terminal and metering equipment at the POI.

It should be noted that the results described in this report do not guarantee transmission service for the customer. Transmission Service should be requested through the BHCT OASIS and the request will be granted on a first-come, first serve basis.

4. Cost and Construction Schedule Estimates

The cost estimates represent good faith estimates necessary to interconnect to the system. The non-binding, good faith cost and time estimates are in 2015 dollars.

4.1. Direct Assigned Upgrades

The addition of all equipment associated with the generating plant and all Interconnection Facilities up to the high side of the generator step-up ("GSU") power transformer to accommodate the integration of BHCT-G11 is estimated to cost $3,015,281 and take approximately 12 months to complete. This includes a 5 MVAR reactor connected to the 13.8 kV tertiary winding of the 115/34.5 kV transformer. Estimates are based on 2015 dollars and lead times for materials were considered for the project schedule.

4.2. Network Upgrades

The addition of a new 115 kV terminal position at the BHCE 115 kV Rattlesnake Butte substation to accommodate the integration of BHCT-G11 is estimated to cost $1,499,602 and take approximately 12 months. Estimates are based on 2015 dollars and lead times for materials were considered for the project schedule.

The network upgrades identified in Section 3.4 have been identified in previous transmission planning analyses and have an associated implementation schedule. In order to accommodate the full project as requested those implementation schedules need to be accelerated. Alternatively, the output of the project may be subject to curtailment or the ISD of the project could be delayed until the upgrades are completed.

5. Conclusions

The 29-MW injection from BHCT-G11 (ER or NR) could be accommodated at the POI with the following required network upgrades:

- New 115 kV terminal position at the BHCE 115 kV Rattlesnake Butte substation

The new 115 kV circuit breaker required for this new terminal will convert the bus configuration from a three breaker ring bus to a four breaker ring bus. In addition to the network upgrades mentioned above, a 5 MVAR shunt reactor at the POI substation will be required of the Interconnection Customer. This requirement is independent and in addition to that required for BHCT-G11 as shown in Figure 3. The estimated cost of the network upgrades is $1,499,602 and direct assigned upgrades is $3,015,281. The estimated completion time for the system upgrades is approximately 12 months (engineering design/materials procurement/construction & commissioning).

There were transmission loading concerns encountered in the BHCT-G11 analyses that were previously identified and not directly attributed to the BHCT-G11 project. Black Hills is developing a plan to address thermal loading issues on the following transmission lines:

- Hyde Park-West Station 115 kV line
- Reader-Pueblo 115 kV line
- Desert Cove-Fountain Valley-Midway 115 kV line

To ensure the BHCT-G11 project can be operated at the requested capacity of 29 MW, the aforementioned projects should be completed to prevent the thermal ratings from being exceeded under contingency conditions. If the previously identified upgrades cannot be completed by the ISD of the BHCT-G11 project, generation curtailments for the proposed project or other operational measures may have to be implemented until the upgrades are complete.

Appendix A

Benchmark Case
Power Flow Model Updates

```
# LaJunta Interconnection Project and 69 kV Network Upgrades - ISD 2017
# Remove planned upgrades based upon - BHCE&BHCI_Facility Ratings_Rev AC
psspy.branch_chng(70060,70249,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 39.0, 39.0, 39.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
                                                                              #Boone-LaJuntaW 115kV line existing rating
psspy.two_winding_chng_4(70249,70250,r"""T2""",[0,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i],[_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_
f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f],[r"""LAJUNTAW""",""])                   #LaJuntaW 115:69kV T2 transformer ISD 2017
psspy.switched_shunt_chng_3(70366,[2,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i],[_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f],_s)
                                                                              #Rockyford 69kV Shunt Capacitors 2x6MVAr Banks
psspy.two_winding_chng_4(70060,70062,r"""T1""",[_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i,_i],[_f,_f,_f,_f,_f,_f,_f,_f, 33.0,
33.0, 33.0,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f],[r"""BOONE""",""])       #Boone 115:69kV T1 transformer legacy 33 MVA unit
psspy.branch_chng(70062,70063,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 23.0, 23.0, 23.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
                                                                              #Boone-Boone Tap 69kV line
psspy.branch_chng(70250,70366,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 24.0, 24.0, 24.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
                                                                              #LaJuntaW-Rockyford 69kV line
psspy.branch_chng(70366,70372,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 24.0, 24.0, 24.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
                                                                              #Rockyford-South Fowler Tap 69kV line
#
# Facility Rating Updates to BHCE&BHCI_Facility Ratings_Rev AC
psspy.branch_chng(70236,70456,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 119.0, 119.0, 119.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
                                                                              #Hyde Park-West Station 115kV line
psspy.branch_chng(70236,70339,r"""1""",[_i,_i,_i,_i,_i,_i],[_f,_f,_f, 160.0, 160.0, 160.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
                                                                              #Hyde Park-Pueblo Plant 115kV line
#
# Replace 40MW CT at Pueblo Airport with a 90MW CT to align with BHCT-G6 LGIR
# Check Dynamics File - BAC_MSA 71005 Model should be a clone of 71001 or 71002
# 12-30-14 Jim Farby
psspy.load_chng_4(71005,r"""SS""",[_i,_i,_i,_i,_i,_i],[ 5.0, 3.1,_f,_f,_f,_f])
psspy.machine_chng_2(71005,r"""G1""",[_i,_i,_i,_i,_i,_i],[ 90.0,_f, 94.0,-58.0, 90.6,_f, 155.07,
0.003,_f,_f,_f,_f,_f,_f,_f,_f,_f])
#
#BUSCH RANCH WIND PROJECT PHASE 3 IN-SERVICE DECEMBER 1 2016
#INSERT BUSCH RANCH WIND PROJECT PHASE 2 BUSES (DISCONNECTED)
psspy.bus_data_2(71014,[4,70,712,66],[ 34.5, 1.02, 47.0],r"""BUSCHRNCH5""")  #34.5 KV STATION BUS
psspy.bus_data_2(71013,[4,70,712,66],[ 34.5, 1.02, 47.0],r"""BUSCHRNCH6""")  #34.5 KV COLLECTOR BUS
psspy.bus_data_2(71015,[4,70,712,66],[ 0.69, 1.02, 47.0],r"""BUSCHRWTG3""")  #0.69 KV TERMINAL BUS
#
#INSERT WTG PLANT DATA (CONTROL TERMINAL BUS)
psspy.plant_data(71015,71006,[1.01,_f])
#
#INSERT MACHINE DATA (OFFLINE)
psspy.machine_data_2(71015,r"""G3""",[0,66,0,_i,_i,1],[28.8,_f,9.44,-13.92,28.8,0.0,32.0,0.0, 0.17337,_f,_f,_f,_f,1.0,_f,_f,1])
#
#INSERT GSU TRANSFORMER DATA (DISCONNECTED)
psspy.two_winding_data_3(71013,71015,r"""1""",[0,71015,66,_i,_i,_i,33,_i,71013,_i,_i,0,2,2,_i],[ 0.008163, 0.089629, 30.4, 34.5,
34.5,_f, 0.69, 0.69, 35.0, 35.0, 35.0,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f,_f],r"""BUSCHRWTG3""")
#
#INSERT STATION XFMR DATA (NAMEPLATE DATA 111011 Z=7% AND X/R=29.52) (DISCONNECTED)
psspy.two_winding_data_3(71006,71014,r"""T3""",[0,71006,66,_i,_i,_i,33,_i,71006,0,0,0,2,2,1],[ 0.0024, 0.06996, 24.0, 115.0,
115.0,0.0, 34.5, 34.5, 35.0,35.0,35.0, 1.0,_f,_f,_f,0.0,0.0, 1.1, 0.9, 1.1, 0.9,0.0,0.0,0.0],r"""RTLSNAKEB3""")
#
#INSERT 5 MVAR REACTOR AT BUSCH RANCH 34.5 KV BUS (DISCONNECTED)
psspy.switched_shunt_data_3(71014,[1,_i,_i,_i,_i,_i,_i,_i,1,0,0,1],[-5.0,_f,_f,_f,_f,_f,_f,_f, 1.03, 0.99, -5.0, 100.0],"")
#
#INSERT 34.5 KV COLLECTOR SYSTEM APPROXIMATION (WECC EQUIVALENT MODEL) (DISCONNECTED)
psspy.branch_data(71014,71013,r"""1""",[0,_i,66,_i,_i,_i],[ 0.017, 0.014, 0.030, 35.0, 35.0, 35.0,_f,_f,_f,_f,_f,_f,_f,_f,_f])
```

Appendix B

Power Flow Analysis: Prior and Forced Outage List

2016 STEADY STATE FORCED OUTAGES (WITH PRIOR OUTAGES)					
1	BACULITE MESA GEN #1	35	LAJUNTAT-LAJUNTAW 115	69	WSTATN-STEMBCH115+WSTATN115 XFMR+2.7CAP
2	BACULITE MESA GEN #2	36	AREQUA GULCH-NORTH CANONW 69	70	WSTATN-HYDE115+WSTATN115 XFMR+3.6CAP
3	ROCKY FORD DIESELS	37	CANON CITY-EAST CANON 69	71	WSTATN-MWPS115+WSTATN115 XFMR+3.6CAP
4	BOONE-NYBERG #1 & #2 115	38	PORTLAND-EAST CANON 69	72	WSTATN-DCOVE115+WSTATN115 XFMR+3.6CAP
5	BOONE-LAJUNTAW 115	39	CANON CITY-HIGHLAND 69	73	WSTATN-BACULITEMSA115 #2+WSTATN115 XFMR+3.6CAP
6	NYBERG-BACULITE MESA 115	40	WEST STATION-SUNSET 69	74	WSTATN-BACULITEMSA115 #2+WSTATN115 XFMR+2.7CAP
7	NYBERG-APTMEMORIAL 115	41	PUEBLO-WEST STATION 69	75	READER-APTMEMORIAL 115+READER 115 XFMR #1
8	APT INDUSTRIAL PARK-BACULITE MESA 115	42	WEST STATION-BELMONT 69	76	READER-COMANCHE 115 #1 + READER 115 XFMR #2
9	APT INDUSTRIAL PARK-APTMEMORIAL 115	43	READER-BELMONT 69	77	READER-COMANCHE 115 #2 + READER 115 XFMR #1
10	READER-APTMEMORIAL 115	44	BOONE-ROCKY FORD 69	78	READER-GREENHORN 115 + READER 115 XFMR #1
11	PUEBLO-READER 115	45	ROCKY FORD-FOWLER 69	79	READER-PUEBLO 115 + READER 115 XFMR #2
12	HYDE PARK-PUEBLO 115	46	LAJUNTAW-ROCKY FORD 69	80	READER-RATTLESNAKE 115 + READER 115 XFMR #1
13	HYDE PARK-WEST STATION 115	47	LAJUNTAT-LAJUNTAW 69	81	CCY 115 XFMR+CCY-E.CANON69+CCY-SCANON69
14	BACULITE MESA-WEST STATION 115 #1	48	LAJUNTAW-LAMAR 69	82	NYBERG-BACULITE MESA 115+ NYBERG-APTMEMORIAL 115
15	BACULITE MESA-WEST STATION 115 #2	49	BOONE 230 XFMR #1	83	READER-APTMEMORIAL 115+READER-GREENHORN 115
16	BACULITE MESA-MIDWAY 115	50	WEST CANON 230 XFMR	84	READER-COMANCHE 115 #1 & #2
17	MIDWAYPS-NORTHRIDGE-BACULITE MESA 11	51	CANON CITY 115 XFMR	85	READER-RATTLESNAKE 115+READER-PUEBLO 115
18	MIDWAYPS-WEST STATION 115	52	PORTLAND 115 XFMR #1	86	BURNT MILL 115 SUB
19	DESERT COVE-WEST STATON 115	53	PORTLAND 115 XFMR #2	87	GREENHORN 115 SUB
20	MIDWAYBR-FTNVLY-DESERT COVE 115	54	AREQUA GULCH 115 XFMR #1	88	APTINDUSTRIAL PARK 115 SUB
21	PORTLAND-WEST STATION 115 #1	55	AREQUA GULCH 115 XFMR #2	89	APTMEMORIAL 115 SUB
22	PORTLAND-WEST STATION 115 #2	56	WEST STATION 115 XFMR #1	90	HYDE PARK 115 SUB
23	WEST STATION-STEM BEACH 115	57	WEST STATION 115 XFMR #2	91	BACULITE MESA-NYBERG 115+BACULITE MESA GEN #1
24	BURNT MILL-PUBRES-WEST STATION 115	58	READER 115 XFMR #1	92	BACULITE MESA-APTINDUSTRIAL115+BACULITE MESA GEN #2
25	BURNT MILL-GREENHORN 115	59	READER 115 XFMR #2	93	BACULITE MESA-W.STATION 115 #2 + BACULITE MESA GEN #3
26	GREENHORN-READER 115	60	BOONE 115 XFMR	94	BACULITE MESA-W.STATION 115 #1 + BACULITE MESA GEN #4
27	COMANCHE-READER 115 #1	61	LAJUNTAW 115 XFMR #1	95	WSTATN-BURNT MILL 115+WSTATN-HYDEPARK 115
28	COMANCHE-READER 115 #2	62	LAJUNTAW 115 XFMR #2	96	WSTATN-PORTLAND 115 #1 + WSTATN-MIDWAYPS 115
29	READER-RATTLESNAKE 115	63	WEST CANON 115 CAPACITOR	97	WSTATN-STEMBEACH 115 + WSTATN-DESERT COVE 115
30	PORTLAND-SKALA 115	64	PORTLAND 115 CAPACITOR	98	PORTLAND-WSTATN 115 #1 + PORTLAND-SKALA 115
31	CANON CITY-SKALA 115	65	BOONE 115 REACTOR	99	PORTLAND 115 XFMRS #1 & #2
32	CANON CITY-WEST SCANON 115	66	BOONE-LAJUNTAW 115 + LAJUNTAW 115 XFMR #2	100	BACULITE MESA-MIDWAYPS 115 + BACULITE MESA GEN #5
33	WEST CANON-PONCHA 115	67	WSTATN-BURNTMILL115+WSTATN115 XFMR #1+2.7CAP	101	WEST STATION-MIDWAYBR 115
34	AREQUA GULCH-WEST CANON 115	68	WSTATN-PORTLAND115+WSTATN115 XFMR+2.7CAP	102	SKALA 115 SUB

2016 STEADY STATE FORCED OUTAGES (WITH PRIOR OUTAGES)					
103	WEST CANON-PONCHA+WCANON 115 CAP	137	MIDWAYBR-RD_NIXON 115	171	
104	WSTATN-MWPS 115 + BACMSA-MWPS 115	138	MIDWAYBR-RD_NIXON 230	172	
105	MWPS-BACMSA 115 + WSTATN-BELMONT 69	139	MIDWAYBR-MIDWAYPS 230	173	
106	BACULITE MESA-WSTATN 115 #1 & #2	140	MIDWAYBR-LINCOLN 230	174	
107	EX_PUEBLO 115 SUB	141	MIDWAYBR-WEST CANON 230	175	
108	EX_BOONE 115 SUB	142	WEST CANON-PONCHA 230	176	
109	EX_BACMSA-WST115 1&2+MWPS-BACMSA+WS	143	COMANCHE 230:115 XFMR #2	177	
110	EX_PORTLAND-WSTATN 115 #1 & #2	144	COMANCHE 345:230 XFMR #4	178	
111	EX_PORTLAND 115 SUB	145	LAJUNTAT 115:69 XFMR #2	179	
112	EX_BACULITE MESA 115 SUB	146	LAMAR 230:115 XFMR #1	180	
113	EX_NYBERG 115 SUB	147	MIDWAYPS 230:115 XFMR	181	
114	EX_READER 115 SUB	148	MIDWAYPS 345:230 XFMR	182	
115	EX_CANON CITY 115 SUB	149	MIDWAYPS-FTNVLY GSU XFMR+FTNVLY GEN 3&4	183	
116	EX_WEST CANON 115 SUB	150	WALSENBURG 230:115 XFMR #3	184	
117	EX_WEST STATION 115 SUB	151	MIDWAYBR 230:115 XFMR	185	
118	READER-WEST STATION 69	152	RD_NIXON 230:115 XFMR	186	
119	WALSENBURG-GLADSTONE 230	153	FULLER 230:115 XFMR	187	
120	BOONE-LAJUNTAT 115	154	COMANCHE #1 GEN	188	
121	BOONE-COMANCHE 230 #1	155	COMANCHE #2 GEN	189	
122	BOONE-LAMAR 230 + RAS	156	COMANCHE #3 GEN	190	
123	BOONE-MIDWAYPS 230	157	RD_NIXON #1 GEN	191	
124	CF&IFURN-COMANCHE 230	158	BOONE-NYBERG 115 #1 & #2	192	
125	COMANCHE-MIDWAYPS 230 #2	159		193	
126	COMANCHE-WALSENBURG+WALS-GLADSTO	160		194	
127	LAJUNTAT-WILLOWCREEK 115	161		195	
128	LAMAR-VILAS 115	162		196	
129	LAMAR-WILLOWCREEK 115	163		197	
130	MIDWAYPS-FULLER 230	164		198	
131	PONCHA-SARGENT 115	165		199	
132	PONCHA-CURRECANTI 230	166		200	
133	STEMBEACH-WALSENBURG 115	167		201	
134	MIDWAYPS-WATERTON 345	168		202	
135	DANIELPK-COMANCHE 345 #2	169		203	
136	MIDWAYBR-RANCHO 115	170		204	

2016 Reliability Analysis Prior Outages

PO 345 SERIES		PO 230 SERIES		PO 115 SERIES		PO 69 SERIES		PO X SERIES		PO GEN SERIES	
LABEL	DESCRIPTION	LABEL	DESCRIPTION	LABEL	DESCRIPTION	LABEL	DESCRIPTION	LABEL	DESCRIPTION	LABEL	DESCRIPTION
POSTSINT	SYTEM INTACT	PO230-1	BOONE-MIDWAYPS	PO115-1	MIDWAYBR-RANCHO	PO69-1	ROCKY FORD-LAJUNTAW	POX-1	MIDWAYPS 345:230	POGEN-1	COMANCHE 3
PO345-1	DAN PARK-COMANCHE-1	PO230-2	BOONE-COMANCHE	PO115-2	MIDWAYBR-NIXON	PO69-2	BLENDE-ST. CHARLES***	POX-2	COMANCHE 345:230-T3	POGEN-2	BAC MESA GEN 1
PO345-2		PO230-3	BOONE-LAMAR	PO115-3	FTN VALLEY-MIDWAYBR	PO69-3	WEST STATION-STONEMOOR	POX-3	LAMAR 230:115	POGEN-3	BAC MESA GEN 2
PO345-3		PO230-4	COMANCHE-MIDWAYPS-1	PO115-4	FTN VALLEY-DESERT COVE	PO69-4	READER-FREEMARY	POX-4	BOONE 230:115-1	POGEN-4	
PO345-4		PO230-5	MIDWAYPS-FULLER	PO115-5	DESERT COVE-WEST STATION	PO69-5	PORTLAND-HIGHLAND	POX-5	WEST CANON 230:115	POGEN-5	
PO345-5		PO230-6	MIDWAYBR-NIXON	PO115-6	MIDWAYPS-WEST STATION	PO69-6		POX-6	COMANCHE 230:115-T1	POGEN-6	
PO345-6		PO230-7	MIDWAYBR-LINCOLN	PO115-7	MIDWAYPS-NORTHRIDGE	PO69-7		POX-7	WALSENBURG 230:115-1	POGEN-7	
PO345-7		PO230-8	MIDWAYBR-WEST CANON	PO115-8	OVERTON-NORTHRIDGE	PO69-8		POX-8	MIDWAYPS 230:115	POGEN-8	
PO345-8		PO230-9	WEST CANON-PONCHA	PO115-9	BACULITE MESA-OVERTON	PO69-9		POX-9	MIDWAYBR 230:115	POGEN-9	
PO345-9		PO230-10		PO115-10	BACULITE MESA-WEST STATION-1	PO69-10		POX-10	LAJUNTAW 115:69-1***	POGEN-10	
PO345-10		PO230-11		PO115-11	BACULITE MESA-WEST STATION-2	PO69-11		POX-11	BOONE 115:69***	POGEN-11	
PO345-11		PO230-12		PO115-12	HYDE PARK-WEST STATION	PO69-12		POX-12	READER 115:69-T1	POGEN-12	
PO345-12		PO230-13		PO115-13	HYDE PARK-PUEBLO PLANT	PO69-13		POX-13	WEST STATION 115:69-1	POGEN-13	
PO345-13		PO230-14		PO115-14	PUEBLO PLANT-READER	PO69-14		POX-14	PORTLAND 115:69-T1	POGEN-14	
PO345-14		PO230-15		PO115-15	PORTLAND-WEST STATION-1	PO69-15		POX-15	CANON CITY 115:69	POGEN-15	
PO345-15		PO230-16		PO115-16	PORTLAND-WEST STATION-2	PO69-16		POX-16	AREQUA GULCH 115:69	POGEN-16	
PO345-16		PO230-17		PO115-17	PUEBLO TAP-STEM BEACH	PO69-17		POX-17		POGEN-17	
PO345-17		PO230-18		PO115-18	PUEBLO TAP-WEST STATION	PO69-18		POX-18		POGEN-18	
PO345-18		PO230-19		PO115-19	BURNT MILL-WEST STATION	PO69-19		POX-19		POGEN-19	
PO345-19		PO230-20		PO115-20	BURNT MILL-GREENHORN	PO69-20		POX-20		POGEN-20	
PO345-20		PO230-21		PO115-21	GREENHORN-READER	PO69-21		POX-21		POGEN-21	
PO345-21		PO230-22		PO115-22	READER-AIRPORT MEMORIAL	PO69-22		POX-22		POGEN-22	
PO345-22		PO230-23		PO115-23	AIRPORT PARK-AIRPORT MEMORIAL	PO69-23		POX-23		POGEN-23	
PO345-23		PO230-24		PO115-24	AIRPORT PARK-BACULITE MESA	PO69-24		POX-24		POGEN-24	
PO345-24		PO230-25		PO115-25	NYBERG-BACULITE MESA	PO69-25		POX-25		POGEN-25	
PO345-25		PO230-26		PO115-26	NYBERG-AIRPORT MEMORIAL	PO69-26		POX-26		POGEN-26	
PO345-26		PO230-27		PO115-27	NYBERG-DOT TAP	PO69-27		POX-27		POGEN-27	
PO345-27		PO230-28		PO115-28	BOONE-DOT TAP	PO69-28		POX-28		POGEN-28	
PO345-28		PO230-29		PO115-29	BOONE-LAJUNTAW	PO69-29		POX-29		POGEN-29	
PO345-29		PO230-30		PO115-30	BOONE-LAJUNTAT	PO69-30		POX-30		POGEN-30	
PO345-30		PO230-31		PO115-31	LAJUNTAT-LAJUNTAW	PO69-31		POX-31		POGEN-31	
PO345-31		PO230-32		PO115-32	COMANCHE-READER-1	PO69-32		POX-32		POGEN-32	
PO345-32		PO230-33		PO115-33	COMANCHE-READER-2	PO69-33		POX-33		POGEN-33	
PO345-33		PO230-34		PO115-34	PORTLAND-SKALA	PO69-34		POX-34		POGEN-34	
PO345-34		PO230-35		PO115-35	CANON CITY-SKALA	PO69-35		POX-35		POGEN-35	
PO345-35		PO230-36		PO115-36	CANON CITY-WEST CANON	PO69-36		POX-36		POGEN-36	
				PO115-37	AREQUA GULCH-WEST CANON						
PO345-36		PO230-37		PO115-38	SMELTER-WEST CANON	PO69-37		POX-37		POGEN-37	

*** INDICATES MUST RUN GENERATION AT ROCKY FORD WAS UTILIZED FOR THIS PRIOR OUTAGE

Appendix C

Colorado Springs Utilities Sensitivity

During a recent BHCT-G11 interconnection customer meeting, Colorado Springs Utilities (CSU) questioned whether certain contingencies on their system were studied and the topology around Palmer Lake was modeled correctly. The main focus of their modeling questions was on the Palmer Lake series reactor on the Palmer Lake-Monument 115kV line which is owned by PSCo. PSCo stated that the reactor was to minimize overloading on the Palmer Lake-Monument line following certain double contingencies, but they are not pursuing the project and have developed an operating procedure to mitigate the overload.

Upon CSU's request Black Hills verified that the Palmer Lake reactor was not in the 2016HS base case and then performed a small study with the supplied contingencies. The study showed there were no thermal overloads or voltage violations due to the BHCT-G11 project. All changes to existing overloads from pre to post project were less than 2% except the PSCo Midway 230/115kV transformer which has previously been identified.