

COLORADO COORDINATED PLANNING GROUP (CCPG) NERC/WECC COMPLIANCE REPORT AND REACTIVE MARGIN ANALYSIS August 3, 2007

1. INTRODUCTION

The purpose of this study is to help CCPG participants meet selected WECC/NERC compliance standards via the coordinated planning process. Included in this report are the transmission system performance assessment studies for standards TPL-001, TPL-002, TPL-003, and TPL-004. Also included is the Reactive Margin analysis required to meet the associated WECC requirement.

The study area consists of the states of Wyoming and Colorado or electrically described as the area bounded by Yellowtail, TOT4A, TOT1A, and TOT2A.

This report is a source of data for CCPG participants to use when certifying their compliance with WECC/NERC planning standards TPL-001-0_R1/R2/R3, TPL-002-0_R1/R2/R3, TPL-003-0_R1/R2/R3, and TPL-004-0_R1/R2. This report may not completely meet the compliance requirements and participants may have to supplement this information to meet their needs and avoid sanctions.

The study was performed using PTI version 29.4 and 30.3.

2. BASE CASES

The base cases were obtained from the Western Electricity Coordinating Council (WECC). The two base cases included in this study are a 2006 heavy summer loading case (06hs4a1pv29) and a 2016 long term case with heavy summer loading (16hs1p).

In the steady state analysis all high voltage ($\geq 115\text{kV}$) bus voltages and non-radial branch flows in the CCPG area are monitored for criteria violations.

The transient stability cases include the detailed Sidney DC tie, Stegall DC tie, and Rapid City DC tie models. All buses in the study area are monitored for voltage and major generating units in the area are monitored for stability.

3. CRITERIA

a) Steady State - System Intact

Voltages are maintained between 1.05 p.u. and 0.95 p.u. Transmission line and transformer loading may not exceed 100% of continuous rating. Shunt reactive device switching and transformer tap adjustments are enabled. Phase shifters are locked.

b) Steady State - Contingency

Voltages are maintained between 1.10 p.u. and 0.90 p.u. Platte River Power minimum bus voltage is 0.92 p.u. Transmission line and transformer loading may not exceed 100% of continuous rating or an established emergency rating. Automatic shunt reactive device switching is enabled. Transformer tap adjustments are locked. Phase shifters are locked.

c) Transient Stability

The system is positively damped and the low voltage swing will not drop below 0.70 p.u.

4. PLANNING STANDARDS AND MEASUREMENTS

The following procedures were used for both the 2006 Heavy Summer Loading base case and the Long Term 2016 Heavy Summer Loading base case. The NERC/WECC Table 1, which contains the Category A, B, C, and D outage definitions, is provided in Appendix A.

TPL-001 N-0 System Performance (NERC Category A Outages)

Steady State: The case is checked for system intact criteria violations.

Transient Stability: A non-disturbance case is run.

TPL-002 N-1 System Performance (NERC Category B Outages)

Steady State: The NERC Category B "Outage List" consists of all branches in the CCPG study area operated at 230 kV or above, plus the following major generating units in the CCPG area; Cherokee4, Comanche1, Pawnee, Rawhide, MBPP1, Nixon, Craig1, DJ4, and Wyodak. Previous studies in the CCPG

area indicate that outages of facilities operated at 115 kV and below show no effect on the bulk transmission system; therefore they are not included in the analysis.

Transient Stability: A list of Category B faults was created by the CCPG study participants to meet the requirements of the WECC/NERC standard. This Category B fault list for the 2006 and 2016 cases is provided in Appendix B.

TPL-003 N-2 System Performance (NERC Category C Outages)

Steady State: A list of Category C outages was created by the CCPG study participants to meet the requirements of the WECC/NERC standard. This Category C outage list for the 2006 and 2016 cases is provided in Appendix C.

Transient Stability: A list of Category C faults was created by the CCPG study participants to meet the requirements of the WECC/NERC standard. This Category C fault list for the 2006 and 2016 cases is provided in Appendix B.

TPL-004 Extreme Contingency (NERC Category D Outages)

Steady State: A list of Category D outages was created by the CCPG study participants to meet the requirements of the WECC/NERC standard. This Category D outage list for the 2006 and 2016 cases is provided in Appendix C.

Transient Stability: A list of Category D faults was created by the CCPG study participants to meet the requirements of the WECC/NERC standard. This Category D fault list for the 2006 and 2016 cases is provided in Appendix B.

5. VOLTAGE STABILITY

The voltage stability study consists of a PV analysis of the system contained within the TOT3/TOT5 area. The 2006 and 2016 heavy summer cases are studied. Load within the TOT3/TOT5 area will be scaled up in order to create the PV plots. The forced outage list is NERC A, B, C, and D steady state lists described in Section 4. Also, prior outage of major area generation is included. Separate results for the prior outages of Pawnee #1, Cherokee #4, Comanche #2 in the 2006 case and also Comanche #3 in the 2016 case are provided. For each generator prior outage other area generation is redispatched to make up for the lost generation. The WECC has established voltage stability criteria for acceptable real power

(MW) margins as follows: 5% for Category A and B outages, 2.5% for Category C, and 0% for Category D outages.

6. RESULTS

BASE CASE – 2006 HEAVY SUMMER

AREA PATH FLOW; TOT3 = 1288, TOT7 = 448, TOT5 = 531, TOT4A = 516

TPL-001 N-0 System Performance (NERC Category A Outages)

Steady State: The results of the N-0 Steady State Analysis indicate one voltage violation at the Boone 69KV bus at 1.052 p.u., This violation can be cleared by adjusting the Boone 115/69kV transformer tap. The results of the N-0 Steady State Analysis are listed in Appendix D.

Transient Stability: The results of the N-0 Transient Stability Analysis indicate NO criteria violations. The results of the N-0 Transient Stability Analysis are listed in Appendix E.

TPL-002 N-1 System Performance (NERC Category B Outages)

Steady State: The results of the N-1 Steady State Analysis indicate numerous voltage and loading violations that appear to exceed the criteria stated in Section 4 of this report. The detailed results of the N-1 analysis are shown in Appendix D. In some instances, the simplified analysis showed violations that wouldn't occur under actual system operation. For other violations there are plans to achieve required system performance are listed. These plans include planned system upgrades or established operating procedures. The results of the N-1 Steady State Analysis are listed in Appendix D, violations are highlighted in yellow and the associated explanation is also provided.

Transient Stability: The results of the N-1 Transient Stability Analysis indicate NO criteria violations.

TPL-003 N-2 System Performance (NERC Category C Outages)

Steady State: The results of the N-2 Steady State Analysis indicate numerous voltage and loading violations that appear to

exceed the criteria stated in Section 4 of this report. The detailed results of the N-1 analysis are shown in Appendix D. In some instances, the simplified analysis showed violations that wouldn't occur under actual system operation. For other violations there are plans to achieve required system performance are listed. These plans include planned system upgrades or established operating procedures. The results of the N-2 Steady State Analysis are listed in Appendix D, violations are highlighted in yellow and the associated explanations are also provided.

Transient Stability: The results of the N-2 Transient Stability Analysis indicate several transient voltage violations exceeding the criteria stated in Section 4 of this report. However the violations are resolved through planned system improvements or other considerations. The results of the N-2 Transient Stability Analysis are listed in Appendix E, violations and associated explanations are highlighted in Yellow.

TPL-004 Extreme Contingency (NERC Category D Outages)

Steady State: The results of the "Extreme Contingency" Steady State Analysis indicate several loading violations, which exceeded the criteria stated in Section 4 of this report. However, resolutions exist that clear each violation. The results of the "Extreme Contingency" Steady State Analysis are listed in Appendix D, violations are highlighted in yellow and the associated explanations are also provided.

Transient Stability: The results of the "Extreme Contingency" Transient Stability Analysis indicate NO transient voltage violations.

LONG TERM BASE CASE – 2016 HEAVY SUMMER

AREA PATH FLOW; TOT3 = 882, TOT7 = 171, TOT5 = 596, TOT4A = 425

TPL-001 N-0 System Performance (NERC Category A Outages)

Steady State: The results of the N-0 Steady State Analysis indicated one overload violation. The Weld 230/115kV transformer loading is 101.9% of 150MVA. Addition of a second unit is scheduled which eliminates the overload. The results of the N-0 Steady State Analysis are listed in Appendix F.

Transient Stability: The results of the N-0 Transient Stability Analysis indicate NO criteria violations. The results of the N-0 Transient Stability Analysis are listed in Appendix G.

TPL-002 N-1 System Performance (NERC Category B Outages)

Steady State: The results of the N-1 Steady State Analysis indicate numerous voltage and loading violations that appear to exceed the criteria stated in Section 4 of this report. The detailed results of the N-1 analysis are shown in Appendix D. In some instances, the simplified analysis showed violations that wouldn't occur under actual system operation. For other violations there are plans to achieve required system performance are listed. These plans include planned system upgrades or established operating procedures. , The results of the N-1 Steady State Analysis are listed in Appendix F, violations are highlighted in yellow and the associated explanations are also provided.

Transient Stability: The results of the N-1 Transient Stability Analysis indicate NO criteria violations. The results of the N-1 Transient Stability Analysis are listed in Appendix G.

TPL-003 N-2 System Performance (NERC Category C Outages)

Steady State: The results of the N-2 Steady State Analysis indicate numerous voltage and loading violations that appear to exceed the criteria stated in Section 4 of this report. The detailed results of the N-1 analysis are shown in Appendix D. The results of the N-2 Steady State Analysis are listed in Appendix F, violations are highlighted in yellow and the associated explanations are also provided.

Transient Stability: The results of the N-2 Transient Stability Analysis indicate NO transient voltage violations.

TPL-004 Extreme Contingency (NERC Category D Outages)

Steady State: The results of the "Extreme Contingency" Steady State Analysis indicate several loading violations, which exceed criteria. However, resolutions exist that clear each violation. The results of the "Extreme Contingency" Steady State

Analysis are listed in Appendix F, violations are highlighted in yellow and the associated explanations are also provided.

Transient Stability: The Daniel Park 230kV bus outage results in an unstable condition. These category D disturbances are modeled to explore extreme type events. PSCO will continue to evaluate Category D disturbances for risk and consequence. All other disturbances met criteria. The results of the Extreme Contingency Stability Analysis are listed in Appendix G.

VOLTAGE STABILITY RESULTS

The WECC criteria is 5% for Category A and B outages, 2.5% for Category C, and 0% for Category D outages. PV analysis of all of the Category A, B, C, and D outages described in section 4 are studied. The following is a summary of results that did not meet WECC criteria. Detailed results are available upon request.

2006 HEAVY SUMMER - NO PRIOR OUTAGE

| CATEGORY A AND B | COLLAPSE POINT DATA | | |
|-----------------------------|---------------------|-----------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| LAMAR CO 115-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| BOONE 230-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| SAN LUIS 230-PONCHABR 230-1 | n/a | n/a | Unsolved |
| CHEROKEE UNIT | 1788 | 9847 | 3.89% |

The Lamar area outages and the San Luis-Poncha 230kV outage did not solve in the base case and therefore have no margin. Operating procedures and localized load shedding are used to mitigate the Lamar and San Luis area violations. The Cherokee 4 Unit outage has a margin of only 3.89%. Other PSCo assessments have shown the Denver-metro system to have adequate voltage stability. PSCo will continue to evaluate its system for voltage stability and reactive reserve.

All Category C outages have margin in excess of criteria.

| CATEGORY D | COLLAPSE POINT DATA | | |
|-----------------------|---------------------|-----------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| DANPARK230 BUS OUTAGE | n/a | n/a | Unsolved |

The Daniel Park 230kV bus outage does not solve and therefore has no margin. PSCo will continue to evaluate Category D disturbances for risk and consequence.

2006 HEAVY SUMMER - ST. VRAIN UNIT PRIOR OUTAGE WITH REDISPATCH

| CATEGORY A AND B | COLLAPSE POINT DATA | | |
|-----------------------------|---------------------|-----------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| LAMAR CO 115-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| BOONE 230-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| SAN LUIS 230-PONCHABR 230-1 | n/a | n/a | Unsolved |
| CHEROKEE UNIT | 1792 | 9879 | 4.23% |

The Lamar area outages and the San Luis-Poncha 230kV outage did not solve in the base case and therefore have no margin. Operating procedures and localized load shedding are used to mitigate the Lamar and San Luis area violations. The Cherokee 4 Unit outage has a margin of only 4.23%. Other PSCo assessments have shown the Denver-metro system to have adequate voltage stability. PSCo will continue to evaluate its system for voltage stability and reactive reserve.

All Category C outages have margin in excess of criteria.

| CATEGORY D | COLLAPSE POINT DATA | | |
|-----------------------|---------------------|-----------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| DANPARK230 BUS OUTAGE | n/a | n/a | Unsolved |

The Daniel Park 230kV bus outage does not solve and therefore has no margin. PSCo will continue to evaluate Category D disturbances for risk and consequence.

2006 HEAVY SUMMER - CHEROKEE UNIT 4 PRIOR OUTAGE WITH REDISPATCH

| CATEGORY A AND B | COLLAPSE POINT DATA | | |
|------------------------------|---------------------|-----------|----------|
| | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| OUTAGE | | | |
| LAMAR CO 115-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| BOONE 230-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| SAN LUIS 230-PONCHABR 230-1 | n/a | n/a | Unsolved |
| RMEC 230-RMEC3 23.0-T3 | 1733 | 9811 | 3.65% |
| RD_NIXON 230-FRTRANGE 230-1 | 1844 | 9847 | 4.02% |
| PAWNEE 230-QUINCY 230-1 | 1523 | 9849 | 4.04% |
| QUINCY 230-SMOKYHIL 230-1 | 1531 | 9858 | 4.14% |
| COMAN 1 24.0-COMANCHE 230-U1 | 1793 | 9872 | 4.28% |
| COMAN 2 24.0-COMANCHE 230-U2 | 1796 | 9875 | 4.32% |
| DANIELPK 230-PAWNEE 230-1 | 1543 | 9875 | 4.32% |
| COMAN UNIT | 1796 | 9875 | 4.32% |
| ST.VRAIN22.0-ST.VRAIN 230-U1 | 1793 | 9879 | 4.36% |
| STVRAIN UNIT | 1793 | 9879 | 4.36% |
| AULT 345-LAR.RIVR 345-1 | 1574 | 9892 | 4.50% |
| FTLUPTON 230-JLGREEN 230-1 | 1585 | 9932 | 4.92% |
| SPRUCE 230-SPRUCE1 18.0-T1 | 1688 | 9936 | 4.96% |
| SPRUCE 230-SPRUCE2 18.0-T2 | 1688 | 9936 | 4.96% |
| ST.VRAIN 230-ISABELLE 230-1 | 1572 | 9936 | 4.96% |

There are numerous Category B outages with margin less than 5% as shown on the above table. Operating procedures and localized load shedding are used to mitigate the Lamar area violations. Other PSCo assessments have shown the Denver-metro system to have adequate voltage stability. PSCo will continue to evaluate its system for voltage stability and reactive reserve.

| CATEGORY C | COLLAPSE POINT DATA | | |
|----------------------------------|---------------------|-----------|----------|
| | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| OUTAGE | | | |
| PAW-QUIN230 PAW-D.PARK230 OUTAGE | 1288 | 9535 | 0.73% |

The Pawnee-Quincy & Pawnee-Daniel Park 230kV Category C outage has a margin of 0.73%.

| CATEGORY D | COLLAPSE POINT DATA | | |
|-----------------------|---------------------|-----------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| DANPARK230 BUS OUTAGE | n/a | n/a | Unsolved |

The Daniel Park 230kV bus outage does not solve and therefore has no margin.

2006 HEAVY SUMMER - PAWNEE UNIT 1 PRIOR OUTAGE WITH REDISPATCH

| CATEGORY A AND B | COLLAPSE POINT DATA | | |
|-----------------------------|---------------------|-----------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| LAMAR CO 115-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| BOONE 230-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| SAN LUIS 230-PONCHABR 230-1 | n/a | n/a | Unsolved |

The Lamar area outages and the San Luis-Poncha 230kV outage did not solve in the base case and therefore have no margin. Operating procedures and localized load shedding are used to mitigate the Lamar and San Luis area violations.

All Category C and D outages have margin in excess of criteria.

2006 HEAVY SUMMER - COMANCHE UNIT 1 PRIOR OUTAGE WITH REDISPATCH

| CATEGORY A AND B | COLLAPSE POINT DATA | | |
|------------------------------|---------------------|-----------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| LAMAR CO 115-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| BOONE 230-LAMAR CO 230-1 | n/a | n/a | Unsolved |
| SAN LUIS 230-PONCHABR 230-1 | n/a | n/a | Unsolved |
| CHEROK UNIT | 1791 | 9870 | 4.45% |
| COMAN 2 24.0-COMANCHE 230-U2 | 1815 | 9914 | 4.91% |
| COMAN UNIT | 1815 | 9914 | 4.91% |

The Lamar area outages and the San Luis-Poncha 230kV outage did not solve in the base case and therefore have no margin. Operating procedures and localized load shedding are used to mitigate the Lamar and San Luis area violations. The Cherokee and Comanche Unit 2 outages have less than 5% margin. The addition of the

Comanche 3 unit and associated 345kV line will mitigate the reactive power margin violation associated with the loss of generation.

All Category C and D outages have margin in excess of criteria.

BASE CASE – 2016 HEAVY SUMMER

The 2016 case has adequate margin in the system intact and major unit prior outage conditions. The Cherokee and Daniel Park 230kV bus Category D outages caused violations under all conditions.

2016 HEAVY SUMMER - NO PRIOR OUTAGE

All Category A, B and C outages have margin in excess of criteria.

| CATEGORY D | | COLLAPSE POINT DATA | |
|-----------------------|-------------|---------------------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| DANPARK230 BUS OUTAGE | n/a | n/a | Unsolved |
| CHEROKEE BUS OUTAGE | 1156 | 11770 | -1.16% |

The Daniel Park 230kV and Cherokee 230kV bus outages do not meet criteria. PSCO will continue to evaluate Category D disturbances for risk and consequence.

2016 HEAVY SUMMER - COMANCHE UNIT 3 PRIOR OUTAGE WITH REDISPATCH

All Category A, B and C outages have margin in excess of criteria.

| CATEGORY D | | COLLAPSE POINT DATA | |
|-----------------------|-------------|---------------------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| DANPARK230 BUS OUTAGE | n/a | n/a | Unsolved |
| CHEROKEE BUS OUTAGE | 1264 | 11825 | -0.23% |

The Daniel Park 230kV and Cherokee 230kV bus outages do not meet criteria. PSCO will continue to evaluate Category D disturbances for risk and consequence.

2016 HEAVY SUMMER - CHEROKEE UNIT 4 PRIOR OUTAGE WITH REDISPATCH

All Category A, B and C outages have margin in excess of criteria.

| CATEGORY D | | COLLAPSE POINT DATA | |
|-----------------------|-------------|---------------------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| DANPARK230 BUS OUTAGE | n/a | n/a | Unsolved |
| CHEROKEE BUS OUTAGE | 1077 | 11957 | 0.69% |

The Daniel Park 230kV and Cherokee 230kV bus outages do not meet criteria. PSCO will continue to evaluate Category D disturbances for risk and consequence.

2016 HEAVY SUMMER - PAWNEE UNIT 1 PRIOR OUTAGE WITH REDISPATCH

All Category A, B and C outages have margin in excess of criteria.

| CATEGORY D | | COLLAPSE POINT DATA | |
|-----------------------|-------------|---------------------|----------|
| OUTAGE | t3t5 IMPORT | t3t5 LOAD | MARGIN % |
| DANPARK230 BUS OUTAGE | n/a | n/a | Unsolved |
| CHEROKEE BUS OUTAGE | 1205 | 11796 | -0.68% |

The Daniel Park 230kV and Cherokee 230kV bus outages do not meet criteria. PSCO will continue to evaluate Category D disturbances for risk and consequence.

LIST OF APPENDICES

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