Wyoming Centric Study

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Version 2.3

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1 EXECUTIVE SUMMARY

1.1 General

Tri-State has received formal load addition requests from High Plains Power and Carbon Power and Light in central and south central areas of Wyoming. The projected in-service dates for these requests range from 2012 to 2014. These new loads are primarily for oil and gas development, and transportation. Tri-State has very few transmission resources in this geographical area and therefore relies on network transmission service from the Western Area Power Administration (Western) to serve its member loads. These projected loads will exceed Western's Available Transmission Capability (ATC).

The primary transmission constraint in the central Wyoming area is the transfer limit across WECC Path 38 (referred to as TOT4B) from the southeast to the northwest. Western and PacifiCorp share the transfer capability of this path. PacifiCorp is the operating agent and monitors the path using real-time flows. Currently, the TOT4B limit depends on the adjacent TOT4A path flow. The characteristic of this limit is currently defined by an operating procedure and a TOT4A/4B nomogram.

It should be noted that a significant transmission system expansion, called the Gateway project, is also scheduled in the area. It is scheduled to be completed in phases, starting in 2015 and finishing by 2017. Gateway will have a significant impact on the operational relationship between TOT4A and 4B. After Gateway is constructed, TOT4A will be re-defined and the TOT4A/4B nomogram relationship will be removed.

The goal of this study is to develop a long-range transmission plan for the area that will identify and evaluate both transmission and resource alternatives to alleviate existing constraints on TOT4B so that Tri-State load additions can be accommodated. A high-level cost estimate associated with scenarios developed under each alternative will also be identified. In addition to the Gateway project, the analyses will incorporate other existing construction plans in Wyoming as necessary.

Performance of the transmission system was measured against the WECC Reliability Criteria and NERC Planning Standards.

1.2 Conclusions

Study results narrowed proposed projects down to two alternatives that can effectively serve the additional 445 MW of new load at the Badwater 230kV substation. In addition, a rough cost estimate for each component is provided, which is based on 2015 dollars. These estimates are for comparison of the relative costs of each project and are not budget costs. Alternative A includes the construction of a new 230kV line which would require land easement acquisitions. The cost of a right of way easement is included in the rough estimate of the line cost for comparison to Alternative C2 and its rebuild of lines in existing right of ways. Details of each alternative are provided:

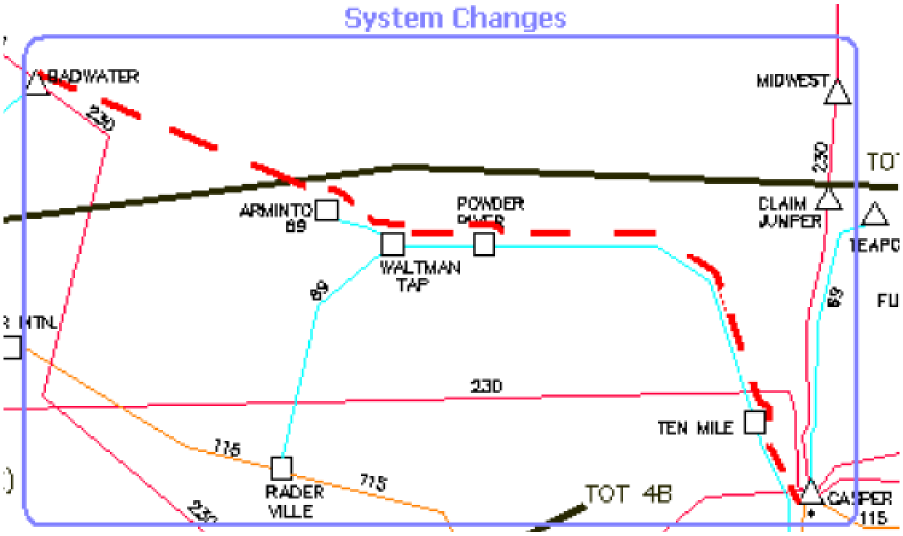
Alternative A

Prior to the construction of the Gateway project, the following upgrades are needed to serve 445 MW of additional new load near the Badwater substation.

1. Construct a new 70 mile, 1-1272 ACSR transmission line between the Casper and Badwater 230 kV substations. This line would have Tri-State thermal line ratings of 1538/1661 amps (612/661 MVA) normal/emergency. (~$48 million)
2. Install three (3) 15 MVAr shunt capacitors at the Lovell 115 kV substation. Shunt capacitors are required to switch quickly. (~ $0.5 million)
3. Install two (2) 30 MVAr shunt capacitors at the Oregon Basin 230 kV substation. Shunt capacitors are required to switch quickly. (~ $0.8 million)
4. Install a +110/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors. (~ $32 million)

Alternative A may need additional system improvements post-Gateway. The Gateway project does not have a concrete planned addition of new resources. Therefore, the negative impact on this project by new resources would be the responsibility of the interconnection customer to resolve. The additional system improvements outlined below are representative of possible future projects that would be needed to be implemented post-Gateway should the generation and load scenario in the case be realized.

5. Rebuild the Casper – Badwater 230 kV (~70 mile) with 2-1272 ACSR for a Tri-State thermal line rating of 3076/3322 amps (1224/1322 MVA) normal/emergency. (~35 million)
6. Increase Badwater-Elk Petroleum-Spence 230kV (65.2 miles) emergency thermal capacity to achieve a flow of at least 1330 amps (530 MVA). (~ $16.3 million)
7. Install one (1) 30 MVAr shunt capacitor at the Badwater 230 kV substation. Shunt capacitor is required to switch quickly. (~ $0.4 million)
8. Install one (1) 30 MVAr shunt capacitor at the Casper 230 kV substation. Shunt capacitor is required to switch quickly. (~ $0.4 million)
9. Install two (2) 20 MVAr shunt capacitors at the Refinery 115 kV substation. Shunt capacitors are required to switch quickly. (~ $0.5 million)
10. Install one (1) 15 MVAr shunt capacitor at the Denbury 115 kV substation. Shunt capacitors are required to switch quickly. (~ $0.2 million)



Alternative C2

Prior to the construction of the Gateway project, the following upgrades are needed to serve 445 MW of additional new load near the Badwater substation.

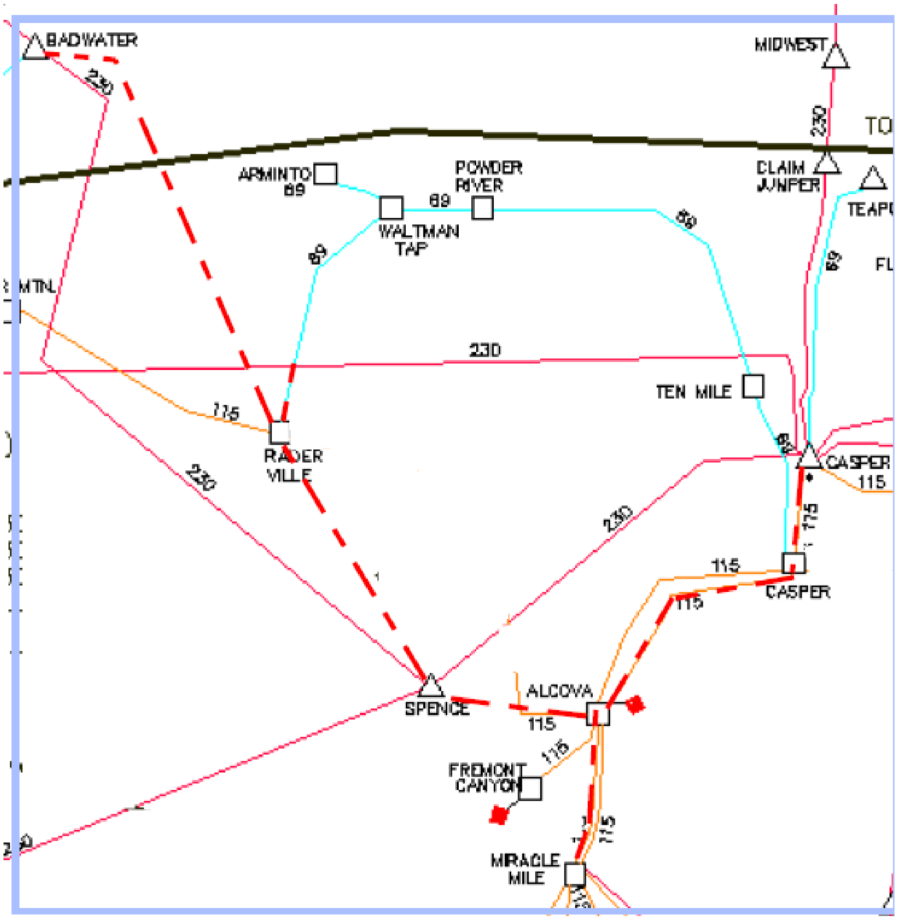
1. Rebuild the Casper - Alcova No.1 115 kV line (23.8 miles) with 1-795 ACSS conductor to operate at 230 kV and interconnect to a new Alcova 230 kV substation creating a Casper - Alcova 230 kV line. (~ $8.4 million)
2. Construct a new Alcova 230kV substation, 3 breaker ring bus. (~ $3.1 million)
3. Rebuild the Miracle Mile - Alcova No.1 115 kV line (23.8 miles) to operate at 230 kV on one side of tower and rebuild the Alcova - Miracle Mile No.2 115 kV line (23.8 miles) with 1-1272 ACSR on the other side of tower.
(~ $23.8 million)
4. Rebuild the Alcova - Raderville 115 kV line (45.2 miles) to operate at 230 kV and loop this new line through Spence creating an Alcova - Spence 230kV line and Spence-

Raderville 230kV line. The newly created Alcova-Spence 230kV line (13.7 miles) requires 1-795 ACSS conductor. (~ $15.8 million)

5. Install new Raderville 230/115 kV, 200 MVA transformer. (~ $2.5 million)
6. Construct new 31.5 mile, 1-795 ACSS transmission line between the Raderville and Badwater 230 kV substations. (~ $11.1 million)
7. Install four (4) 15 MVAr shunt capacitors at the Lovell 115 kV substation. Shunt capacitors are required to switch quickly. (~ $0.8 million)
8. Install one (1) 30 MVAr shunt capacitor at the Oregon Basin 230 kV substation. (~ $0.4 million)
9. Install two (2) 30 MVAr shunt capacitors at the Spence 230 kV substation. (~ $0.8 million)
10. Install a +120/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors. (~ $32.5 million)

Alternative C2 may need additional system improvements post-Gateway. The Gateway project does not have a concrete planned addition of new resources. Therefore, the negative impact on this project by new resources would be the responsibility of the interconnection customer to resolve. The additional system improvements outlined below are representative of possible future projects that would be needed to be implemented post-Gateway should the generation and load scenario in the case be realized.

11. Increase Sheridan-Yellowtail 230kV (41.2 miles) continuous and emergency thermal capacity to achieve a flow of at least 950/1066 amps (380/425 MVA), normal/emergency. (~ $10.4 million)
12. Increase Badwater-Elk Petroleum-Spence 230kV (65.2 miles) emergency thermal capacity to achieve a flow of at least 1330 amps (530 MVA). (~ $16.3 million)
13. Increase Sheridan-Buffalo 230kV (39.77 miles) emergency thermal capacity to achieve flow of at least 1042 amps (415 MVA). (~ $9.9 million)
14. Install three (3) 30 MVAr shunt capacitors at the Badwater 230 kV substation. Shunt capacitors are required to switch quickly. (~ $1.2 million)
15. Install two (2) 20 MVAr shunt capacitors at the Refinery 115 kV substation. Shunt capacitors are required to switch quickly. (~ $0.5 million)



The identified system additions with use of the post-Gateway case are notional since the base case has many proxy generation projects modeled that may not be constructed for many years. The abnormal power flow caused by these projects may result in unnecessary thermal overloads. For example, a lumped generator with a Pmax of 1850 MW is modeled at the Windstar 230kV substation and three additional large projects are modeled at the Aeolus 230kV substation. These large generation projects can change the Wyoming system power flow distribution. As a result, the identified additions should be factored into the cost analysis; however, they may not be required. Any system improvement needed beyond those identified prior to implementation of Gateway would be the responsibility of the interconnecting customer. This is due to the fact that there are currently no identified interconnections that supersede this project that make up the large generation projects included in the post-Gateway case.

Alternative A has an approximate pre-Gateway cost of $82 million while alternative C2 has an approximate pre-Gateway cost of $99 million. In addition, alternative A could be constructed in a shorter timeframe than alternative C2 since the project has less to construct. The shorter timeframe is attractive since the new load is scheduled to come on line during 2012 - 2014.

With post-Gateway additions, alternative A costs could increase by approximately $53 million and alternative C2 could increase by approximately $39 million in order to mitigate identified system upgrade requirements. As identified above, these system upgrades should be looked at more closely to determine valid system upgrades once the Energy Gateway project is constructed.

In the pre-Gateway case, alternative A has more power margin for all contingencies, which indicates a stronger system that can serve more load. The larger power margin value is an indication that the system is stronger because it can support more load prior to the power margin going to zero. Conversely, in the post-Gateway case, alternative C2 has more power margin for all contingencies.

Alternative A does not have any transient stability WECC Performance criteria violations with exception of a known frequency excursion of 59.563 Hz at the 73341 NSS2 13.8 bus for loss of the Dave Johnston -

Casper 230kV line. However, Alternative C2 has three other buses that result in a frequency excursion for this contingency, which include the following: the Wygen 2, Wygen 3 and BHPLPLAN 13.8kV buses experienced a low frequency of 59.597 Hz.

2 STUDY ASSUMPTIONS

This section of the report provides details pertaining to the power flow case development and an overview of study assumptions.

2.1 Power Flow Case Modeling

Two power flow cases were developed for both pre and post-Gateway system conditions. For pre-Gateway system conditions, a 2012 heavy winter WECC approved base case was modified to assume 2014 heavy winter system conditions. For post-Gateway system conditions, the Energy Gateway path rating study case was used for these studies.

Following is a summary of modifications for developing the 2014 heavy winter, pre-Gateway power flow base case:

- The 2012 heavy winter (12hw2ap.sav) WECC approved base case was used as the starting point.
- The Standpipe 230 kV project was modeled, which is to be constructed adjacent to the Miners 230 kV and Platte 230 kV substations. (Miners 230 SVC 2x25 Cap Dec 2012.idv)
- Change files from WAPA were inserted into the case. (2-BEPC 2011-12 HW_rev.idv, 1-2012HW Updates BHP_rev.py, 2-CLFP EXPANSION_rev.py)
- Northern Wyoming load revisions based on forecast were inserted into the case. (3-LoadRevisions-PACW.idv)
- Whiskey Peak and Bairoil load is served from Mustang. Great Divide (65730) - Bairoil (65100) 230 kV line is closed and Whiskey Peak (66685) - Platte (66245) 230 kV line open.
- The PacifiCorp Transmission Line Facilities Ratings data base was used to establish winter and summer thermal ratings.

Following is a summary of modifications for developing the 2019 heavy summer, post-Gateway power flow base case:

- The 2019 heavy summer conditions case developed by PacifiCorp and area members used for the Energy Gateway path rating studies was used as the starting point for these studies. This case was originally constructed from the 2010 heavy summer (10hs3b.sav) WECC approved base case.
- The Standpipe 230 kV project was modeled, which is to be constructed adjacent to the Miners 230 kV and Platte 230 kV substations. (Miners 230 SVC 2x25 Cap Dec 2012.idv)
- Change files from WAPA were inserted into the case. (2-BEPC 2011-12 HW_rev.idv, 1-2012HW Updates BHP_rev.py, 2-CLFP EXPANSION_rev.py)

Additional system modifications for each alternative are listed in the power flow section.

2.2 Post-Transient Power Flow Contingencies

The following contingencies were simulated for each corner point case:

1. Loss of Dave Johnston – Difficulty 230 kV line.
2. Loss of Difficulty - Shirley Basin 230 kV line.
3. Loss of Shirley Basin - Freezeout 230 kV line.
4. Loss of Standpipe – Freezeout 230 kV line.
5. Loss of Dave Johnston – Windstar No.2 230 kV line.
6. Loss of Casper – Latigo 230 kV line.
7. Loss of Windstar – Latigo 230 kV line.
8. Loss of Dave Johnston – Casper 230 kV line.
9. Loss of Casper – Spence 230 kV line.

10. Loss of Casper – Claim Jumper 230 kV line.
11. Loss of Casper – Riverton 230 kV line.
12. Loss of Spence – Mustang 230 kV line.
13. Loss of Spence – Badwater 230 kV line.
14. Loss of Mustang – Jim Bridger 230 kV line.
15. Loss of Point of Rocks – Platte 230 kV line.
16. Loss of Platte – Standpipe 230 kV line.
17. Loss of Standpipe – Foote Creek 230 kV line.
18. Loss of Jim Bridger – Point of Rocks – Rock Springs 230 kV line.
19. Loss of Riverton – Wyopo – Atlantic City 230 kV line.
20. Loss of Buffalo – Carr Draw 230 kV line.
21. Loss of Buffalo – Sheridan 230 kV line.
22. Loss of Buffalo – Kaycee – Midwest 230 kV line.
23. Loss of Sheridan – Yellowtail 230 kV line.
24. Loss of Thermopolis – Riverton 230 kV line.
25. Loss of Thermopolis – Badwater 230 kV line.
26. Loss of Oregon Basin – Grass Ck – Thermopolis 230 kV line.
27. Loss of Yellowtail – Oregon Basin 230 kV line.
28. Loss of Dry Fork – Arvada 230 kV line
29. Loss of Sheridan – Tongue River 230 kV line
30. Loss of Dave Johnston - Stegall 230 kV line
31. Loss of Dave Johnston - Laramie River 230 kV line

For loss of the Dave Johnston - Difficulty 230 kV line or loss of the Difficulty - Shirley Basin 230 kV line, the system may experience low voltage in the local area. However, all Dunlap generation will be tripped, as identified in the interconnection agreement, if post-contingency voltage at Shirley Basin 230 kV bus is less than 0.85 per unit for 20 cycles.

The Foote Creek SPS was modeled for contingencies that triggered trip requirements.

2.3 Transient Stability Modeling and Dynamic Data

Transient stability simulations were performed for both pre and post-Gateway conditions.

2.3.1 Transient Stability Modeling

Since actual load composition data is not available, induction motors were represented with the motorw model and default data as recommended by WECC. Induction motors were assumed to make up 20% of the WECC system load. However, for the Wyoming load around the Platte 230kV substation, a 60% induction motor load is used, which is more appropriate for this area. In addition, all proposed load modeled a 60% induction motor load.

Since there is not a good equivalent model for the Foote Creek generation, the full detail model was inserted for the transient stability analysis.

Studies identified that base cases with 445 MW load require an SVC. For these cases, transient stability studies used a CSVGN5 model with generic data. However, Bmax and Bmin values were consistent with identified maximum and minimum values for each project.

2.3.2 Transient Stability Contingencies

Since there are several alternative configurations, transient stability disturbances will be listed in each section of this report.

2.4 Reliability Criteria

A system reliability evaluation consists primarily of determining if thermal overloads exist, that voltages are within criteria (not too high or low), and that the system is stable (the system should not oscillate excessively and generators should remain synchronized with one another). Additional criteria may include assurance that there is sufficient reactive power available. Evaluation of these criteria must be conducted for credible ‘emergency’ conditions that the system might sustain, such as loss of a single or double circuit line, a transformer, or a combination of these facilities. The following reliability criteria were employed for this study:

2.4.1 Transient Stability

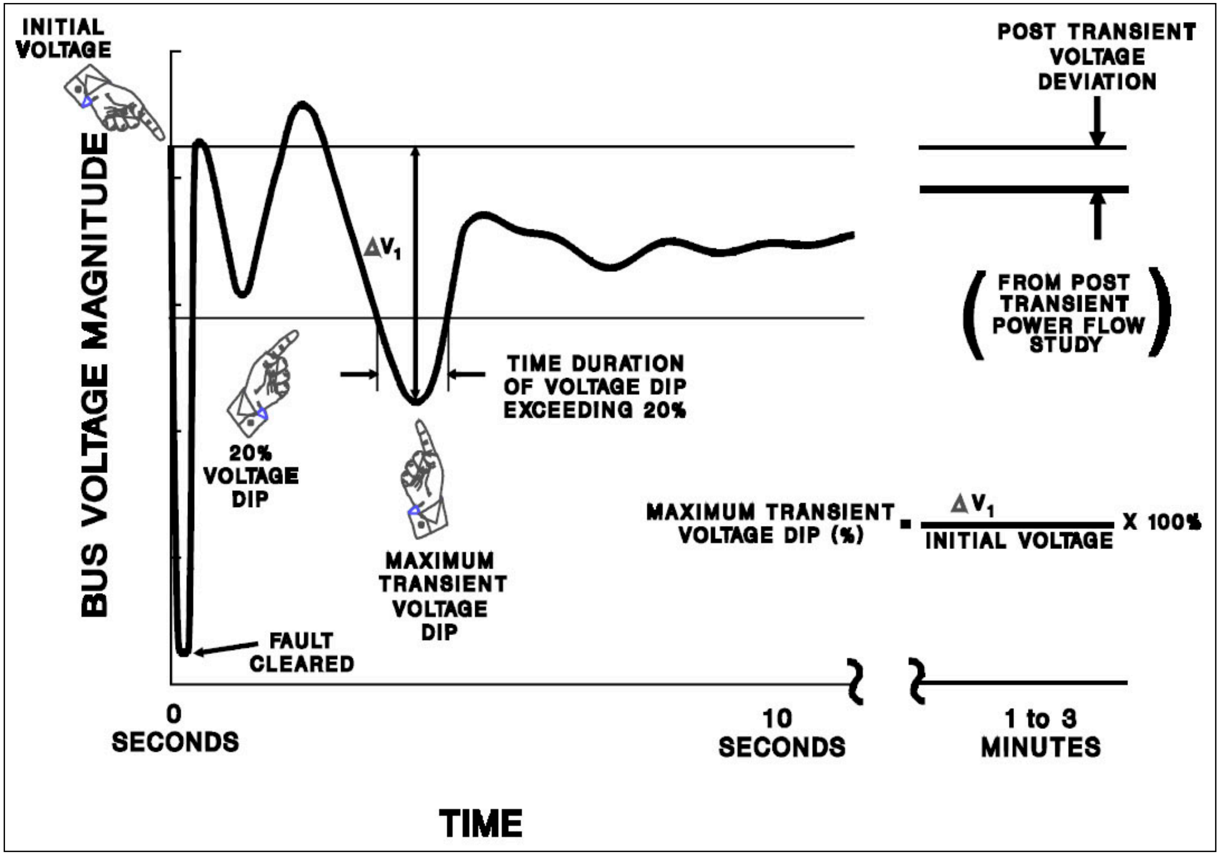
Performance of the transmission system was measured against the following planning criteria: the Western Electricity Coordinating Council (“WECC”) Reliability Criteria, and the North American Electric Reliability Council (“NERC”) Planning Standards.

Table 1 and **Figure 2** are excerpts from the WECC Reliability Criteria. The reliability and performance criteria were applied to the entire WECC transmission system.

Table 1. WECC Disturbance-Performance Table Of Allowable Effects On Other Systems

NERC and WECC Categories	Outage Frequency Associated with the Performance Category (outage/year)	Transient Voltage Dip Standard	Minimum Transient Frequency Standard	Post Transient Voltage Deviation Standard (See Note 2)
A	Not Applicable	Nothing in addition to NERC		
B	≥ 0.33	Not to exceed 25% at load buses or 30% at non-load buses. Not to exceed 20% for more than 20 cycles at load buses.	Not below 59.6Hz for 6 cycles or more at a load bus.	Not to exceed 5% at any bus.
C	0.033 – 0.33	Not to exceed 30% at any bus. Not to exceed 20% for more than 40 cycles at load buses.	Not below 59.0Hz for 6 cycles or more at a load bus.	Not to exceed 10% at any bus.
D	< 0.033	Nothing in addition to NERC		

Figure 2. NERC/WECC Voltage Performance Parameters



3 STUDY METHODOLOGY

This section of the report provides a summary of methods employed for determining the power flow and transient stability results.

3.1 Power Flow

Power flow analysis considers a snapshot in time where transformer tap changers and switchable shunt capacitors have had time to adjust. In addition, a swing bus balances the system during each contingency scenario.

Traditional power flow analysis was used to evaluate thermal (and voltage) performance of the system under N-0 (all lines in-service) conditions. Reported thermal overloads were limited to the condition where a modeled transmission component is loaded over 100% of its appropriate normal MVA rating (as entered in the power flow database).

All power flow analysis was conducted with version 30.3.2 of Siemens PSS/E software.

3.2 Transient Stability

Transient stability analysis is a time-based simulation that assesses performance of the power system during (and shortly following) a contingency. Transient stability studies were performed to ensure system stability following a critical fault on the system. Prior to finalization of the power flow and dynamics data set, a flat-run and bump test was run to ensure true power system behavior is not masked by any remote dynamic modeling anomalies.

USE performed a transient stability analysis based on WECC Disturbance-Performance Criteria for selected system contingencies. Initial transient stability contingencies were performed out to 20 seconds. All 230 kV contingencies modeled a 5 cycle clearing time.

All transient stability simulations were conducted using version 30.3.2 of Siemens PSS/E software.

The Global Bus Voltage and Frequency Scanning Model (vfscan.obj) tracks and records the transient stability behavior of all output channels contained within the binary output file of a transient stability simulation. System damping was assessed visually with the aid of stability plots.

Parameters Monitored to Evaluate System Stability Performance

Rotor Angle

Rotor angle plots provide a measure for determining how the proposed generation unit would swing with respect to other generation units in the area. This information is used to determine if a machine would remain in synchronism or go out-of-step following a disturbance.

Bus Voltage

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 steady state conditions.

Bus Frequency

Bus frequency plots provide information on magnitude and duration of post fault frequency swings with the Project in service. These plots indicate the extent of possible over-frequency or under-frequency, which can occur because of an imbalance between generation and load within an area.

Other Parameters

- Generator Terminal Power
- Generator Terminal Voltage
- Generator Rotor Speed
- Generator Field Voltage
- Voltage Spread
- Frequency Spread

4 RESULTS & FINDINGS

This section of the report provides results obtained in utilizing the above assumptions and methodology. It illustrates all findings associated with power flow and transient stability analysis.

Results in **Section 4.1** are valid; however, they are relativistic in nature due to modeling errors present in cases used in the analysis. Considering that the error has an equal impact on all cases, ranking of alternatives will not change. In addition, the validity of an alternative being removed from consideration still holds true whether it was eliminated based on not being able to meet projected load growth or being cost prohibitive. Two assumptions and one case revision were identified after this study had been deep into analysis, which impacts the outcome of each corner point case. Therefore, selected alternatives from **Section 4.1** will be restudied in **Section 4.2** with the revised case and study assumptions, which include the following:

1. The Dry Fork generator step-up transformer impedance was incorrect (consuming 246 MVAr), which resulted in low pre and post-contingency voltage levels in the surrounding area.
2. An assumption listed in the Study Plan limited corner point cases to a 7% voltage deviation. However, studies in the Wyoming system do not limit results based on this criteria. Instead, bus voltage levels are not allowed to drop below 0.90 per unit. Initially, the 7% was agreed upon; however, after study results were obtained, the 0.90 per unit criteria is to be used. Tri-State buses will adhere to the 7% voltage deviation criteria.
3. Loss of two transmission elements (N-2) in this area of the system will not be simulated; since, WECC has since revised the TPL-001-WECC-CRT-2 - System Performance Criterion. This document identifies that Adjacent Transmission Circuit contingencies do not apply to voltage levels below 300kV.

4.1 Post-Transient Governor Power Flow - Initial Results

Post-transient governor power flow analysis was simulated for all contingencies listed in **Section 2.2**. Results from this section will vet inferior projects from feasible projects, which will then be further analyzed in the transient stability section of this report.

Corner point cases were initially developed with use of winter ratings. After winter rating corner point cases were developed, summer ratings were modeled in the corner point cases to determine the most limiting case based on thermal limitations.

4.1.1 Pre-Gateway, Pre Load

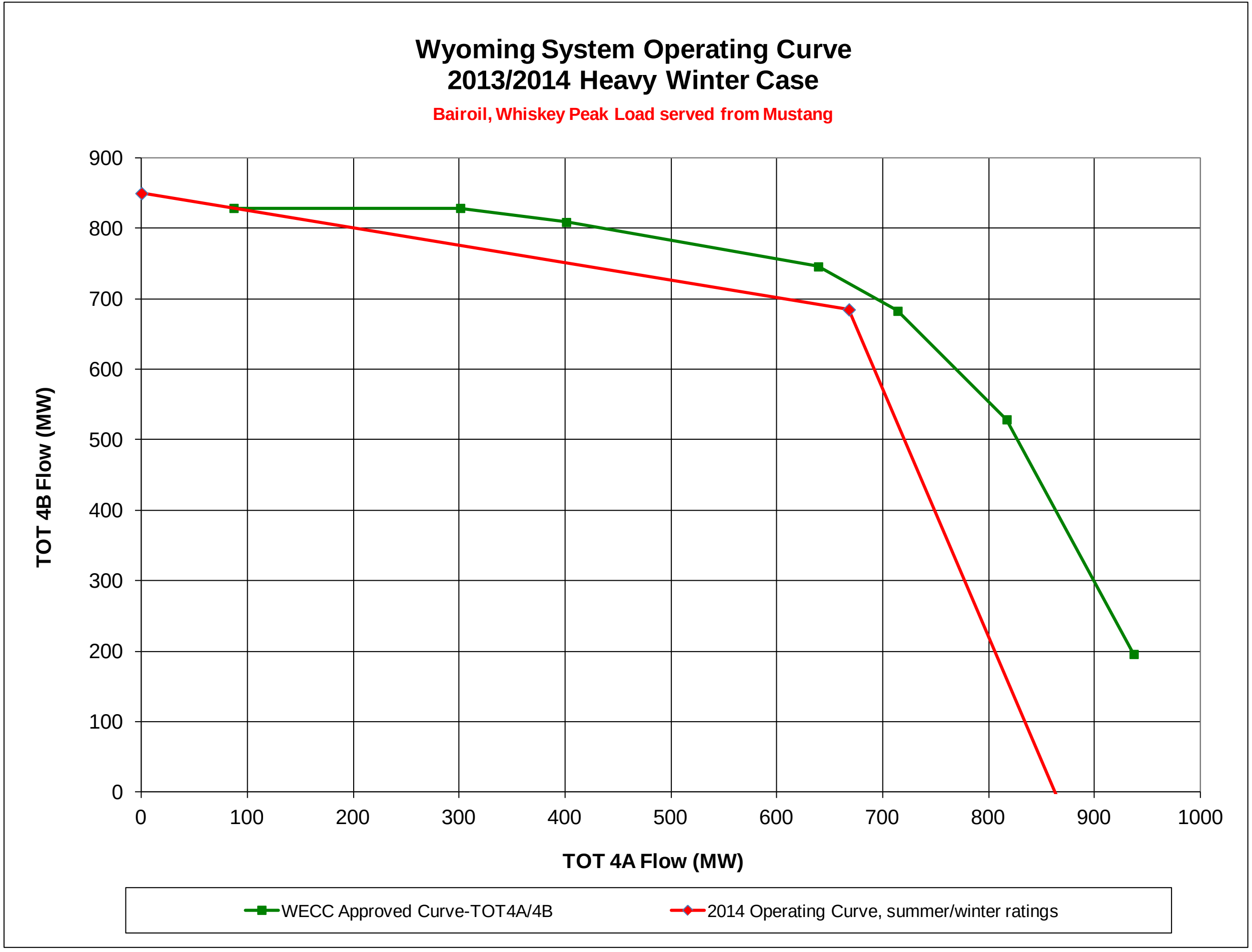
Three (3) corner point base cases with TOT4A and TOT4B flow was developed to determine benchmark flow prior to installation of new load and hence, new transmission projects. Corner point case flows are tabulated in **Table 2a** with limiting elements identified for each data point and a plot of data points is provided in **Figure 2**. Note the curve is the same for either the summer or winter ratings.

Table 2a. Operating Curve Data Points, Pre-Gateway, 0 MW Project Load Modeled

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South† (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Initial Badwater Load (MW)	Limiting Element
1	0	850	-246	0	529	48	N-1: Buffalo-Sheridan 230 kV line [Wyomont 230 kV @ 0.904 pu]
2	668	685	-101	264	882	48	N-1: Platte-Standpipe 230 kV line [Wyomont 230kV @ 7% Vdev]
3	865	-7	601	264	1006	48	N-1: Platte-Standpipe 230 kV line [Riverton 230kV @ 7% Vdev]

† Positive value indicates north to south flow.

Figure 2. Pre-Gateway, Pre-Load TOT4A/TOT4B Operating Curve



Three (3) additional corner point base cases with TOT4A and TOT4B flow were developed with the new 150 MW Project load included to determine benchmark flow prior to new transmission project installations. Two (2) 30 MVAr shunt capacitors were modeled at the Oregon Basin 230 kV bus and two (2) 15 MVAr shunt capacitors were modeled at the Lovell 115 kV bus to support voltage levels.

Table 2b. Operating Curve Data Points, Pre-Gateway, 150 MW Project Load Modeled

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South† (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Badwater Load (MW)	Limiting Element
1	0	910	-163	0	648	198	N-1: Thermopolis-Riverton 230 kV line [Riverton 230/115kV Trans @ 99.8%]
2	668	780	-47	264	978	198	N-1: Platte-Standpipe 230kV line [Spence 230kV Vdev @ 7%]
3	853	161	579	264	1134	198	N-1: Yellowtail-OregonBasin 230 kV line [Basin-NahneJen 115kV @ 99.8%, NahneJen 115kV Vdev @7%, 0.927 pu]

† Positive value indicates north to south flow.

4.1.2 Pre-Gateway, Addition of New 150 MW Load, Transmission Alternatives

The new 150 MW load was modeled at the following locations:

1. Badwater 230 kV (includes EnCana - Moneta):	120 MW
2. Denbury:	10 MW
3. Elk Petroleum:	15 MW
4. US Bentonite	5 MW

The new Badwater load was modeled via two buses, which are radial from the Badwater 230 kV bus, that include Kanson Plant and Compressor Station 230 kV buses. Each bus has two (2) 15 MVAr shunt capacitors modeled to support local area voltage.

Denbury was modeled 4 miles from the DutonBas 115 kV bus (73335), which is a radial line off of the Raderville 115 kV substation. The Spence - Badwater 230 kV line was looped into the new Elk Petroleum 230 kV bus 21.7 miles from the Spence 230 kV bus. The US Bentonite load was modeled on the CasperPP 69 kV bus (65306). All loads modeled a 0.95 power factor.

For all project cases, the TOT4B flow for corner point cases 1 and 2a was increased by 150 MW to ensure the new load can be accommodated on TOT4B. The pre-load cases achieved a TOT4B flow of 850 and 685 MW, respectively for case 1 and 2a. System limitations were mitigated and identified in order to maintain a reliable system.

Following are studied alternatives with the additional 150 MW of new load modeled.

4.1.2.1 Alternative A: Casper - Badwater 230 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 3**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations. Following is a tabulation of corner point case values with winter ratings included.

Table 3 Alternative A: Corner Point Cases, 150 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1000	-249	0	480	150	None
2a	668	835	-103	264	820	150	N-1: Latham-Platte 230 kV [Difficulty 230 kV, Vdev @ 6%]
2b‡	668	890	-264	264	928	0	N-1: Sheridan-Yellowtail 230 kV line [Thermopolis 230 kV Vdev @ 7%]
2c‡	668	990	-241	264	1006	150	N-1: Latham-Platte 230 kV line [Wyomont 230 kV @ 0.903 pu]
3	865	52	700	264	1133	150	N-1: Yellowtail-OregonBasin 230 kV [Nahnejen 115kV @ 6.8% Vdev]

† Positive value indicates north to south flow.

‡ This case modeled 2 - 30 MVAr shunt capacitors at the Sheridan 230 kV bus.

Following is a list of elements that are required to yield reliable operation with no thermal or voltage violations.

1. Construct new 70 mile, 1-1272 ACSR transmission line between the Casper and Badwater 230 kV substations.
2. Install two (2) 30 MVAr shunt capacitors at the Lovell 115 kV substation. Shunt capacitors are required to switch quickly.
3. Install two (2) 30 MVAr shunt capacitors at the Oregon Basin 230 kV substation. Shunt capacitors are required to switch quickly.

The Casper - Badwater 230 kV flow was added to the TOT4B calculation; since, it crosses the TOT4B cutplane.

Shunt capacitors at the Lovell 115 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors at Lovell 115 kV substation are required to mitigate voltage deviations greater than 7% for several buses in the underlying 115 kV system for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail - Frannie - Garland - Oregon Basin 230 kV line.

Shunt capacitors at the Oregon Basin 230 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors are required to support voltage deviations greater than 7% for loss of the Sheridan - Yellowtail 230 kV line. In addition to low voltage, this bus can experience high voltage for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail-Frannie-Garland-Oregon Basin 230 kV line.

Case 2b and 2c are corner point cases of the TOT4A/4B operating curve stressed until a post-contingency limitation is identified. Case 2b (0 MW new load) is limited based on loss of the Sheridan - Yellowtail 230 kV line, which results in a voltage deviation of 7% at the Thermopolis 230 kV bus. Case 2c is limited by loss of the Platte - Latham 230 kV line, which results in voltage levels in the Wyomont 230 kV area to drop near the 0.9 per unit. Note loss of the Platte - Standpipe 230kV line was not the limiting element since the Foote Creek generation trips for this contingency.

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flows were reduced to the limiting elements thermal limit.

Corner point case 2c exceeded the continuous thermal rating of the Sheridan - Yellowtail 230 kV line (820 amps, 326.7 MVA). As a result, TOT4B flow for this corner point case was reduced to 972 MW. All other corner point cases in **Table 3** are valid for both summer and winter system conditions.

4.1.2.2 Alternative B: Thermopolis - Lovell 230 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 4**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations. Following is a tabulation of corner point case values with winter ratings included.

Table 4 Alternative B: Corner Point Cases, 150 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1000	-246	0	638	150	N-1: Thermopolis-Riverton 230 kV [Riverton 230-115kV Tran, 105.8%]
2a	668	835	-98	264	871	150	N-1: Platte-Standpipe 230 kV line [Wyomont, Decker, Arvada 230 kV, Vdev @ 7.0%]
2b‡	668	895	-153	264	978	150	N-1: Spence-Casper 230 kV line [Alcova-Raderville 115 kV @ 100% of 98 MVA rating, has 30 min rating]
3	865	48	700	264	1212	150	N-1: Spence-Casper 230 kV line [Oregon Basin 69kV @ 6.1% Vdev]

† Positive value indicates north to south flow.
‡ This case modeled an additional 30 MVAr shunt capacitor at the Sheridan 230 kV bus.

Following is a list of elements that are required to yield reliable operation with no thermal or voltage violations.

1. Construct new Lovell 230 kV substation.
2. Install new Lovell 230/115 kV, 250 MVA transformer with 9% impedance.
3. Construct new 100 mile (closer to 85 miles; however, for this analysis 100 miles was used due to available information at the time of study), 1272 ACSR transmission line between the Thermopolis and Lovell 230 kV substations.
4. Install two (2) 15 MVAr shunt capacitors at the Lovell 115 kV substation.
5. Install one (1) 30 MVAr shunt capacitor at the Lovell 230 kV substation.
   Shunt capacitor is required to switch quickly.
6. Install two (2) 30 MVAr shunt capacitors at the Oregon Basin 230 kV substation.
   Shunt capacitors are required to switch quickly.
7. Install one (1) 15 MVAr shunt capacitor at the Badwater 230 kV substation.
   Shunt capacitor is required to switch quickly.
8. Install one (1) 30 MVAr shunt capacitor at the Sheridan 230 kV substation.

Items 1 through 3 represent the initial proposed project and items 4 through 8 were included to mitigate voltage violations. Explanations for the additional elements are identified in the following paragraphs.

Shunt capacitors at the Lovell 115 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors at Lovell 230 kV substation are required to mitigate voltage deviations greater than 7% for several buses in the underlying 115 kV system for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail - Frannie - Garland - Oregon Basin 230 kV line.

Shunt capacitors at the Oregon Basin 230 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors are required to support voltage deviations greater than 7% for loss of the Sheridan - Yellowtail 230 kV line. In addition to low voltage, this bus can experience high voltage for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail - Frannie - Garland - Oregon Basin 230 kV line.

Case 1 has a maximum TOT4B flow of 1000 MW (850 MW pre-load + 150 MW new load). For loss of the Riverton - Thermopolis 230 kV line, the Riverton 230/115 kV transformer loads to 105.8% of its emergency thermal rating of 100 MVA. Reducing the TOT4B flow by 110 MW would mitigate this thermal overload. This requirement may be moot since the system does not operate at Yellowtail South flow of 700 MW.

Case 2b is the corner point case of the TOT4A/4B operating curve stressed until there is a post-contingency limitation. Loss of the Spence - Casper 230 kV line results in the Alcova - Raderville 115kV line loading to 100% of its 98 MVA thermal rating. In addition, loss of the Platte - Standpipe 230 kV line results in Wyomont 230 kV voltage dropping near 0.9 per unit.

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit.

Corner point case 2b exceeded the Casper - Riverton 230 kV line rating (940 amps, 374.5 MVA) for loss of the Spence - Casper 230 kV line. As a result, the TOT4B flow for this corner point case was reduced to 860 MW. All other corner point cases in **Table 4** are valid for both summer and winter system conditions.

4.1.2.3 Alternative C: Miracle Mile - Spence - Raderville - Badwater 230 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 5**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations. Following is a tabulation of corner point case values with winter ratings included.

Table 5 Alternative C: Corner Point Cases, 150 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1000	-253	0	488	150	N-1: Thermopolis-Riverton 230kV [Riverton 230-115kV Tran, 99.2% of 100MVA rating]
2a	668	835	-107	235	855	150	N-1: Platte-Standpipe 230kV [Difficult 230kV @ 6.8% Vdev]
2b‡	668	778	-213	264	806	0	N-1: Platte-Standpipe 230kV [Sheridan, Wyomont, Tongue River 230kV, 7.0% Vdev]
2c‡	668	916	-181	264	875	150	N-1: Platte-Standpipe 230kV [Casper 230kV @ 6.9% Vdev]
3	865	53	700	264	1172	150	N-1: Platte-Standpipe 230kV [Riverton 230kV @ 6.8% Vdev]

† Positive value indicates north to south flow.
‡ This case modeled one 30 MVAr shunt at the Spence 230 kV bus.

Following is a list of elements that are required to yield reliable operation with no thermal or voltage violations.

1. Rebuild the Miracle Mile - Alcova No.1 115 kV line (23.8 miles) to operate at 230 kV. Conductor capacity needs to be able to achieve emergency thermal rating of 527 amps (210 MVA).
2. Rebuild the Alcova - Raderville 115 kV line (45.2 miles) to operate at 230 kV.
3. Remove both lines from the Alcova 115 kV substation.
4. Loop the new line into Spence creating a Miracle Mile - Spence 230 kV line and Spence - Raderville 230 kV line.
5. Install new Raderville 230/115 kV, 200 MVA transformer.
6. Construct new 31.5 mile, 1272 ACSR transmission line between the Raderville and Badwater 230 kV substations.
7. Rebuild the Alcova - Miracle Mile No.2 115 kV line (23.8 miles) with 1-1272 ACSR.
8. Install three (3) 30 MVAr shunt capacitors at the Lovell 115 kV substation. Shunt capacitors are required to switch quickly.
9. Install four (4) 30 MVAr shunt capacitors at the Oregon Basin 230 kV substation. Shunt capacitors are required to switch quickly.
10. Install two (2) 30 MVAr shunt capacitors at the Sheridan 230 kV substation.

The Spence - Raderville 230 kV flow was added to the TOT4B calculation (metered at Spence 230 kV end); since, it crosses the TOT4B cutplane.

Items 1 through 6 represent the initial proposed project and items 7 through 10 were included to mitigate both thermal and voltage violations. Explanations for the additional elements are identified in the following paragraphs.

The Alcova - Miracle Mile No.1 115 kV line thermally overloads for a number of contingencies; however, loss of the Spence - Casper 230 kV line results in the highest overload at 176% of its emergency thermal rating of 109 MVA. Therefore, the Alcova-Miracle Mile No.1 115kV conductor capacity needs to be increased to sustain the higher flow.

Shunt capacitors at the Lovell 115 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors at Lovell 115 kV substation are required to mitigate voltage deviations greater than 7% for several buses in the underlying 115 kV system for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail - Frannie - Garland - Oregon Basin 230 kV line.

Shunt capacitors at the Oregon Basin 230 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors are required to support voltage deviations greater than 7% for loss of the Sheridan - Yellowtail 230 kV line. In addition to low voltage, high voltage can be experienced for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail-Frannie-Garland-Oregon Basin 230 kV line.

Case 2b and 2c are corner point cases of the TOT4A/4B operating curve stressed until there is a post-contingency limitation. Case 2b (0 MW new load) is limited based on loss of the Platte - Standpipe 230 kV line, which results in a voltage deviation of 7% for several buses in the Sheridan 230 kV area. Loss of the Platte-Standpipe 230 kV line results in voltage levels in the Wyomont 230 kV area to drop near 0.9 per unit and voltage deviations near 7%.

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit.

Corner point case 3 exceeded the Platte - Standpipe 230 kV line rating with all lines in-service. As a result, the TOT4A flow for this corner point case was reduced to 836 MW. All other corner point cases in **Table 5** are valid for both summer and winter system conditions.

4.1.2.4 Alternative D: Laramie River - Badwater 345 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 6**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations. Following is a tabulation of corner point case values with winter ratings included.

Table 6 Alternative D: Corner Point Cases, 150 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1000	-249	0	383	150	None
2a	668	835	-103	264	748	150	N-1: Platte-Standpipe 230 kV line [Difficult 230kV Vdev @ 6.4%]
2b‡	668	1015	-264	264	990	150	N-1: Platte-Standpipe 230 kV line [Wyomont, Decker, Tongue River 230kV @ 0.90 pu]
3	865	52	700	264	1055	150	N-1: Laramie-Badwater 230kV [Badwater 230 kV Vdev @ 5.5%]

† Positive value indicates north to south flow.

‡ This case modeled 2 - 30 MVAr shunt capacitors and 1 - 30 MVAr fast switching shunt capacitor at the Sheridan 230 kV bus.

Following is a list of elements that are required to yield reliable operation with no thermal or voltage violations.

1. Construct new Badwater 345 kV substation.
2. Install new Badwater 345/230 kV, 300 MVA transformer with 9% impedance.
3. Construct new 200 mile, 1-1272 ACSR transmission line between the Laramie River and new Badwater 345 kV substations.
4. Install one (1) 15 MVAr shunt capacitor at the Badwater 230 kV substation. Shunt capacitor is required to switch quickly.
5. Install two (2) 30 MVAr shunt capacitors at the Lovell 115 kV substation. Shunt capacitors are required to switch quickly.
6. Install three (3) 30 MVAr shunt capacitors at the Oregon Basin 230 kV substation. Shunt capacitors are required to switch quickly.

The Laramie River - Badwater 345 kV flow was added to the TOT4B calculation; since, it crosses the TOT4B cutplane.

Items 1 through 3 represent the initial proposed project and items 4 through 6 were included to mitigate voltage and thermal violations. Explanations for the additional elements are identified in the following paragraphs.

The fast switching shunt capacitor at Badwater 230 kV substation is required to mitigate voltage deviations greater than 7% at the Badwater 230 kV bus for loss of the Badwater - Laramie 345 kV line.

Shunt capacitors at the Lovell 115 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors at Lovell 115 kV substation are required to mitigate voltage deviations greater than 7% for several buses in the underlying 115 kV system for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail - Frannie - Garland - Oregon Basin 230 kV line.

Shunt capacitors at the Oregon Basin 230 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors are required to support voltage deviations greater than 7% for loss of the Sheridan - Yellowtail 230 kV line. In addition to low voltage, high voltage can be experienced for loss of the Oregon Basin-Grass Creek-Thermopolis 230 kV line or loss of the Yellowtail-Frannie-Garland-Oregon Basin 230 kV line.

The Laramie River - Badwater 345 kV line loaded lightly during all lines in-service conditions. However, it supported the Badwater 230 kV voltage during contingency events. If further analysis is pursued with this alternative, series capacitors may be explored to load the line higher during all lines in-service conditions, while supporting system voltage.

Case 2b is the corner point case of the TOT4A/4B operating curve stressed until there is a post-contingency limitation. Loss of the Platte - Standpipe 230 kV line results in voltage levels in the Wyomont 230 kV area to drop near 0.9 per unit.

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit.

Corner point case 2b exceeded the Sheridan - Yellowtail 230 kV line rating with all lines in-service. As a result, the TOT4B flow for this corner point case was reduced to 964 MW. Corner point case 3 exceeded the Platte - Standpipe 230 kV line rating with all lines in-service. As a result, the TOT4A flow for this corner point case was reduced to 854 MW. All other corner point cases in **Table 6** are valid for both summer and winter system conditions.

4.1.2.5 Alternative E: Laramie River - Spence 345 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 7**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations. Following is a tabulation of corner point case values with winter ratings included.

Table 7 Alternative E: Corner Point Cases, 150 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1000	-160	0	370	150	None
2a	668	835	-30	264	747	150	N-1: Platte-Standpipe 230 kV line [Difficult 230 kV Vdev @ 6.4%]
2b‡	668	1108	-219	264	1002	150	N-1: Platte-Standpipe 230 kV line [Wyomont, Decker, Tongue River 230kV @ 0.90 pu]
3	865	57	700	264	1069	150	None

† Positive value indicates north to south flow.
‡ This case modeled two 30 MVAr shunt capacitors at the Sheridan 230 kV bus.

Following is a list of elements that are required to yield reliable operation with no thermal or voltage violations.

1. Construct new Spence 345 kV substation.
2. Install new Spence 345/230 kV, 250 MVA transformer with 9% impedance.
3. Construct new 135 mile, 1-1272 ACSR transmission line between the Laramie River and new Spence 345 kV substations.
4. Install three (3) 15 MVAr shunt capacitors at the Badwater 230 kV substation. Shunt capacitors are required to switch quickly.
5. Install two (2) 30 MVAr shunt capacitors at the Lovell 115 kV substation. Shunt capacitors are required to switch quickly.
6. Install three (3) 30 MVAr shunt capacitors at the Oregon Basin 230 kV substation. Shunt capacitors are required to switch quickly.

Items 1 through 3 represent the initial proposed project and items 4 through 6 were included to mitigate thermal and voltage violations. Explanations for the additional elements are identified in the following paragraphs.

The fast switching shunt capacitors at Badwater 230 kV substation are required to mitigate voltage deviations greater than 7% at the Badwater 230 kV bus for loss of the Badwater - Elk Petroleum 230 kV line or Elk Petroleum - Spence 230 kV line.

Shunt capacitors at the Lovell 230 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors at Lovell 115 kV substation are required to mitigate voltage deviations greater than 7% for several buses in the underlying 115 kV system for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail - Frannie - Garland - Oregon Basin 230 kV line.

Shunt capacitors at the Oregon Basin 230 kV substation are required to support all lines in-service voltage. The fast switching shunt capacitors are required to support voltage deviations greater than 7% for loss of the Sheridan - Yellowtail 230 kV line. In addition to low voltage, high voltage can be experienced for loss of the Oregon Basin - Grass Creek - Thermopolis 230 kV line or loss of the Yellowtail-Frannie-Garland-Oregon Basin 230 kV line.

Case 2b is the corner point case of the TOT4A/4B operating curve stressed until there is a post-contingency limitation. Loss of the Platte - Standpipe 230 kV line results in voltage levels in the Wyomont 230 kV area to drop near the 0.9 per unit level.

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit.

Corner point case 2b exceeded the Sheridan - Yellowtail 230 kV line rating with all lines in-service. As a result, the TOT4B flow for this corner point case was reduced to 1061 MW. Corner point case 3 exceeded the Platte - Standpipe 230 kV line rating with all lines in-service. As a result, the TOT4A flow for this corner point case was reduced to 855 MW. All other corner point cases in **Table 7** are valid for both summer and winter system conditions.

4.1.3 Pre-Gateway, Addition of New 150 MW Load, Generation Alternatives

Addition of generation interconnecting to the new Kanson Plant 230 kV bus, which interconnects to the Badwater 230 kV bus, was analyzed to support the additional 150 MW of new load. Three levels of new generation were analyzed with a reactive capability of +0.9 leading/-0.95 lagging power factor: 25 MW, 50 MW and 150 MW. In addition, a 30 MVAr shunt capacitor was modeled at the Lovell 115 kV bus and the Oregon Basin 230 kV bus. An analysis of a TOT4A flow of 0, 668 and maximum TOT4A flow will be discussed to determine correlations for the various levels of generation.

With a TOT4A flow of zero MW, the Yellowtail South Flow (YTS) increases with higher levels of new generation as shown in **Table 8**. This increase does not affect the system in achieving the maximum TOT4B corner point. These data points were not limited by voltage or thermal limitations; however, in order to further increase these corner point cases, additional resources would be required.

Table 8 New Generation Impacts to TOT4A /TOT 4B Data Point - TOT4A of 0 MW

New Gen (MW)	Net New Load (MW)	TOT4A (MW)	TOT 4B (MW)	YTS (MW)	Limiting Element
25	125	0	850	-115	Not limited
50	100	0	850	-158	Not limited
150	0	0	850	-250	Not limited

With a TOT4A flow of 668 MW, the Yellowtail South Flow (YTS) increases with higher levels of new generation as shown in **Table 9**. All data points were limited by loss of the Platte - Standpipe 230 kV line, which resulted in voltage near 0.9 per unit. With the new 25 MW generator, a voltage deviation of 7% was identified at the Spence 230 kV bus.

With higher generation (lower net load), the TOT4B corner point flow is reduced as seen in the following table. With lower generation, the existing system serves a higher load level, which is captured on the TOT4B metered lines.

Table 9 New Generation Impacts to TOT4A /TOT 4B Data Point - TOT4A of 668 MW

New Gen (MW)	Net New Load (MW)	TOT4A (MW)	TOT 4B (MW)	YTS (MW)	Limiting Element
25	125	668	790	-81	Loss of Platte-Standpipe 230 kV [Spence 230 kV Vdev @ 7%, Arvada, Wyomont, TongueRiver 230kV @ 0.90 pu]
50	100	668	775	-92	Loss of Platte-Standpipe 230 kV [Arvada, Wyomont, TongueRiver, Decker 230kV @ 0.90 pu]
150	0	668	735	-152	Loss of Platte-Standpipe 230 kV [Arvada, Wyomont, TongueRiver, Decker 230kV @ 0.90 pu]

With maximum TOT4A flow, the Yellowtail South Flow (YTS) decreases as the net new load are increased as shown in **Table 10**. The additional load puts pressure on the underlying Yellowtail South 115 kV system. Also, even with a net zero load (new generation minus new load), the YTS flow is less than the 700 MW limit identified by WAPA.

Table 10 New Generation Impacts to TOT4A /TOT 4B Data Point - TOT4A of 865 MW

New Gen (MW)	Net New Load (MW)	TOT4A (MW)	TOT 4B (MW)	YTS (MW)	Limiting Element
25	125	865	122	594	Loss of Yellowtail-Oregon Basin 230 kV [Basin - Nahnejen 230 kV @ 100% of its 109 MVA emergency rating]
50	100	865	85	606	Loss of Yellowtail-Oregon Basin 230 kV [Basin - Nahnejen 230 kV @ 100% of its 109 MVA emergency rating]
150	0	865	-52	645	Loss of Yellowtail-Oregon Basin 230 kV [Basin - Nahnejen 230 kV @ 100% of its 109 MVA emergency rating]

These results identify that the various new generation increments have an effect on the TOT4A/TOT4B operating curve. All three levels of generation can maintain a reliable system; however, the 150 MW generation alternative yields YTS flow that is similar to pre-load cases. The other generation levels result in YTS flow that is higher, which puts additional stress on the surrounding Yellowtail system.

4.1.4 Pre-Gateway, Addition of New 445 MW Load, Transmission Alternatives

The new 445 MW load was modeled at the following locations:

	Location	Load
1.	Badwater 230 kV (includes EnCana - Moneta):	400 MW
2.	Denbury:	20 MW
3.	Elk Petroleum:	20 MW
4.	US Bentonite	5 MW

The new Badwater load was modeled via two buses, which are radial from the Badwater 230 kV bus, that include Kanson Plant and Compressor Station 230 kV buses. Each bus had two (2) 15 MVAr shunt capacitors modeled with the 150 MW load addition. However, with the 445 MW load, additional shunt capacitors were required to support local area voltage, which include the following:

1. Install three (3) 30 MVAr shunt capacitors at the Kanson Plant 230 kV substation.
2. Install three (3) 30 MVAr shunt capacitors at the Compressor Station 230 kV substation.

Denbury was modeled 4 miles from the DutonBas 115 kV bus (73335), which is a radial line off of the Raderville 115 kV substation. The Spence - Badwater 230 kV line was looped into the new

Elk Petroleum 230 kV bus 21.7 miles from the Spence 230 kV bus. The US Bentonite load was modeled on the CasperPP 69 kV bus (65306). All loads modeled a 0.95 power factor.

Four alternatives were selected for further analysis with the 445 MW load, which include Alternative A (Casper - Badwater 230 kV line), Alternative C (Miracle Mile - Spence - Raderville - Badwater 230 kV line), Alternative D (Laramie River - Badwater 345kV line) and Alternative E (Laramie River - Badwater 345kV line) from **section 4.1.2**. An additional alternative, which is a permutation from Alternative C, was investigated to increase the TOT4A limit with Alternative C upgrades with use of summer ratings.

The TOT4B flow for corner point cases 1 and 2a were increased by 445 MW to ensure the new load can be accommodated on TOT4B. The pre-load cases achieved a TOT4B flow of 850 and 685 MW, respectively for case 1 and 2a. System limitations were mitigated and identified in order to maintain a reliable system.

4.1.4.1 Alternative A: Casper - Badwater 230 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 11**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations.

Table 11 Alternative A: Corner Point Cases, 445 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)†	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1295	-230	0	549	445	None
2a	668	1130	-81	264	842	445	None
2b	668	1175	-124	264	900	445	N-1: Casper-Badwater 230kV [Alcova-Raderville 115 kV Line at 100% of 98 MVA rating]
3	865	362	700	264	967	445	None

† Positive value indicates north to south flow.

Following is a list of additional elements (included to the 150 MW Project load additions) that are required to yield reliable operation with no thermal or voltage violations.

1. Install two (2) 15 MVAr shunt capacitors at the Lovell 115 kV substation.
   Shunt capacitors are required to switch quickly.
2. Install one (1) 30 MVAr shunt capacitor at the Oregon Basin 230 kV substation.
   Shunt capacitors are required to switch quickly.
3. Install one (1) 30 MVAr shunt capacitor at the Spence 230 kV substation.
4. Install a +120/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors.

Shunt capacitors located at the Spence 230 kV and Sheridan 230 kV substations are required to support all lines in-service voltage and post-contingency voltage. Loss of the Platte - Standpipe 230 kV line requires these shunt capacitors for voltage support.

A static var system (SVS) located at the Badwater 230 kV substation or Kanson Plant 230 kV is required to control all local area shunt capacitors while providing smooth reactive output during contingency events. Loss of the Platte - Standpipe 230 kV line results in the largest reactive requirement.

Case 2a was stressed until a post-contingency limitation is identified, which is denoted by case 2b. Loss of the Casper - Badwater 230 kV line results in the Alcova - Raderville 115 kV line loading to its emergency thermal rating of 98 MVA (492 amps). Therefore, in order to further increase the TOT4B rating, the Alcova - Raderville 115 kV line would need to use its 30 minute emergency rating of 582 amps (116 MVA).

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit. Following is a tabulation of corner point case values with summer ratings included (changes from winter values are highlighted).

Table 12 Alternative A: Corner Point Cases, 445 MW Load - Summer Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)†	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1295	-230	0	549	445	N-1: Thermopolis-Riverton 230kV [Riverton 230/115 kV Tran, 101.3%]
2a	668	1130	-81	264	842	445	N-1: Platte-Standpipe 230kV [Difficulty 230 kV, Vdev 6.4%]
3	810	356	700	264	991	445	N-0: Platte - Standpipe 230kV

† Positive value indicates north to south flow.

4.1.4.2 Alternative C1: Miracle Mile - Spence - Raderville - Badwater 230 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 15**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations.

Table 15 Alternative C1: Corner Point Cases, 445 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1295	-239	0	548	445	N-1: Thermopolis-Riverton 230kV [Riverton 230-115kV Tran, 119.6%]
2a	668	1130	-92	264	838	445	N-1: Platte-Standpipe 230kV [Casper 230kV, Vdev @ 6.7%]
3	865	359	699	264	1242	445	N-1: Yellowtail-OregonBasin 230kV [Nahnejen 115kV, 0.912 pu]

† Positive value indicates north to south flow.

Following is a list of additional elements (included to the 150 MW Project load additions) that are required to yield reliable operation with no thermal or voltage violations.

1. Install two (2) 15 MVAr shunt capacitor at the Lovell 115 kV substation.
   Shunt capacitor is required to switch quickly.
2. Install three (3) 30 MVAr shunt capacitors at the Oregon Basin 230 kV substation.
   Shunt capacitors are required to switch quickly.
3. Install two (2) 30 MVAr shunt capacitors at the Casper 230 kV substation.
   Shunt capacitors are required to switch quickly.
4. Install two (2) 30 MVAr shunt capacitors at the Spence 230 kV substation.
5. Install five (5) 30 MVAr shunt capacitors at the Sheridan 230 kV substation.
   Shunt capacitors are required to switch quickly.

6. Install a +170/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors.

The Spence - Raderville 230 kV flow was added to the TOT4B calculation (metered at Spence 230 kV end); since, it crosses the TOT4B cutplane.

A static var system (SVS) located at the Badwater 230 kV substation or Kanson Plant 230 kV is required to control all local area shunt capacitors while providing smooth reactive output during contingency events. Loss of the Platte - Standpipe 230 kV line results in the largest reactive requirement.

Shunt capacitors located at the Spence 230 kV and Sheridan 230 kV substations are required to support all lines in-service voltage and post-contingency voltage. Loss of the Platte - Standpipe 230 kV line requires these shunt capacitors for voltage support.

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit. Following is a tabulation of corner point case values with summer ratings included (changes from winter values are highlighted).

Table 16 Alternative C1: Corner Point Cases, 445 MW Load - Summer Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
3	589	355	700	264	858	445	N-1: Platte-Standpipe 230kV [Spence-Casper 230kV line @ 100%]

† Positive value indicates north to south flow.

Case 3 is limited by loss of the Platte - Standpipe 230 kV line that results in the Spence - Casper 230 kV line loading to its emergency thermal limit of 519 MVA (1302 amps). Case 3 has a TOT4A flow that is less than the Case 2a TOT4A flow. Therefore, a corner point case with TOT4A flow between 0 and 589 would need to be developed to complete the curve. However, this alternative is not reasonable since the curve would be severely restricted when summer ratings are in use. Alternative C1 is eliminated due to the large curve derate.

4.1.4.3 Alternative C2: Miracle Mile - Spence - Raderville - Badwater 230 kV line and Rebuild Casper - Alcova No.2 115 kV line to Casper - Alcova 230 kV line.

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 17**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations.

Table 17 Alternative C2: Corner Point Cases, 445 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1295	-239	0	488	445	N-1: Thermopolis-Riverton230kV [Riverton 230/115 kV Tran, 110%]
2a	668	1130	-92	264	783	445	N-1: Spence-Casper 230kV [Spence-Alcova 230kV @ 98.6%]
2b	668	1312	-255	264	807	445	N-1: Spence-Casper 230kV [Spence-Alcova 230kV @ 107.7%]
3	865	359	699	264	1201	445	N-1: Yellowtail-OregonBasin 230kV [Nahnejen 115kV 0.921 pu]

† Positive value indicates north to south flow.

‡ This case modeled one additional 30 MVAr shunt capacitor at the Sheridan 230 kV bus and three 30 MVAr shunt capacitors at the Casper 230 kV bus.

This alternative was further explored to increase the TOT4A limit with use of summer ratings and Alternative C upgrades. Following is a list of additional elements (included to the 150 MW Project load additions) that are required to yield reliable operation with no thermal or voltage violations.

1. Rebuild the Casper - Alcova No.1 115 kV line (23.8 miles) with 1-1272 ACSR conductor to operate at 230 kV and interconnect to a new Alcova 230 kV substation creating a Casper - Alcova 230 kV line.
2. Install Riverton 230/115 kV No.2, 100 MVA transformer.
3. Construct new 13.7 mile, 1-1272 ACSR transmission line between the Alcova 230 kV and Spence 230 kV substations.
4. Install five (5) 15 MVAr shunt capacitor at the Lovell 115 kV substation.
   Shunt capacitor is required to switch quickly.
5. Install two (2) 30 MVAr shunt capacitors at the Spence 230 kV substation.
6. Install three (3) 30 MVAr shunt capacitors at the Sheridan 230 kV substation.
7. Install a +160/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors.

The Spence - Raderville 230 kV flow was added to the TOT4B calculation (metered at Spence 230 kV end); since, it crosses the TOT4B cutplane.

Shunt capacitors at the Spence 230 kV substation are required to support all lines in-service voltage and post-contingency voltage.

A static var system (SVS) located at the Badwater 230 kV substation or Kanson Plant 230 kV is required to control all local area shunt capacitors while providing smooth reactive output during contingency events. Loss of the Platte - Standpipe 230 kV line results in the largest reactive requirement.

Case 2a was stressed until a post-contingency limitation was identified, which is denoted by case 2b. Loss of the Platte - Standpipe 230 kV line results in voltage deviations near 7% in the Casper and Sheridan 230 kV areas. Also, loss of the Spence - Casper 230 kV line results in the Spence - Alcova 230 kV line to exceed its rating of 627 MVA (1572 amps) by 8%. For this higher flow, the proposed conductor would be increased in the project details.

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit. Following is a tabulation of corner point case values with summer ratings included (changes from winter values are highlighted).

Table 18 Alternative C2: Corner Point Cases, 445 MW Load - Summer Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1276	-222	0	474	445	N-0: Sheridan-Yellowtail 230kV 820 amps (327 MVA)
2a	668	795	231	264	976	445	N-1: Alcova-Spence 230kV [Spence-Casper 230 kV line @ 100% 1302 amps (519 MVA)]
3	795	332	700	264	1072	445	N-0: Platte - Standpipe 230kV 1064 amps (424 MVA)

4.1.4.4 Alternative D: Laramie River - Badwater 345 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 19**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations.

Table 19 Alternative D: Corner Point Cases, 445 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1295	-231	0	527	445	N-1: Thermopolis-Riverton 230kV [Riverton 230/115 kV Tran, 104.4%]
2a	668	1130	-86	264	738	445	N-1: Casper-Riverton 230kV line [Alcova-Raderville 115kV @ 99%]
2b	668	1140	-94	264	744	445	N-1: Casper-Riverton 230kV line [Alcova-Raderville 115kV @ 100%]
3	865	359	700	264	1211	445	N-1: Laramie-Badwater 345kV [Difficult 230 kV Vdev @ 5.7%]

† Positive value indicates north to south flow.

Following is a list of additional elements (included to the 150 MW Project load additions) that are required to yield reliable operation with no thermal or voltage violations.

1. Transformer revision from 150 MW load project:
   Install a new Badwater 345/230 kV, 400 MVA transformer.
2. Install Riverton 230/115 kV No.2, 100 MVA transformer.
3. Install two (2) 30 MVAr shunt capacitors at the Sheridan 230 kV substation.
4. Install one (1) 15 MVAr shunt capacitor at the Lovell 115 kV substation.
   Shunt capacitors are required to switch quickly.
5. Install a +90/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors.

Shunt capacitors located at the Sheridan 230 kV substation are required to support all lines in-service and post-contingency voltage.

A static var system (SVS) located at the Badwater 230 kV substation or Kanson Plant 230 kV is required to control all local area shunt capacitors while providing smooth reactive output during contingency events. Loss of the Platte - Standpipe 230 kV line results in the largest reactive requirement.

Case 2b is a corner point case of the TOT4A/4B operating curve stressed until there is a post-contingency limitation. Loss of the Casper - Riverton 230 kV line results in the Alcova-Raderville 115 kV line to exceed its thermal rating of 98 MVA (492 amps).

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit. Following is a tabulation of corner point case values with summer ratings included (changes from winter values are highlighted).

Table 20 Alternative D: Corner Point Cases, 445 MW Load - Summer Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1295	-231	0	527	445	N-0: Sheridan-Yellowtail 230kV 820 amps (327 MVA)
2a	668	1130	-86	264	738	445	N-1: Casper-Riverton 230kV line [Alcova-Raderville 115kV @ 99% of 98 MVA rating]
3	800	358	700	264	1107	445	N-0: Platte - Standpipe 230kV 1064 amps (424 MVA)

c. **Sensitivity Analysis** - Laramie River - Badwater 230 kV line

This sensitivity models a Laramie River - Badwater 230 kV line instead of at the 345 kV voltage level. Winter ratings were used to develop all corner point cases in **Table 21** and summer ratings were used to develop all corner point cases in **Table 22**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations.

Table 21 Sensitivity Analysis: Laramie River - Badwater 230 kV line, Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1295	-225	0	564	445	N-1: Thermopolis-Riverton 230kV [Riverton 230/115 kV Tran @ 107.3%]
2a	668	1130	-79	264	809	445	N-1: Platte-Standpipe 230kV line [Difficult 230kV Vdev @ 6.4%]
2b	668	1190	-132	264	850	445	N-1: Platte-Standpipe 230kV line [ClaimJumper 230kV Vdev @ 7.0%]
3	865	363	700	264	1205	445	N-1: Yellowtail-Oregon Basin 230kV [Nahnejen 115kV Vdev @ 6.3%]

† Positive value indicates north to south flow.

Following is a list of additional elements (included to the 445 MW Project load additions at 345 kV voltage level) that are required to yield reliable operation with no thermal or voltage violations when operated at the 230 kV voltage level.

1. Install one (1) 15 MVAr shunt capacitor at the Lovell 115 kV substation.
   Shunt capacitors are required to switch quickly.

2. Reconductor the Alcova - Raderville 115 kV line (45.2 miles) to 1-795 ACSR. This is required since loss of the Casper-Riverton 230 kV line or loss of the Spence-Casper 230 kV line results in the line loading to 106% of its 98 MVA rating.
3. Install a +100/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors.

The following table has limits identified with use of summer ratings (changes from winter values are highlighted).

Table 22 Sensitivity Analysis: Laramie River-Badwater 230 kV line, Summer Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	0	1285	-216	0	555	445	N-0: Sheridan-Yellowtail 230kV 820 amps (327 MVA)
2a	668	1074	-28	264	773	445	N-0: Platte - Standpipe 230kV 1064 amps (424 MVA)
3	785	360	700	264	1068	445	N-0: Platte - Standpipe 230kV 1064 amps (424 MVA)

† Positive value indicates north to south flow.

4.1.4.5 Alternative E: Laramie River - Spence 345 kV line

a. Winter *Ratings*

Winter ratings were used to develop the corner point case in **Table 23**.

Table 23 Alternative E: Corner Point Cases, 445 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)†	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
2b	668	1130	77	264	939	445	N-1: Spence-Elk Petroleum 230 kV [Alcova-Raderville 115 kV @123% of 98 MVA, voltage issues]

† Positive value indicates north to south flow.

Loss of the Spence - Elk Petroleum 230 kV line or loss of the Badwater - Elk Petroleum 230 kV line results in the Badwater 230kV bus to exhibit low voltage. Initially, a 500 MVAr SVC was modeled at the Badwater 230 kV substation to get a solution; however, the case would not solve for either contingency. After further analysis additional shunt capacitors were modeled at Oregon Basin 230 kV bus (4 - 30 MVAr) and Lovell 115 kV bus (4 - 30 MVAr). With the additional shunt capacitors modeled and the large SVC, a case solution was obtained. However, the Alcova - Raderville 115 kV line exceeded its thermal line rating of 98 MVA (492 amps) by 24% and voltage deviations exceeded 11% at the Copper Mtn 115 kV bus.

Based on study results, it is determined that this alternative is not feasible and therefore will not be further studied.

4.1.5 Pre-Gateway, Addition of New 445 MW Load, Generation Alternatives

Addition of generation interconnecting to the new Kanson Plant 230 kV bus, which interconnects to the Badwater 230 kV bus, was analyzed to support the additional 445 MW of new load. Two levels of new generation were analyzed with a reactive capability of +0.9 leading/-0.95 lagging power factor: 300 MW and 445 MW. In addition, a 30 MVAr shunt capacitor was modeled at the Lovell 115 kV bus and Oregon Basin 230 kV bus. An analysis of a TOT4A flow of 0, 668 and maximum TOT4A flow will be discussed to determine correlations for the various levels of generation.

With a TOT4A flow of zero MW, the Yellowtail South Flow (YTS) increases with higher levels of new generation as shown in **Table 24**. This increase does not affect the system in achieving its maximum TOT4B corner point. These data points were not limited by voltage or thermal limitations; however, additional resources would be required to further increase these corner point cases.

Table 24 New Generation Impacts to TOT4A /TOT 4B Data Point - TOT4A of 0 MW

New Gen (MW)	Net New Load (MW)	TOT4A (MW)	TOT 4B (MW)	YTS (MW)	Limiting Element
300	145	0	850	-115	Not limited
445	0	0	850	-252	Not limited

With a TOT4A flow of 668 MW, the Yellowtail South Flow (YTS) increases with higher levels of new generation as shown in **Table 25**. All data points were limited by loss of the Platte - Standpipe 230 kV line, which resulted in voltage near 0.9 per unit. With the new 300 MW generator, a voltage deviation of 6.9% was identified at the Difficulty 230 kV bus.

With higher generation (lower net load), the TOT4B corner point flow is reduced. The reduced TOT4B flow is a result of the existing system serving a higher load level, which is captured on the TOT4B metered lines.

Table 25 New Generation Impacts to TOT4A /TOT 4B Data Point - TOT4A of 668 MW

New Gen (MW)	Net New Load (MW)	TOT4A (MW)	TOT 4B (MW)	YTS (MW)	Limiting Element
300	145	668	795	-66	Loss of Platte-Standpipe 230 kV [Difficulty 230 kV Vdev @ 6.9%, Arvada, Wyomont, TongueRiver 230kV @ 0.90 pu]
445	0	668	720	-138	Loss of Platte-Standpipe 230 kV [Arvada, Wyomont, TongueRiver, Decker 230kV @ 0.90 pu]

With maximum TOT4A flow, the Yellowtail South Flow (YTS) decreases as the net new load are increased as shown in **Table 26**. The additional load puts pressure on the underlying Yellowtail South 115 kV system. Also, even with a net zero load (new generation minus new load), the YTS flow is less than the 700 MW limit identified by WAPA.

Table 26 New Generation Impacts to TOT4A /TOT 4B Data Point - TOT4A of 865 MW

New Gen (MW)	Net New Load (MW)	TOT4A (MW)	TOT 4B (MW)	YTS (MW)	Limiting Element
300	145	865	152	584	Loss of Yellowtail-Oregon Basin 230 kV [Basin - Nahnejen 230 kV @ 100% of its 109 MVA emergency rating]
445	0	865	-52	645	Loss of Yellowtail-Oregon Basin 230 kV [Basin - Nahnejen 230 kV @ 100% of its 109 MVA emergency rating]

These results identify that the various new generation increments have an effect on the TOT4A/TOT4B operating curve. The two levels of generation can maintain a reliable system; however, the 445 MW generation alternative yields YTS flow that is similar to pre-load cases. The other generation levels result in YTS flow that is higher, which puts additional stress on the surrounding Yellowtail system.

4.2 Post-Transient Governor Power Flow - Revised Case Analysis

Results in **Section 4.1** are valid; however, they are relativistic in nature due to the modeling error present in all cases used in the analysis. Considering that the error has an equal impact on all cases, ranking of alternatives will not change. In addition, the validity of an alternative being removed from consideration still holds true whether it was eliminated based on not being able to meet projected load growth or being cost prohibitive. Two assumptions and one case revision were identified after this study had been deep into analysis, which impacts the outcome of each corner point case. Therefore, selected alternatives from **Section 4.1** will be restudied in this section with the revised case and study assumptions, which include the following:

1. The Dry Fork generator step-up transformer impedance was incorrect (consuming 246 MVAr), which resulted in low pre and post-contingency voltage levels in the surrounding area.
2. An assumption listed in the Study Plan limited corner point cases to a 7% voltage deviation. However, studies in the Wyoming system do not limit results based on this criteria. Instead, bus voltage levels are not allowed to drop below 0.90 per unit. Initially, the 7% was agreed upon; however, after study results were obtained, the 0.90 per unit criteria is to be used. Tri-State buses will adhere to the 7% voltage deviation criteria.
3. Loss of two transmission elements (N-2) in this area of the system will not be simulated; since, WECC has since revised the TPL-001-WECC-CRT-2 - System Performance Criterion. This document identifies that Adjacent Transmission Circuit contingencies do not apply to voltage levels below 300kV.

Post-transient governor power flow analysis was simulated for all contingencies listed in **Section 2.2**. Results from this section will vet inferior projects from feasible projects, which will then be further analyzed in the transient stability section of this report.

Corner point cases were initially developed with use of winter ratings. After winter rating corner point cases were developed, summer ratings were modeled in corner point cases to determine thermal limitations with the lower ratings.

4.2.1 Pre-Gateway, Pre Load

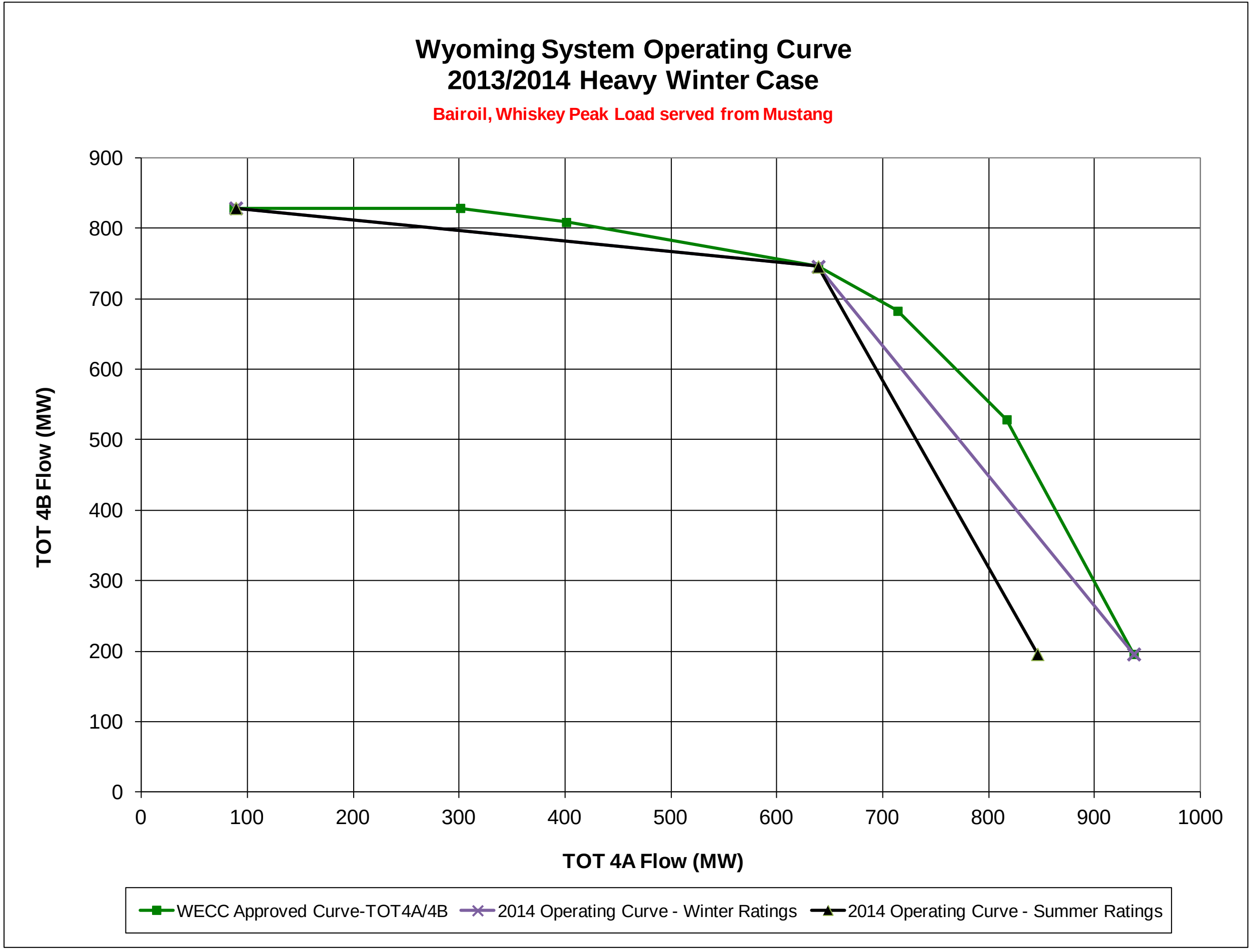
Three (3) corner point base cases were developed based on benchmark TOT4A and TOT4B flow from prior WECC studies. Since, these corner point cases have been approved by WECC members; they will be the starting point for new load additions. Corner point case flows are tabulated in **Table 27a** and a plot of the data points is provided in **Figure 3**.

Table 27a. Operating Curve Data Points, Pre-Gateway, 0 MW Project Load Modeled

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South† (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Initial Badwater Load (MW)	Limiting Element
Winter Ratings							
1	89	829	-225	0	635	48	None identified
2	639	746	-155	264	711	48	None identified
3	937	196	386	264	1260	48	None identified
Summer Ratings							
3	846	196	384	264	1091	48	N-0: Platte-Standpipe 230kV

† Positive value indicates north to south flow.

Figure 3. Pre-Gateway, Pre-Load TOT4A/TOT4B Operating Curve



Three (3) additional corner point base cases were developed with the new 150 MW Project load included to determine benchmark flow prior to new transmission project installations.

Table 27b. Operating Curve Data Points, Pre-Gateway, 150 MW Project Load Modeled

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South† (MW)	Yellowtail South Generation (MW)	TOT3 (MW)	Badwater Load (MW)	Limiting Element
1	89	925	-174	0	765	198	N-1: Elk Petroleum-Badwater 230 kV line [Badwater 230kV @ 0.93 pu, reactive limited]
2	639	830	-92	264	938	198	N-1: Platte-Standpipe 230kV line [Elk Petroleum 230kV, 0.906 pu]
3	747	196	544	264	1029	198	N-1: Yellowtail-OregonBasin 230 kV line [NahneJen 115kV, 0.907 pu]

† Positive value indicates north to south flow.

4.2.2 Pre-Gateway, Addition of New 445 MW Load, Transmission Alternatives

The new 445 MW load was modeled at the following locations:

1. Badwater 230 kV (includes EnCana - Moneta):	400 MW
2. Denbury:	20 MW
3. Elk Petroleum:	20 MW
4. US Bentonite	5 MW

The new Badwater load was modeled via two buses, which are radial from the Badwater 230 kV bus, that include Kanson Plant and Compressor Station 230 kV buses. Each bus had two (2) 15 MVAr shunt capacitors modeled with the 150 MW load addition. However, with the 445 MW load, additional shunt capacitors were required to support local area voltage, which include the following:

1. Install three (3) 30 MVAr shunt capacitors at the Kanson Plant 230 kV substation.
2. Install three (3) 30 MVAr shunt capacitors at the Compressor Station 230 kV substation.

Denbury was modeled 4 miles from the DutonBas 115 kV bus (73335), which is a radial line off of the Raderville 115 kV substation. The Spence - Badwater 230 kV line was looped into the new Elk Petroleum 230 kV bus 21.7 miles from the Spence 230 kV bus. The US Bentonite load was modeled on the CasperPP 69 kV bus (65306). All loads modeled a 0.95 power factor.

Two alternatives were selected for further analysis with the 445 MW load, which include Alternative A (Casper - Badwater 230 kV line) and Alternative C2 (Miracle Mile - Spence - Raderville - Badwater 230 kV line) from **section 4.1**.

The TOT4B flow for corner point cases 1 and 2a were increased by 445 MW to ensure the new load can be accommodated on TOT4B. The pre-load cases achieved a TOT4B flow of 829 and 746 MW, respectively for case 1 and 2a. System limitations were mitigated and identified in order to maintain a reliable system with the new load modeled.

For case 3 in alternatives A and C2, the TOT4B flow was also increased by the load amount of 445 MW in order to increase the YTS flow to an agreed 600 MW. In addition, Yellowtail South Flow greater than 600 MW with high TOT4A flow does not seem probable.

4.2.2.1 Alternative A: Casper - Badwater 230 kV line

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 28**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations.

Table 28 Alternative A: Corner Point Cases, 445 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)†	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	12	1274	-211	0	555	445	None
2a	639	1191	-137	264	839	445	None
2b	639	1210	-153	264	812	445	N-1: Casper-Badwater 230kV [Alcova-Raderville 115 kV at 98MVA thermal limit]
3	937	460	600	264	1061	445	N-1: Yellowtail-Oregon Basin 230kV [Nahnejen 115kV 0.90 pu]

† Positive value indicates north to south flow.

Following is a total list of elements that are required to yield reliable operation with no thermal or voltage violations.

1. Construct a new 70 mile, 1-1272 ACSR transmission line between the Casper and Badwater 230 kV substations. This line would have Tri-State thermal line ratings of 1538/1661 amps (612/661 MVA) normal/emergency.
2. Install three (3) 15 MVAr shunt capacitors at the Lovell 115 kV substation. Shunt capacitors are required to switch quickly.
3. Install two (2) 30 MVAr shunt capacitors at the Oregon Basin 230 kV substation. Shunt capacitors are required to switch quickly.
4. Install a +110/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors.

The Casper - Badwater 230 kV flow was added to the TOT4B calculation (metered at Casper 230 kV end); since, it crosses the TOT4B cutplane.

A static var system (SVS) located at the Badwater 230 kV substation or Kanson Plant 230 kV is required to control all local area shunt capacitors while providing smooth reactive output during contingency events. Loss of the Platte - Standpipe 230 kV line results in the largest reactive requirement.

Case 2a was stressed until a post-contingency limitation is identified, which is denoted by case 2b. Loss of the Casper - Badwater 230 kV line results in the Alcova - Raderville 115 kV line loading to its emergency thermal rating of 98 MVA (492 amps). Therefore, in order to further increase the TOT4B rating beyond 1210 MW, the Alcova - Raderville 115 kV line would need to use its 30 minute emergency rating of 116 MVA.

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit. Following is a tabulation of corner point case values with summer ratings included (changes from winter values are highlighted).

Table 29 Alternative A: Corner Point Cases, 445 MW Load - Summer Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)†	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	12	1274	-211	0	555	445	None
2a	639	1191	-137	264	839	445	None
3	805	454	600	264	802	445	N-0: Platte-Standpipe 230kV at 424 MVA thermal limit

† Positive value indicates north to south flow.

4.2.2.2 Alternative C2: Miracle Mile - Spence - Raderville - Badwater 230 kV line and Rebuild Casper - Alcova No.2 115 kV line to Casper - Alcova 230 kV line.

a. Winter *Ratings*

Winter ratings were used to develop all corner point cases in **Table 30**. Corner point cases were checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions and that there were no voltage violations.

Table 30 Alternative C2: Corner Point Cases, 445 MW Load - Winter Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)†	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	87	1274	-218	0	572	445	Loss of Thermopolis-Riverton 230kV, Riverton 230/115 kV Transformer at 100 MVA rating
2a	639	1191	-143	264	757	445	Loss of Spence-Casper 230kV line, Spence-Alcova 230kV at 98% of 442 MVA rating
2b‡	639	1345	-283	264	864	445	Loss of Platte-Standpipe 230kV, Sheridan-Yellowtail 230 kV line At 525 MVA thermal limit
3	937	454	600	264	1135	445	Loss of Yellowtail-Oregon Basin 230kV, Nahnejen 115kV 0.90 pu

† Positive value indicates north to south flow.
‡ This case modeled three (3) additional 30 MVAr shunt capacitors at the Sheridan 230 kV bus and a SVC with maximum output of 210 MVAr at the Badwater 230kV bus.

Following is a total list of elements that are required to yield reliable operation with no thermal or voltage violations.

1. Rebuild the Casper - Alcova No.1 115 kV line (23.8 miles) with 1-795 ACSS conductor to operate at 230 kV and interconnect to a new Alcova 230 kV substation creating a Casper - Alcova 230 kV line. The 1-1272 ACSR conductor was not sufficient for this line due to loss of the Spence-Casper 230 kV line resulting in this line exceeding the 442 MVA line rating by 22% with use of Case 3.
2. Remove both Alcova-Miracle Mile lines from the Alcova 115 kV substation.
3. Rebuild the Miracle Mile - Alcova No.1 115 kV line (23.8 miles) to operate at 230 kV.
4. Rebuild the Alcova - Raderville 115 kV line (45.2 miles) to operate at 230 kV. The new Alcova-Spence 230kV line (13.7 miles) requires 1-795 ACSS conductor. The 1-1272 ACSR conductor was not sufficient for this line due to loss of the Spence-Casper 230 kV line resulting in this line exceeding the 442 MVA line rating by 30% with use of Case 3.
5. Loop the new Alcova - Raderville 230kV line into Spence creating an Alcova - Spence 230 kV line and Spence - Raderville 230 kV line.
6. Install new Raderville 230/115 kV, 200 MVA transformer.
7. Construct new 31.5 mile, 1-795 ACSS transmission line between the Raderville and Badwater 230 kV substations. The 1-1272 ACSR conductor was not used for this line due to loss of the Spence-Elk Petroleum 230 kV line or Elk Petroleum-Badwater 230 kV line resulting in this line exceeding the 442 MVA line rating by 7% with use of Case 1.
8. Rebuild the Alcova - Miracle Mile No.2 115 kV line (23.8 miles) with 1-1272 ACSR.
9. Install four (4) 15 MVAr shunt capacitors at the Lovell 115 kV substation. Shunt capacitors are required to switch quickly.
10. Install one (1) 30 MVAr shunt capacitor at the Oregon Basin 230 kV substation.
11. Install two (2) 30 MVAr shunt capacitors at the Spence 230 kV substation.
12. Install a +120/-20 MVAr static var system (SVS) at the Badwater 230 kV substation. The SVS will control the Kanson Plant and Compressor Station 230 kV shunt capacitors.

The Spence - Raderville 230 kV flow was added to the TOT4B calculation (metered at Spence 230 kV end); since, it crosses the TOT4B cutplane.

Shunt capacitors at the Spence 230 kV substation are required to support all lines in-service voltage and post-contingency voltage.

A static var system (SVS) located at the Badwater 230 kV substation or Kanson Plant 230 kV is required to control local area shunt capacitors while providing smooth reactive output during contingency events. Loss of the Platte - Standpipe 230 kV line results in the largest reactive requirement.

Case 2a was stressed until a post-contingency limitation was identified, which is denoted by case 2b. Loss of the Platte - Standpipe 230 kV line results in the Sheridan-Yellowtail 230 kV line loading to its emergency thermal limit of 524.6 MVA (1317 amps).

b. Summer *Ratings*

Summer ratings replaced winter ratings in the developed corner point cases. Corner point cases were then checked to ensure that line ratings were not exceeded for both all lines in-service and post-contingency conditions. If thermal ratings were exceeded, the corner point case flow was adjusted until flow was at its thermal limit. Following is a tabulation of corner point case values with summer ratings included (changes from winter values are highlighted).

Table 31 Alternative C2: Corner Point Cases, 445 MW Load - Summer Ratings

Case	TOT4A (MW)	TOT4B (MW)	Yellowtail South (MW)†	Yellowtail South Generation (MW)	TOT3 (MW)	Project Load (MW)	Limiting Element
1	87	1261	-207	0	563	445	All Lines In-Service: Sheridan-Yellowtail 230kV at 402 MVA thermal limit
2a	639	875	153	264	710	445	Loss of Alcova-Spence 230kV, Casper-Spence 230kV at 519 MVA thermal limit
3	783	450	600	264	848	445	All Lines In-Service: Platte-Standpipe 230kV at 424 MVA thermal limit

† Positive value indicates north to south flow.

4.2.3 Pre-Gateway, PV Analysis

The PV values or power margin was determined with use of the pre-Gateway case. The PV values were determined for both Alternative A and C2 projects. Power margin can be defined as the additional load that can be added to the Badwater 230kV bus before voltage drops below acceptable levels. Acceptable voltage with the system intact is 0.95 and for contingency conditions it is 0.90 per unit. In addition, the PV curves can be used to determine voltage stability at all buses.

For the PV analysis, the Badwater 230kV bus was defined as the sink and a subsystem of buses in the surrounding area were the source. In addition, all solution parameters (TCUL, switchable shunt capacitors, area interchange and phase-shift transformers) were disabled as the load was incremented.

PV values for Alternative A are tabulated in **Table 32**. The table provides progression of each phase, which includes, the base case condition prior to any load or projects, the base case with Alternative A components modeled, base case with Alternative A components and 150 MW of new load and base case with Alternative A components and 445 MW of new load. Each case has corner point cases 1, 2 and 3, which is identified by its TOT4A/4B flow.

Table 32 PV values, Alternative A: Casper-Badwater 230kV line

Contingency / (TOT4A/4B)	**Base Case**			**Base Case + Alternative A**			**Base Case + Alternative A + 150 MW Load**			**Base Case + Alternative A + 445 MW Load**		
	89/829 (MW)	**639/746 (MW)**	**937/196 (MW)**	**89/829 (MW)**	**639/746 (MW)**	**937/196 (MW)**	**0/1000 (MW)**	**668/835 (MW)**	**865/0 (MW)**	**0/1274 (MW)**	**639/1191 (MW)**	**937/459 (MW)**
All Lines In-Service	207	212	203	371	376	374	305	264	244	279	238	237
Platte-Standpipe 230kV	193	89	44	359	210	165	295	16	72	266	24	24
Casper-Badwater 230kV	NA	NA	NA	187	208	203	121	98	93	54	34	34
Casper-Spence 230kV	156	161	125	332	319	295	261	191	180	224	154	154
Badwater-Thermopolis 230kV	121	100	83	307	284	264	234	189	186	192	157	157
Sheridan-Yellowtail 230kV	123	117	203	288	275	378	222	173	189	197	125	125

Based on these results, power margin is available for all corner point cases. However, loss of the Platte-Standipe 230kV line results in the lowest power margin values.

PV values for Alternative C2 are tabulated in **Table 33**. The table provides progression of each phase, which includes, the base case condition prior to any load or projects, the base case with Alternative C2 components modeled, base case with Alternative C2 components and 150 MW of new load and base case with Alternative C2 components and 445 MW of new load. Each case has corner point cases 1, 2 and 3, which is identified by its TOT4A/4B flow.

Table 33 PV values, Alternative C2: Miracle Mile - Spence - Raderville - Badwater 230 kV line and Rebuild Casper - Alcova No.2 115 kV line to Casper - Alcova 230 kV line.

Contingency / (TOT4A/4B)	**BaseCase**			**BaseCase + Alt C2**			**BaseCase + AltC2 + 150 MW Load**			**BaseCase + Alt C2 + 445 MW Load**		
	89/829 (MW)	**639/746 (MW)**	**937/196 (MW)**	**87/829 (MW)**	**639/746 (MW)**	**937/196 (MW)**	**0/1000 (MW)**	**668/835 (MW)**	**865/0 (MW)**	**0/1274 (MW)**	**639/1191 (MW)**	**937/454 (MW)**
All Lines In-Service	207	212	203	505	521	509	254	245	187	287	206	194
Platte-Standpipe 230kV	193	89	44	496	407	368	242	35	9	270	7	12
Casper-Spence 230kV	NA	NA	NA	463	475	456	314	201	141	238	151	132
Badwater-Thermopolis 230kV	156	161	125	440	428	412	177	167	146	210	122	119
Spence-Raderville 230kV	NA	NA	NA	375	399	396	128	137	94	0.92 - 124	61	0.91 - 61
Spence-ElkPetroleum 230kV	NA	NA	NA	382	404	402	135	142	103	0.91 - 140	72	76

Based on these results, power margin is available for all corner point cases. However, power margins with the 150 MW and 445 MW load cases are reduced. Loss of the Platte-Standpipe 230kV line results in low power margins for the 150MW load and 445 MW load cases.

With the 445 MW load case, with minimum TOT4A flow and maximum TOT4B flow, two contingencies did not result in the post-contingency voltage getting to 0.90 per unit. The case solution blew up prior to it reaching 0.90 per unit. This also was present for the maximum TOT4A flow case for loss of the Spence-Raderville 230kV line.

All PV plots are provided in **Appendix B**.

4.2.4 Post-Gateway, Addition of New 445 MW Load, Transmission Alternatives

The new 445 MW load was modeled at the following locations:

1.	Badwater 230 kV (includes EnCanaEnCana - Moneta):	400 MW
2.	Denbury:	20 MW
3.	Elk Petroleum:	20 MW
4.	US Bentonite	5 MW

The new Badwater load was modeled via two buses, which are radial from the Badwater 230 kV bus, that include Kanson Plant and Compressor Station 230 kV buses. Each bus had two (2) 15 MVAr shunt capacitors modeled with the 150 MW load addition. However, with the 445 MW load, additional shunt capacitors were required to support local area voltage, which include the following:

1. Install three (3) 30 MVAr shunt capacitors at the Kanson Plant 230 kV substation.
2. Install three (3) 30 MVAr shunt capacitors at the Compressor Station 230 kV substation.

Denbury was modeled 4 miles from the DutonBas 115 kV bus (73335), which is a radial line off of the Raderville 115 kV substation. The Spence - Badwater 230 kV line was looped into the new Elk Petroleum 230 kV bus 21.7 miles from the Spence 230 kV bus. The US Bentonite load was modeled on the CasperPP 69 kV bus (65306). All loads modeled a 0.95 power factor.

Two alternatives were selected for further analysis with the 445 MW load, which include Alternative A (Casper - Badwater 230 kV line) and Alternative C2 (Miracle Mile - Spence - Raderville - Badwater 230 kV line) from **section 4.1**.

The maximum TOT4B flow from the benchmark case was increased by 445 MW to ensure the new load can be accommodated on TOT4B. The pre-load case achieved a TOT4B flow of 829 MW; therefore, the post load case modeled a TOT4B flow of 1274 MW (829 + 445 MW).

4.2.4.1 Alternative A: Casper - Badwater 230 kV line

The post-Gateway case models summer ratings. Therefore, thermally overloaded elements may not actually be violations based on a path rating study, which has used winter ratings in past studies.

Following is a list of additional elements (in addition to **Section 4.2.2.1**) that are required to yield reliable operation with no thermal or voltage violations.

1. Construct a new 70 mile, 2-1272 ACSR transmission line between the Casper and Badwater 230 kV substations. This line would have Tri-State thermal line ratings of 3076/3322 amps (1224/1322 MVA) normal/emergency.

   The double bundled conductor is specified in order to maintain acceptable voltage levels during contingency events. With a single conductor, loss of the Aeolus-Anticline 500kV line and 600 MW gen trip yields voltage less than 0.90 per unit in the Casper 115kV system. In addition, loss of the Spence-Elk Petroleum 230kV line or loss of the Badwater-Elk Petroleum 230kV line results in voltage dropping below 0.90 per unit at several 230kV buses in addition to the Casper 115kV system.
2. Install one (1) 30 MVAr shunt capacitor at the Badwater 230 kV substation.
   Shunt capacitor is required to switch quickly.
3. Install one (1) 30 MVAr shunt capacitor at the Casper 230 kV substation.
   Shunt capacitor is required to switch quickly.
4. Install two (2) 20 MVAr shunt capacitors at the Refinery 115 kV substation.
   Shunt capacitors are required to switch quickly.
5. Install one (1) 15 MVAr shunt capacitor at the Denbury 115 kV substation.
   Shunt capacitors are required to switch quickly.

Following is a tabulation of transmission elements that exceeded their summer thermal ratings with use of the post-Gateway power flow case:

Table 34 Thermally Affected Elements, Alternative A

Contingency	Affected Element	Thermal Rating		% Loading
		MVA1	MVA2	
N-0: All Lines In-Service	Sheridan-Yellowtail 230kV	327	402	101%
N-1: Casper-Riverton 230kV	Alcova-Raderville 115kV	98	98	118%
N-1: Casper-Badwater 230kV	Alcova-Raderville 115kV	98	98	116%
N-1: Thermopolis-Badwater 230kV	Alcova-Raderville 115kV	98	98	111%
N-1: Spence-Elk Petroleum 230kV	Alcova-Raderville 115kV	98	98	109%
N-1: Badwater-Elk Petroleum 230kV	Alcova-Raderville 115kV	98	98	109%
N-1: Sheridan-Yellowtail 230kV	Alcova-Raderville 115kV	98	98	109%
N-1: Aeolus-Anticline 500kV w/600 MW gen trip	Alcova-Raderville 115kV	98	98	108%
N-1: DJ-Shirley Basin 230kV	Alcova-Raderville 115kV	98	98	104%
N-1: Populus-Anticline 500kV	Alcova-Raderville 115kV	98	98	101%
N-1: Aeolus-Windstar 230kV	Alcova-Raderville 115kV	98	98	101%
N-1: Spence-Casper 230kV	Alcova-Raderville 115kV	98	98	101%
N-1: Buffalo-Sheridan 230kV	Alcova-Raderville 115kV	98	98	101%
N-1: Casper-Badwater 230kV	Badwater-Elk Petroleum 230kV	442	442	105%
N-1: Jim Bridger-PtRocks-RockSpring 230kV	Jim Bridger-Rock Springs 230kV	424	517	105%
N-1: Casper-Badwater 230kV	Spence-Elk Petroleum 230kV	442	442	110%
N-1: Windstar-Latigo 230kV	Windstar-DJ No.1 230kV	380	380	107%
N-1: Casper-Latigo 230kV	Windstar-DJ No.1 230kV	380	380	107%

The Sheridan-Yellowtail 230kV line slightly exceeds its continuous thermal rating. A reduction of TOT4B flow by 7 MW would mitigate the thermal overload.

The Alcova-Raderville 115kV line has a 30 minute emergency rating of 116 MVA, which would be sufficient to mitigate the thermally overloaded elements.

WAPA is determining whether an emergency rating can be used for the Badwater-ElkPetroleum-Spence 230kV line sections. If not, these transmission lines will need to be reconstructed with a higher ampacity conductor.

The Jim Bridger-Rock Springs 230kV line exceeds its emergency thermal rating by 5% for loss of the Jim Bridger-PtRocks-Rock Springs 230kV line. Perhaps an analysis can be completed to determine if this emergency rating can be increased by 5%. If not, this transmission line will need to be reconstructed with a higher ampacity conductor.

The Windstar-Dave Johnston No.1 230 kV line exceeds its emergency thermal limit of 380 MVA. Reconstruct line with a higher ampacity conductor.

4.2.4.2 Alternative C2: Miracle Mile - Spence - Raderville - Badwater 230 kV line and Rebuild Casper - Alcova No.2 115 kV line to Casper - Alcova 230 kV line.

The post-Gateway case models summer ratings. Therefore, thermally overloaded elements may not actually be violations based on a path rating study, which has used winter ratings in past studies.

Following is a list of additional elements (in addition to **Section 4.2.2.2**) that are required to yield reliable operation with no thermal or voltage violations.

1. Install three (3) 30 MVAr shunt capacitors at the Badwater 230 kV substation.
   Shunt capacitors are required to switch quickly.

2. Install two (2) 20 MVAr shunt capacitors at the Refinery 115 kV substation.
   Shunt capacitors are required to switch quickly.

Loss of the Aeolus - Shirley Basin 230 kV line results in the Sheridan 230 kV voltage dropping to 0.904 per unit, which is the limiting contingency.

Following is a tabulation of transmission elements that exceeded their thermal ratings with use of the post-Gateway power flow case:

Table 35 Thermally Affected Elements, Alternative C2

Contingency	Affected Element	Thermal Rating		% Loading
		MVA1	MVA2	
N-0: All Lines In-Service	Sheridan-Yellowtail 230kV	327	402	110%
N-1: Aeolus-Shirley Basin 230kV	Sheridan-Yellowtail 230kV	327	402	105%
N-1: Aeolus-Anticline 500kV	Sheridan-Yellowtail 230kV	327	402	104%
N-1: Populus-Anticline 500kV	Sheridan-Yellowtail 230kV	327	402	104%
N-1: DJ-Shirley Basin 230kV	Sheridan-Yellowtail 230kV	327	402	101%
N-1: Windstar-Latigo 230kV	Windstar-DJ No.1 230kV	380	380	111%
N-1: Casper-Latigo 230kV	Windstar-DJ No.1 230kV	380	380	111%
N-1: Aeolus-Windstar 230kV	Windstar-DJ No.1 230kV	380	380	101%
N-1: Spence-Raderville 230kV	Spence-Elk Petroleum 230kV	442	442	125%
N-1: Badwater-Raderville 230kV	Spence-Elk Petroleum 230kV	442	442	113%
N-1: DryFork-Arvada 230kV	Sheridan-Buffalo 230kV	327	402	103%
N-1: Spence-Raderville 230kV	Badwater-Elk Petroleum 230kV	442	442	120%
N-1: Badwater-Raderville 230kV	Badwater-Elk Petroleum 230kV	442	442	108%

The Sheridan-Yellowtail 230kV line exceeds its continuous thermal rating by 10%. This 42.2 mile transmission line will need to be reconstructed with a larger (i.e., 1-1272 ACSR) conductor.

The Windstar-Dave Johnston No.1 230 kV line exceeds its emergency thermal limit of 380 MVA. Reconstruct line with a higher ampacity conductor.

WAPA is determining whether an emergency rating can be used for the Badwater-ElkPetroleum-Spence 230kV line sections. If not, these transmission lines will need to be reconstructed with a higher ampacity conductor.

The Sheridan-Buffalo 230kV line exceeds its emergency thermal rating by 3% for loss of the Dry Fork-Arvada 230kV line. Perhaps an analysis can be completed to determine if this emergency rating can be increased by 3%. If not, this transmission line will need to be reconstructed with a higher ampacity conductor.

4.2.5 Post-Gateway, PV Analysis

The PV values or power margin was determined with use of the post-Gateway case. The PV values were determined for both Alternative A and C2 projects. Power margin can be defined as the additional load that can be added to the Badwater 230kV bus before voltage drops below acceptable levels. Acceptable voltage with the system intact is 0.95 and for contingency conditions it is 0.90 per unit. In addition, the PV curves can be used to determine voltage stability at all buses.

For the PV analysis, the Badwater 230kV bus was defined as the sink and a subsystem of buses in the surrounding area were the source. In addition, all solution parameters (TCUL, switchable shunt capacitors, area interchange and phase-shift transformers) were disabled as the load was incremented.

PV values for Alternative A are tabulated in **Table 36**. The table provides the progression of each phase, which includes, the base case condition prior to any load or projects, the base case with Alternative A components modeled, base case with Alternative A components and 150 MW of new load and base case with Alternative A components and 445 MW of new load. Each case has corner point cases 1, 2 and 3, which is identified by its TOT4A/4B flow.

Table 36 PV values, Alternative A: Casper-Badwater 230kV line

Contingency / (TOT4A/4B)	Base Case	Base Case + Alternative A	Base Case + Alternative A + 150 MW Load	Base Case + Alternative A + 445 MW Load
	2174/829 (MW)	2174/829 (MW)	2174/979 (MW)	2174/1274 (MW)
All Lines In-Service	129	229	223	143
Aeolus-Anticline 500kV	0	65	68	0.84 - 6
Platte-Standpipe 230kV	112	207	203	123
Casper-Spence 230kV	189	242	233	144
Badwater-Thermopolis 230kV	71	193	268	124
Casper-Badwater 230kV	NA	126	117	0.929 - 9

All cases have sufficient power margin; however, with the 445 MW load case, loss of the Casper-Badwater 230kV line did not solve at 0.90 per unit voltage.

Loss of the Aeolus-Anticline 500kV line with 600 MW Aeolus wind generation tripping resulted in the post-contingency case to solve down to the 0.84 per unit voltage level. However, at 0.90 per unit, the power margin was less than 0 MW due to the generator tripping SPS.

PV values for Alternative C2 are tabulated in **Table 37**. The table provides the progression of each phase, which includes, the base case condition prior to any load or projects, the base case with Alternative C2 components modeled, base case with Alternative C2 components and 150 MW of new load and base case with Alternative C2 components and 445 MW of new load. Each case has corner point cases 1, 2 and 3, which is identified by its TOT4A/4B flow.

Table 37 PV values, Alternative C2: Miracle Mile - Spence - Raderville - Badwater 230 kV line and RebuildCasper - Alcova No.2 115 kV line to Casper - Alcova 230 kV line.

Contingency / (TOT4A/4B)	BaseCase	BaseCase + Alt C2	BaseCase + AltC2 + 150 MW Load	BaseCase + Alt C2 + 445 MW Load
	2174/829 (MW)	2174/829 (MW)	2174/979 (MW)	2174/1274 (MW)
All Lines In-Service	128	247	220	224
Aeolus-Anticline 500kV	0.64 - 135	92	62	85
Platte-Standpipe 230kV	111	226	199	205
Casper-Spence 230kV	189	251	222	218
Badwater-Thermopolis 230kV	70	200	198	191
Spence-Raderville 230kV	NA	146	107	0.94 - 66

For the base case conditions, loss of the Aeolus-Anticline 500kV line with 600 MW Aeolus wind generation tripping resulted in the post-contingency case solving below the 0.9 per unit voltage level. At 0.90 per unit, the power margin was less than 0 MW due to the generator tripping SPS.

All PV plots are provided in **Appendix B**.

4.3 Transient Stability

Transient stability analysis was simulated for several contingencies in the surrounding Wyoming system.

4.3.1 Pre-Gateway, Addition of New 445 MW Load

4.3.1.1 Alternative A. Casper - Badwater 230 kV line

The following contingencies were simulated for corner point cases developed in the power flow section. In addition, all lines modeled a 5 cycle clearing time.

TR-1:	Three-phase fault at Badwater 230 kV bus with outage of the (new) Casper-Badwater 230 kV line.
TR-2:	Three-phase fault at Dave Johnston 230 kV bus with outage of the Dave Johnston-Casper 230 kV line.
TR-3:	Three-phase fault at Platte 230 kV bus with outage of the Platte-Standpipe 230 kV line.
TR-4:	Three-phase fault at Badwater 230 kV bus with outage of the Badwater-Thermopolis 230 kV line.
TR-5:	Three-phase fault at Badwater 230 kV bus with outage of the Badwater-Elk Petroleum 230 kV line.
TR-6:	Three-phase fault at Elk Petroleum 230 kV bus with outage of the Spence-Elk Petroleum 230 kV line.
TR-7:	Three-phase fault at Casper 230 kV bus with outage of the Casper-Riverton 230 kV line.
TR-8:	Three-phase fault at Oregon Basin 230 kV bus with outage of the Oregon Basin-Garland-Frannie-Yellowtail 230 kV line.

All simulated contingencies were stable and damped for all corner point cases. In addition, there were no WECC performance criteria violations identified.

With maximum TOT4A flow, loss of the Dave Johnston - Casper 230 kV line (TR-2) results in the Foote Creek generation tripping since its voltage was below 0.90 per unit for a 1 second duration. In addition, bus 73341 NSS2 13.8 frequency was triggered with a low value of 59.579 Hz. However, Black Hills Power has identified this issue and is reviewing generator modeling for machines in this area. This issue is not associated with this project.

All transient stability contingency plots are provided in **Appendix C**.

4.3.1.2 Alternative C2: Miracle Mile - Spence - Raderville - Badwater 230 kV line and Rebuild Casper - Alcova No.2 115 kV line to Casper - Alcova 230 kV line.

The following contingencies were simulated for corner point cases developed in the power flow section. In addition, all lines modeled a 5 cycle clearing time.

TR-1:	Three-phase fault at Spence 230 kV bus with outage of the (new) Spence-Raderville 230 kV line.
TR-2:	Three-phase fault at Badwater 230 kV bus with outage of the (new) Badwater-Raderville 230 kV line.
TR-3:	Three-phase fault at Spence 230 kV bus with outage of the (new) Spence-Alcova 230 kV line.
TR-4:	Three-phase fault at Casper 230 kV bus with outage of the (new) Casper-Alcova 230 kV line.
TR-5:	Three-phase fault at Dave Johnston 230 kV bus with outage of the Dave Johnston-Casper 230 kV line.

TR-6: Three-phase fault at Platte 230 kV bus with outage of the Platte-Standpipe 230 kV line.

TR-7: Three-phase fault at Badwater 230 kV bus with outage of the Badwater-Thermopolis 230 kV line.

TR-8: Three-phase fault at Badwater 230 kV bus with outage of the Badwater-Elk Petroleum 230 kV line.

TR-9: Three-phase fault at Elk Petroleum 230 kV bus with outage of the Spence-Elk Petroleum 230 kV line.

TR-10: Three-phase fault at Casper 230 kV bus with outage of the Casper-Riverton 230 kV line.

TR-11: Three-phase fault at Oregon Basin 230 kV bus with outage of the Oregon Basin-Garland-Frannie-Yellowtail 230 kV line.

All simulated contingencies were stable and damped for all corner point cases. In addition, there were no WECC performance criteria violations identified.

With maximum TOT4A flow, loss of the Dave Johnston - Casper 230 kV line (TR-5) results in the Foote Creek generation tripping since its voltage was below 0.90 per unit for a 1 second duration. In addition, bus 73341 NSS2 13.8 frequency was triggered with a low value of 59.582 Hz. However, Black Hills Power has identified this issue and is reviewing generator modeling for machines in this area. This issue is not associated with this project.

All transient stability contingency plots are provided in **Appendix C**.

4.3.2 Post-Gateway, Addition of New 445 MW Load

4.3.2.1 Alternative A. Casper - Badwater 230 kV line

The following contingencies were simulated for the stressed case developed in the power flow section. In addition, all lines modeled a 5 cycle clearing time except 500kV line outages, which modeled a 3 cycle clearing time.

TR-1: Three-phase fault at Badwater 230 kV bus with outage of the (new) Casper-Badwater 230 kV line.

TR-2: Three-phase fault at Dave Johnston 230 kV bus with outage of the Dave Johnston-Casper 230 kV line.

TR-3: Three-phase fault at Platte 230 kV bus with outage of the Platte-Standpipe 230 kV line.

TR-4: Three-phase fault at Badwater 230 kV bus with outage of the Badwater-Thermopolis 230 kV line.

TR-5: Three-phase fault at Badwater 230 kV bus with outage of the Badwater-Elk Petroleum 230 kV line.

TR-6: Three-phase fault at Elk Petroleum 230 kV bus with outage of the Spence-Elk Petroleum 230 kV line.

TR-7: Three-phase fault at Casper 230 kV bus with outage of the Casper-Riverton 230 kV line.

TR-8: Three-phase fault at Spence 230 kV bus with outage of the Spence-Mustang 230 kV line.

TR-9: Three-phase fault at Oregon Basin 230 kV bus with outage of the Oregon Basin-Garland-Frannie-Yellowtail 230 kV line.

TR-10: Three-phase fault at Aeolus 500 kV bus with outage of the Aeolus-Anticline 500 kV line with 600 MW generation trip.

All simulated contingencies were stable and damped. In addition, there were no WECC performance criteria violations identified with exception of the below frequency excursions.

Loss of the Dave Johnston - Casper 230 kV line (TR-2) results in the 73341 NSS2 13.8 bus frequency to trigger with a low value of 59.577 Hz. However, Black Hills Power has identified this issue and is reviewing generator modeling for machines in this area. This issue is not associated with this project.

All transient stability contingency plots are provided in **Appendix C**.

4.3.2.2 Alternative C2: Miracle Mile - Spence - Raderville - Badwater 230 kV line and Rebuild Casper - Alcova No.2 115 kV line to Casper - Alcova 230 kV line.

The following contingencies were simulated for the stressed case developed in the power flow section. In addition, all lines modeled a 5 cycle clearing time.

TR-1: Three-phase fault at Spence 230 kV bus with outage of the (new) Spence-Raderville 230 kV line.

TR-2: Three-phase fault at Badwater 230 kV bus with outage of the (new) Badwater-Raderville 230 kV line.

TR-3: Three-phase fault at Spence 230 kV bus with outage of the (new) Spence-Alcova 230 kV line.

TR-4: Three-phase fault at Casper 230 kV bus with outage of the (new) Casper-Alcova 230 kV line.

TR-5: Three-phase fault at Dave Johnston 230 kV bus with outage of the Dave Johnston-Casper 230 kV line.

TR-6: Three-phase fault at Platte 230 kV bus with outage of the Platte-Standpipe 230 kV line.

TR-7: Three-phase fault at Badwater 230 kV bus with outage of the Badwater-Thermopolis 230 kV line.

TR-8: Three-phase fault at Badwater 230 kV bus with outage of the Badwater-Elk Petroleum 230 kV line.

TR-9: Three-phase fault at Elk Petroleum 230 kV bus with outage of the Spence-Elk Petroleum 230 kV line.

TR-10: Three-phase fault at Casper 230 kV bus with outage of the Casper-Riverton 230 kV line.

TR-11: Three-phase fault at Oregon Basin 230 kV bus with outage of the Oregon Basin-Garland-Frannie-Yellowtail 230 kV line.

TR-12: Three-phase fault at Aeolus 500 kV bus with outage of the Aeolus-Anticline 500 kV line with 600 MW generation trip.

All simulated contingencies were stable and damped. In addition, there were no WECC performance criteria violations identified with exception of the below frequency excursions.

Loss of the Dave Johnston - Casper 230 kV line (TR-5) results in the 73341 NSS2 13.8 bus frequency to trigger with a low value of 59.563 Hz. However, Black Hills Power has identified this issue and is reviewing generator modeling for machines in this area. This issue is not associated with this project.

But, the Wygen 2, Wygen 3 and BHPLPLAN 13.8kV buses experienced a low frequency of 59.597 Hz, which is near the 59.6 Hz threshold.

All transient stability contingency plots are provided in **Appendix C**.