Methodology for Determining System Operating Limits of the Gladstone Phase Shifting Transformer

TRI-STATE
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A Touchstone Energy® Cooperative

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Background

Tri-State installed a Gladstone 230 kV phase shifting transformer (PST) on the Walsenburg-Gladstone 230 kV line in 2014. The Gladstone PST could theoretically vary flows on this line by phase shifting between +60 and -60 degrees. However, the existing system may be constrained to allow full range operation of the Gladstone PST due to the following reasons:

- The Walsenburg-Gladstone 230 kV line connects to the Gladstone Substation, which is located in a weak Northeastern New Mexico (NENM) transmission system. This weak system relies on remote generation to serve heavy NENM loads.

- Previous studies showed that there are low voltage and transient stability issues during periods of high Walsenburg-Gladstone 230 kV line flows and/or heavy NENM loads.

NENM loads consist of the following:

- Clapham load of 10.5 MW based on 2015 heavy winter case,
- Bravo Dome (Rosebud) load of 72 MW,
- Bravo Dome West (Hess) load of 10 MW, and
- Bueyeros load of 20 MW.

The total of these loads is 112.5 MW. Bueyeros load is tapped onto the Gladstone-Hess 115 kV line near Hess. It is currently about 3 MW and is expected to increase to 20 MW by 2023.

There is an existing remedial action scheme (RAS) to drop all Hess and Bueyeros loads; and to reduce Bravo Dome load to 52 MW for the Walsenburg-Gladstone 230 kV line outage. This RAS is needed to correct low voltage and transient stability problems.

Figure 1 shows the southeastern Colorado and northeastern New Mexico Transmission Systems. Figure 2 shows the historical hourly NENM loads and Figure 3 shows the historical hourly Walsenburg-Gladstone 230 kV line flows.

Objectives

The objectives of this study are to define acceptable north to south system operating limits (SOL) for the Walsenburg-Gladstone 230 kV line flows that can be controlled by the Gladstone PST over a range of NENM loads under the following system conditions:

A) Existing System that includes the operation of an out-of-step protection relay commenced on June 16, 2015 to open the Clapham-Bravo Dome 115 kV line and trip the Bravo Dome load to protect the NENM area from the Bravo Dome loads going out-of-step.

B) System Upgrade that includes the installation of 30 MVAR (2 x 15) shunt capacitors at Gladstone 115 kV to support voltages under peak NENM loads. The expected in service date is the fourth quarter of 2017.

Base Case Assumptions

The latest WECC 2015 heavy winter case (15HW) was selected to perform the steady state power flow and transient stability studies because this case contains the latest composite dynamic load model. In addition, the dynamic model for Clapham 50 MVAR SVC was updated with the "svcwsc" model. A light load case is not studied because it was not the worst case scenario for the NENM transmission system.

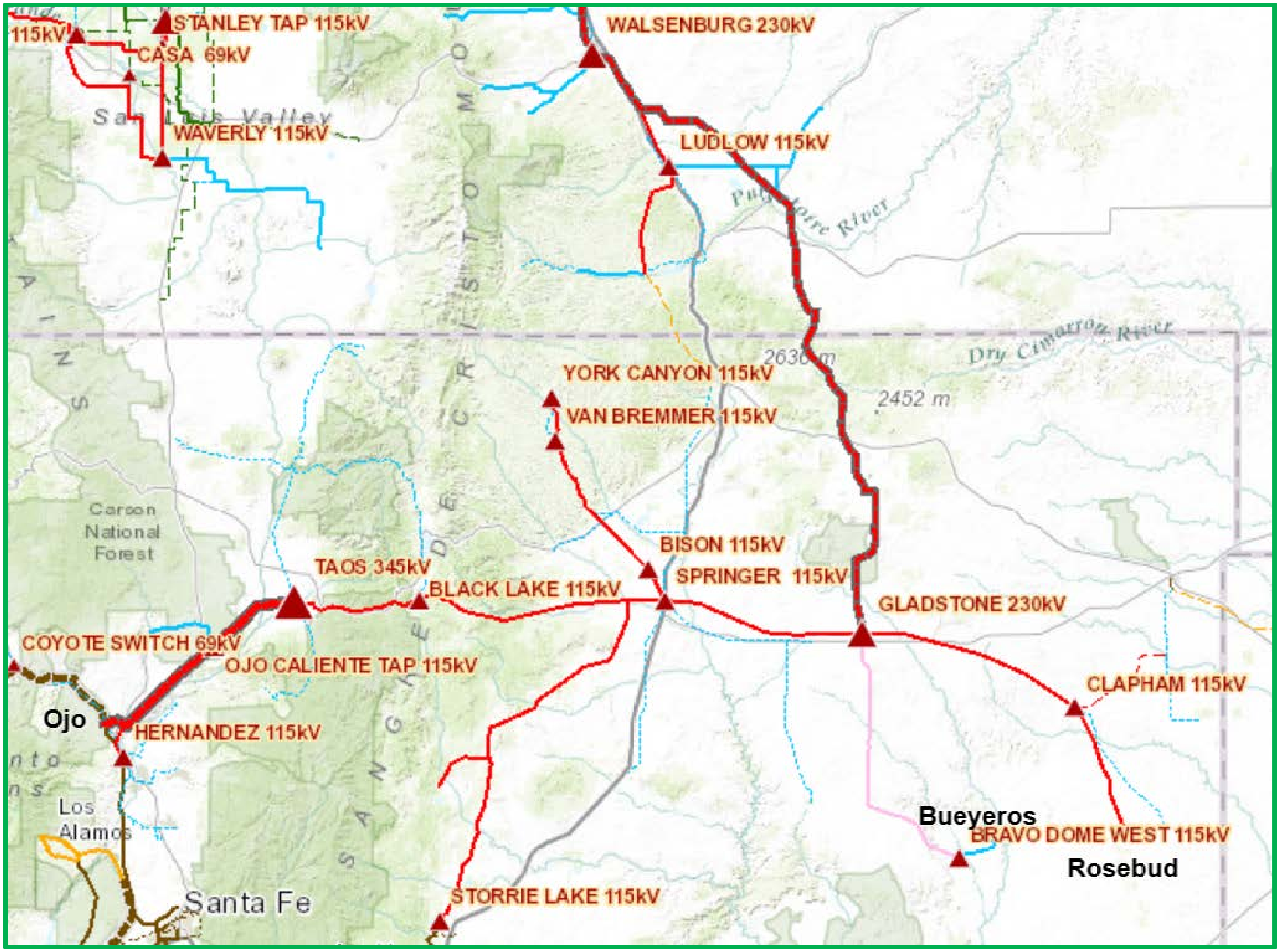

Figure 1: Southeastern Colorado and Northeastern New Mexico Transmission Systems

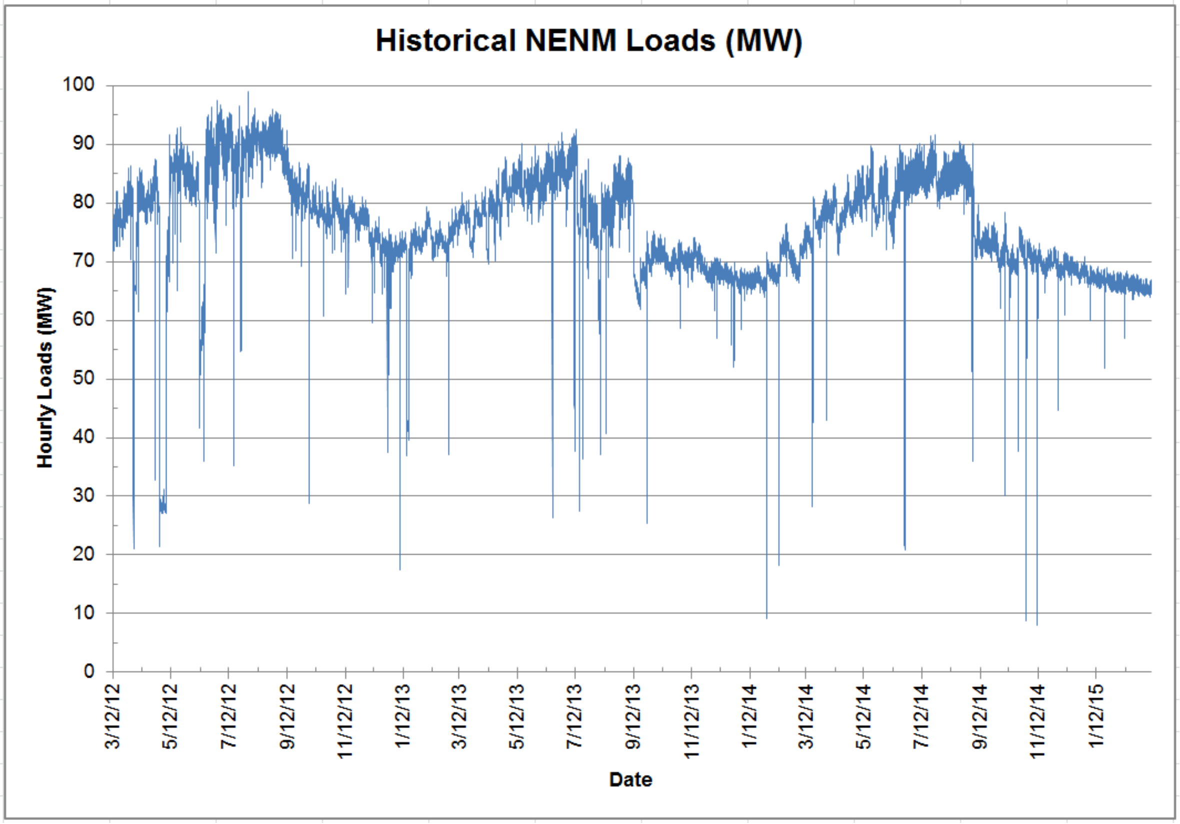

Figure 2: Historical NENM Loads

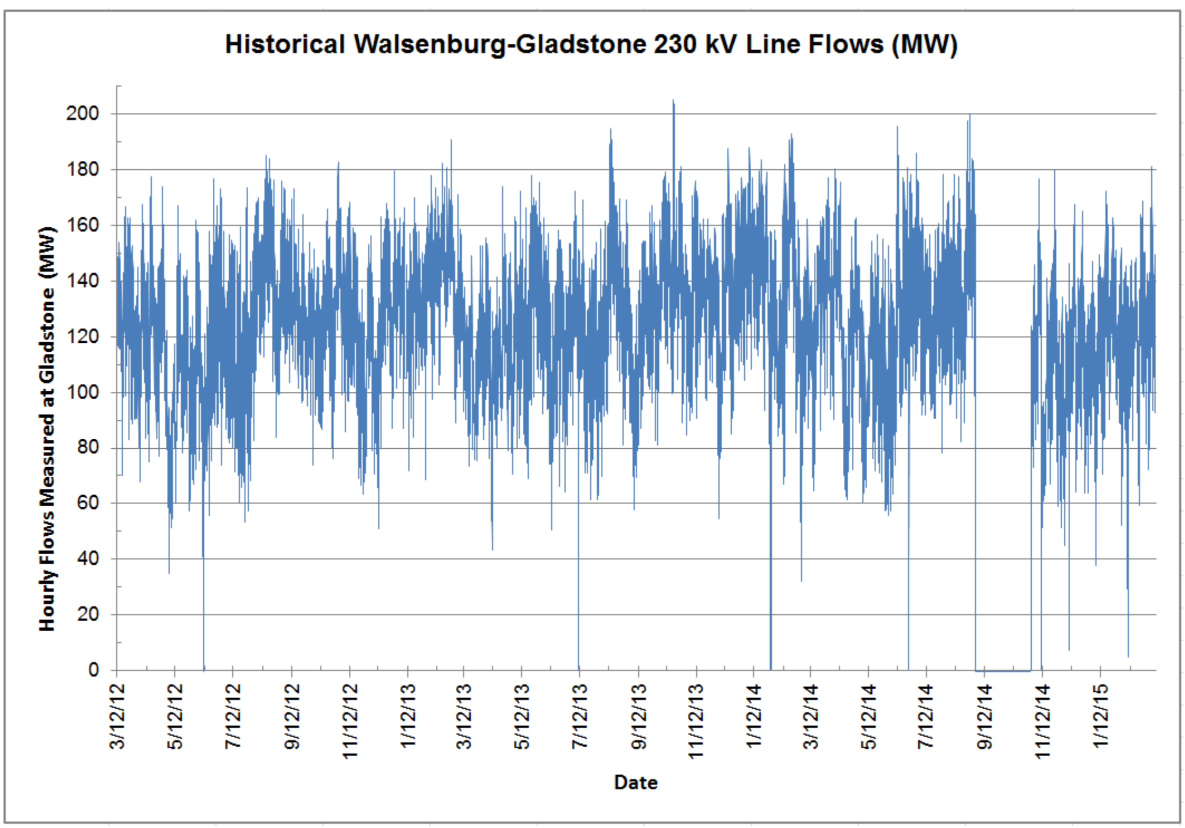

Figure 3: Historical Walsenburg-Gladstone 230 kV Line Flows

Methodology

Steady state power flow and transient stability studies were performed to transfer power from north to south on the Walsenburg-Gladstone 230 kV line to serve the NENM loads. The Gladstone 230 kV PST was used to vary the Walsenburg-Gladstone 230 kV line flows for various NENM load levels, as defined in Table 1.

With these NENM load levels, maximum and minimum north to south Walsenburg-Gladstone 230 kV line flows were studied using the Gladstone 230 kV PST to vary the line flows under all lines in service and single element outage conditions. Voltage and thermal loading were monitored and recorded for checking any planning criteria violations. Tri-Stare planning criteria (including steady state and transient stability studies) are shown in Appendix A.

As suggested by previous studies, the steady state analysis includes the following mostly stressed single line outages:

- Ojo-Taos 345 kV line
- Walsenburg-Gladstone 230 kV line
- Springer-Gladstone 115 kV

Transient stability analysis includes the following simulations:

- Applied a 3-phase line-to-ground fault on the Gladstone 115 kV terminal of the Springer-Gladstone 115 kV line at 0.1 second. Cleared the fault in 4 cycles.

- Applied a 3-phase line-to-ground fault on the Gladstone 230 kV terminal of the Walsenburg-Gladstone 230 kV line at 0.1 second. Cleared the fault in 4 cycles. At the end of 4 cycles, the Walsenburg-Gladstone 230 kV outage RAS was applied to trip all Hess and Bueyeros loads; and to reduce Bravo Dome load to 52 MW.

This study methodology of determining the system operating limits for the Planning Horizon is consistent with the Public Service Company of New Mexico (PNM), which is the Planning Authority of Tri-State. In addition, PNM's methodology is consistent with the NERC Standard FAC-010-2.1 – System Operating Limits Methodology for the Planning Horizon (Attachment A) and NERC Standard FAC-014-2 – Establish and Communicate System Operating Limits (Attachment B).

PNM's Methodology for Determining System Operating Limits for the Planning Horizon report (effective February 17, 2014) lists the following requirements and Tri-State's responses are inserted in blue:

3.1 <u>System Performance</u>

This section defines the acceptable BES performance for both the pre- and post-contingency state (FAC-010-2.1, R2).

3.1.1 Pre-contingency

For the pre-contingency state with all Facilities in-service, the following system performance criterion applies. The pre-contingency state will reflect expected system conditions and changes to topology such as Facility outages. (FAC-010-2.1, R2.1)

1. The BES demonstrates transient, dynamic, and voltage stability
2. All Facilities are within rating their continuous Facility Ratings
3. All Facilities are within their continuous thermal limits

4. All Facilities are within their pre-contingency voltage limits
5. All Facilities are within their stability limits

Yes the study meets these criteria.

3.1.2 Post-contingency – Single Contingency

For the post-contingency state for single contingencies, the following system performance criterion applies (FAC-010-2.1, R2.2).

1. The BES demonstrates transient, dynamic, and voltage stability
2. All Facilities are within rating their continuous Facility Ratings
3. All Facilities are within their continuous thermal limits
4. All Facilities are within their pre-contingency voltage limits
5. All Facilities are within their stability limits
6. Cascading or uncontrolled separation shall not occur

Yes the study meets these criteria.

3.1.2.1 Acceptable System Response

Starting will all Facilities in-service, the following are acceptable system responses to a single contingency (FAC-010-2.1, R2.3).

- Planned or controlled interruption of service to radial customers or local network customers who receive service from the faulted facility or affected area (FAC-010, R2.3.1)
- System reconfiguration by manual or automatic control or protection actions (FAC-010, R2.3.2)

Yes such as the remedial action scheme (RAS) of reducing Bravo Dome load for the Walsenburg-Gladstone 230 kV line outage.

3.1.2.2 System Adjustments for the Next Contingency (FAC-010-2.1, R2.4)

System adjustments required to prepare for the next contingency include generation re-dispatch, scheduled use of the transmission system, and transmission system topology changes associated with SPS or operating procedures.

Yes and the Gladstone 230 kV PST allows additional flexibility to adjust the Walsenburg-Gladstone 230 kV line flows.

3.1.3 Post-contingency – Multiple Contingency

Starting will all Facilities in-service, the following system performance criterion applies for the post-contingency state for multiple contingencies (FAC-010-2.1, R2.5).

1. The BES demonstrates transient, dynamic, and voltage stability
2. All Facilities are within rating their continuous Facility Ratings
3. All Facilities are within their continuous thermal limits
4. All Facilities are within their pre-contingency voltage limits
5. All Facilities are within their stability limits
6. Cascading or uncontrolled separation shall not occur

The NENM system is a radial system with major loads connected at Gladstone. The worst credible multiple contingency scenario would be losing the Gladstone-Walsenburg 230 kV line and the Gladstone-Springer 115 kV line due to failure of opening the Gladstone breakers. If this happens, the NENM loads will be disconnected from the system and will impose no negative impacts on the bulk electric system (BES).

3.1.3.1 Acceptable System Response

For a multiple contingency, the system response may include the following (FAC-010, R2.6 and R2.6.1).

- Planned or controlled interruption of service to radial customers or local network customers who receive service from the faulted facility or affected area
- System reconfiguration by manual or automatic control or protection actions
- Planned or controlled interruption of service to customers
- Planned removal from service of generators
- Curtailment of firm contracts

Yes and as explained in section 3.1.3.

3.2 Study Model (FAC-010-2.1, R3)

The study model must include the entire PNM Planning Authority Area and all other Planning Authority Areas that could potentially impact the Facility or Facilities under study (FAC-010-2.1, R3.1). PNM recommends using an approved WECC base case as a starting point for the study model.

Yes and the study is based on the approved WECC 2015 heavy winter case.

3.2.1 Contingencies (FAC-010, R3.2)

The study will include the contingencies as described in sections 0, 0, and 0.

Yes.

3.2.1.1 Single Contingencies

The study will consist of the following single contingencies.

1. Most severe single line to ground or three phase fault with normal clearing (FAC-010, R2.2.1)
2. Loss of any generator, line, transformer, or shunt device without a fault (FAC-010, R2.2.2)
3. Single pole block in DC system with normal clearing[1] (FAC-010, R2.2.3)
4. Any contingencies previous used to determine the SOL for the Facility or Facilities being studied.
5. Contingency based on historical system response or the judgment of the study engineer.
6. New outages resulting from changes to system topology that have not been studied.

The contingency list used for transient stability studies is a subset of the contingencies used for thermal and voltage stability studies. They are chosen based on historical system response, previous study results or the judgment of the study engineer.

Yes. Most severe single contingencies include the Springer-Gladstone 115 kV line, the Walsenburg-Gladstone 230 kV line and the Ojo-Taos 345 kV line. Generation dispatch does not apply because there is negligible local generation in NENM area. There is no DC system in the NENM area.

[1] There are currently no DC bi-pole transmission contingencies applicable to the PNM Planning Authority area.

3.2.1.2 Multiple Contingencies

The study will consist of the following multiple contingencies.

1. Contingencies identified in TPL-003 (FAC-010, R2)
2. Contingencies identified in the Regional Difference section of FAC-010-0.2.
3. Any contingencies previous used to determine the SOL for the Facility or Facilities being studied.
4. Contingency based on historical system response or the judgment of the study engineer.
5. New outages resulting from changes to system topology that have not been studied.

The contingency list used for transient stability studies is a subset of the contingencies used for steady state thermal and voltage studies and are chosen based on knowledge of the system, previous study practices and the judgment of the study engineers.

Yes and as explained in section 3.1.3.

3.2.2 Level of Detail (FAC-010-2.1, R3.3)

The model shall be a detailed as needed to adequately analyze the facilities or group of facilities being studied. At a minimum, the study model should include all facilities modeled in a WECC base case.

Yes.

3.2.3 Use of Special Protection Systems or Remedial Action Plans (FAC-010-2.1, R3.4)

Special Protection Systems and Remedial Action Schemes are modeled, if applicable, including the following (FAC-010, R3.4).

The following protection schemes were included:

(1) Clapham-Bravo Dome 115 kV out-of-step relay, and
(2) Walsenburg-Gladstone 230 kV RAS.

3.2.4 System Configuration (FAC-010-2.1, R3.5)

Anticipated system configuration, generation dispatch, and load levels shall be included in the model. The study model will include planned outages. The load level will be updated with the latest forecast. The model may include planned generation and transmission facilities.

Yes. Generation dispatch does not apply because there is negligible local generation in NENM area.

3.2.5 Criteria for Determining IROLs (FAC-0.10-2.1, R3.6)

The following criteria will be used to determine what subsets of the SOLs qualify as IROLs (FAC-010, R3.6).

An IROL is defined as a system Operating Limit that, if violated, could lead to instability, uncontrolled separation, or cascading outages that adversely impact the reliability of the Bulk Electric System. If an IROL condition occurs, the time limit to alleviate the IROL is 30 minutes.

IROLs will be determined from power flow and stability analysis that demonstrate risks for cascading. Power flow studies will be used to identify contingency overloads that will lead to cascading. Stability analysis showing undamped or growing oscillations for voltage or frequency at BES facilities requiring manual or automatic removal of additional equipment will be considered IROLs if such removal results in further overloads, voltage collapse or dynamic instability leading to additional equipment loss outside of a local area.

The Walsenburg-Gladstone 230 kV line does not qualify as IROL. This is because the existing protection schemes of dropping and curtailing NENM loads will not lead to cascading outages or negative impacts on the BES.

3.3 Regional Differences

The following regional differences are applicable since PNM is within the Western Interconnection (FAC-010, E1).

3.3.1 Multiple Facility Contingencies

As governed by the R2.5 and R2.6, starting with all Facilities in service, the following multiple Facility Contingencies will be evaluated when establishing SOLs (FAC-010, E1.1).

1. Simultaneous permanent phase to ground Faults on different phases of each of two adjacent transmission circuits on a multiple circuit town, with normal clearing. If multiple circuit towers are used only for station entrance and exit purposes, and if they don't exceed five towers at each station, then this condition is an acceptable risk and can be excluded. (FAC-010, E1.1.1)
2. Permanent phase to ground Fault of any generator, transmission circuit, transformer or bus section with Delayed Fault Clearing, except for bus sectionalizing breakers or bus-tie breakers addressed in E1.1.7. (FAC-010, E1.1.2)
3. Simultaneous permanent loss of both poles of a direct current bipolar Facility without an alternating current Fault[2] (FAC-010, E1.1.3)
4. Failure of a circuit breaker associated with a Special Protection System to operator when required following: the loss of any element without a Fault; or a permanent phase to ground Fault, with Normal Clearing, on any transmission circuit, transformer or bus section. (FAC-010, E1.1.4)
5. Non-three phase Fault with Normal Clearing on a common mode Contingency of two adjacent circuits on separate towers unless the event frequency is determined to be less than one in thirty years. (FAC-010, E1.1.5)
6. Common mode outage of two generating units connected to the same switchyard, not otherwise addressed by FAC-010 (FAC-010, E1.1.6)
7. Loss of multiple bus sections as the result of failure or delayed clearing of a bus tie or bus sectionalizing breaker to clear a permanent Phase to Ground Fault (FAC-010, E1.1.7)

NENM area is a radial system and will not impact the regional BES.

3.3.2 System Performance Criteria

The SOL will be established such that for Multiple Contingencies in E1.1.1 through E1.1.5 operation within the SOL will result in system performance consistent with the following (FAC-010, E1.2).

1. All Facilities shall be operating within their applicable thermal, frequency, and voltage limits (FAC-010, E1.2.1)
2. Cascading shall not occur (FAC-010, E1.2.2)
3. Uncontrolled separation from the system does not occur(FAC-010, E1.2.3)
4. The system demonstrates transient, dynamic , and voltage stability (FAC-010, E1.2.4)
5. Depending on system design and expect system impacts, the controlled interruption of service to customers, planned removal from service of certain generators, and/or curtailment of

[2] There are currently no DC bi-pole transmission contingencies applicable to the PNM Planning Authority area.

contracted firm electric power transfers may be modeled to maintain the overall security of the interconnected transmission systems (FAC-010, E1.2.5)

6. Interruption of firm transfers, Load or system reconfiguration is permitted through manual or automatic control or protection actions (FAC-010, E1.2.6)
7. To prepare for the next Contingency, system adjustments are permitted, including changes to generation, Load, and transmission system topology when determining limits(FAC-010, E1.2.7)

Yes the study meets these criteria.

The SOL will be established such that for Multiple Contingencies in E1.1.6 through E1.1.7 operation within the SOL will provide system performance consistent with the following with respect to impacts on other systems. (FAC-010, E1.3).

1. Cascading does not occur (FAC-010, E1.3.1).

PNM will adhere to any additional changes for specific facilities as required by the Western Interconnection (FAC-010, E1.4)

No and the study does not indicate cascading outages.

3.4 <u>Availability of System Operating Limits (SOLs) Methodology</u>

PNM will make available its SOL Methodology, and any changes to that methodology, to the following prior to the effective date of the change (FAC-010, R4):

1. Each adjacent Planning Authority and each Planning Authority that indicated it has a reliability-related need for the methodology. (FAC-010, R4.1)
2. Each Reliability Coordinator and Transmission Operator that operates any portion of PNM's Planning Authority Area. (FAC-010, R4.2)
3. Each Transmission Planner that works in the PNM Planning Authority Area. (FAC-010, R4.3)

Yes, Tri-State follows PNM's availability of system operating limits methodology.

4 Establishing and Communicating SOLs and IROLs (FAC-014-2)

The following sections describe how PNM will establish and communicate SOLs and IROLs.

Yes, Tri-State follows PNM's establishing and communicating SOLs and IROLs describing in 4.1 through 4.3 below:

4.1 <u>Establishing SOLs and IROLs</u>

PNM does not directly establish SOLs for other entities unless agreed to by the other entity. PNM will utilize SOLs and IROLs established by entities within the PNM Planning Authority Area. If PNM determines a SOL or IROL was not established using the Planning Authority methodology, PNM will request that the entity reestablish the SOL or IROL using the Planning Authority methodology. (FAC-014-2, R3)

4.2 <u>Communicating SOLs and IROL</u>

PNM will provide established SOLs and IROLs to adjacent Planning Authorities, and Transmission Planners, Transmission Service Provides, Transmission Operators, and Reliability Coordinators within the PNM Planning Authority Area with a reliability-related need and who provide a written request including a schedule for delivery (FAC-014-2, R5.3).

4.3 Establishing and Communicating List of Multiple Contingencies

PNM will identify the subset of multiple contingencies from TPL-003 which results in stability limits (FAC-014-2, R6). PNM will provide the list and associated stability limits to the Reliability Coordinator (FAC-014-2, R6.1). If no multiple contingencies are identified, PNM will notify the Reliability Coordinator that no stability related multiple contingencies have be identified (FAC-014-2, R6.2)

Study Results

It was found that there are both upper and lower bound limits for the north to south Walsenburg-Gladstone 230 kV line flows. The limits were caused by multiple factors and are summarized in Table 1 and graphed on Figure 4. The details are addressed in the Gladstone Phase Shifting Transformer Operating Limit Study After System Upgrades report dated May 12, 2015.

There were no planning criteria violations from the Walsenburg-Gladstone 230 kV line outage, the Springer-Gladstone 115 kV line outage under steady state conditions, or the 3-phase line to ground fault at Gladstone on the Walsenburg-Gladstone 230 kV line under transient stability conditions.

It is important to note that the minimum Walsenburg-Gladstone 230 kV line flow curves shown in Figure 4 can shift downwards for lighter load levels. The power flow study results suggested that under peak load conditions, the pre-outage Ojo-Taos 345 kV line flow should not be operated above 108 MW to avoid overloading the Ojo-Hernandez 115 kV line following the Ojo-Taos 345 kV line outage. This could be accomplished by increasing the flows on the Walsenburg-Gladstone 230 kV line.

Table 1: Study Results of 2015HW Case

	System Upgrade that Includes the Gladstone 115 kV, 30 MVAR (2 x 15) Shunt Capacitors	**Existing System that Includes the Operation of the Clapham-Bravo Dome 115 kV Line Out-Of-Step Relay Commenced on June 16, 2015**						
Descriptions	**NENM Load 0****	**NENM Load 1**	**NENM Load 2**	**NENM Load 3**	**NENM Load 4**	**NENM Load 5**	**NENM Load 6**	**NENM Load 7**
Bravo Dome motor load 1 (MW)	36.5	36.5	36.5	36.5	36.5	36.5	25.0	0.0
Bravo Dome motor load 2 (MW)	13.5	13.5	13.5	13.5	13.5	13.5	0.0	0.0
Bravo Dome fixed load (MW) *	22.0	22.0	17.0	12.0	7.0	2.0	0.0	0.0
Total Bravo Dome load (MW)	72.0	72.0	67.0	62.0	57.0	52.0	25.0	0.0
Clapham load (MW), (**29.5** for 2020HS sensitivity)	**29.5**	10.5	10.5	10.5	10.5	10.5	10.5	0.0
Bravo Dome West (Hess) motor load (MW)*	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0
Bueyeros fixed load (MW)*	20.0	20.0	20.0	20.0	20.0	20.0	0.0	0.0
NENM Loads = total of above loads (MW)	**131.5**	**112.5**	**107.5**	**102.5**	**97.5**	**92.5**	**45.5**	**0.0**
Walsenburg-Gladstone 230 kV maximum flows (MW) (North to south)	**180.5**	**192.5**	**194.8**	**198.8**	**201.9**	**200.8**	**201.2**	**166.1**
Gladstone 230 kV PST angles (Degrees)	-2.5	-16.0	-19.0	-23.0	-26.5	-27.5	-40.0	-33.8
Gladstone 230 kV PST voltage under N-0 (Per Unit)	1.004	0.967	0.963	0.956	**0.950**	**0.950**	**0.950**	0.961
Maximum flow limiting factors	3 phase fault at Gladstone on the Springer-Gladstone115 kV line. (Solved with Clapham 115 kV voltage swing measures = 70% and within 1 Gladstone PST degree prior to system oscillations.)				Gladstone 230 kV PST voltage drops to 0.950 Per Unit under N-0. 3 phase fault at Gladstone on the Springer-Gladstone115 kV line. (Solved with Clapham 115 kV voltage swing measures = 70% and within a few Gladstone PST degrees prior to system oscillations.)		Gladstone 230 kV PST voltage drops to 0.950 Per Unit under N-0.	Springer-Gladstone 115 kV line (rated 174 MVA) loads to 100% under N-0.
Walsenburg-Gladstone 230 kV minimum flows (MW) (North to south)	**177.2**	**155.0**	**147.3**	**141.7**	**135.0**	**128.8**	**77.2**	**30.1**
Gladstone 230 kV PST angles (Degrees)	-0.8	4.0	6.0	7.5	9.3	10.8	23.0	33.5
Minimum flow limiting factors	Ojo-Hernandez 115 kV line (rated 183 MVA) loads to 100% following the Ojo-Taos 345 kV line outage.							

* Loads to be dropped (except for Bravo Dome not to below 52 MW) for the Walsenburg-Gladstone 230 kV line outage per existing RAS.

** For NENM Load 0, Clapham load was increased to 2020HS projected value of 29.5 MW. 30 MVAR (2 x 15) shunt capacitors are required at Gladstone 115 kV to support the NENM area voltages under this loading condition.

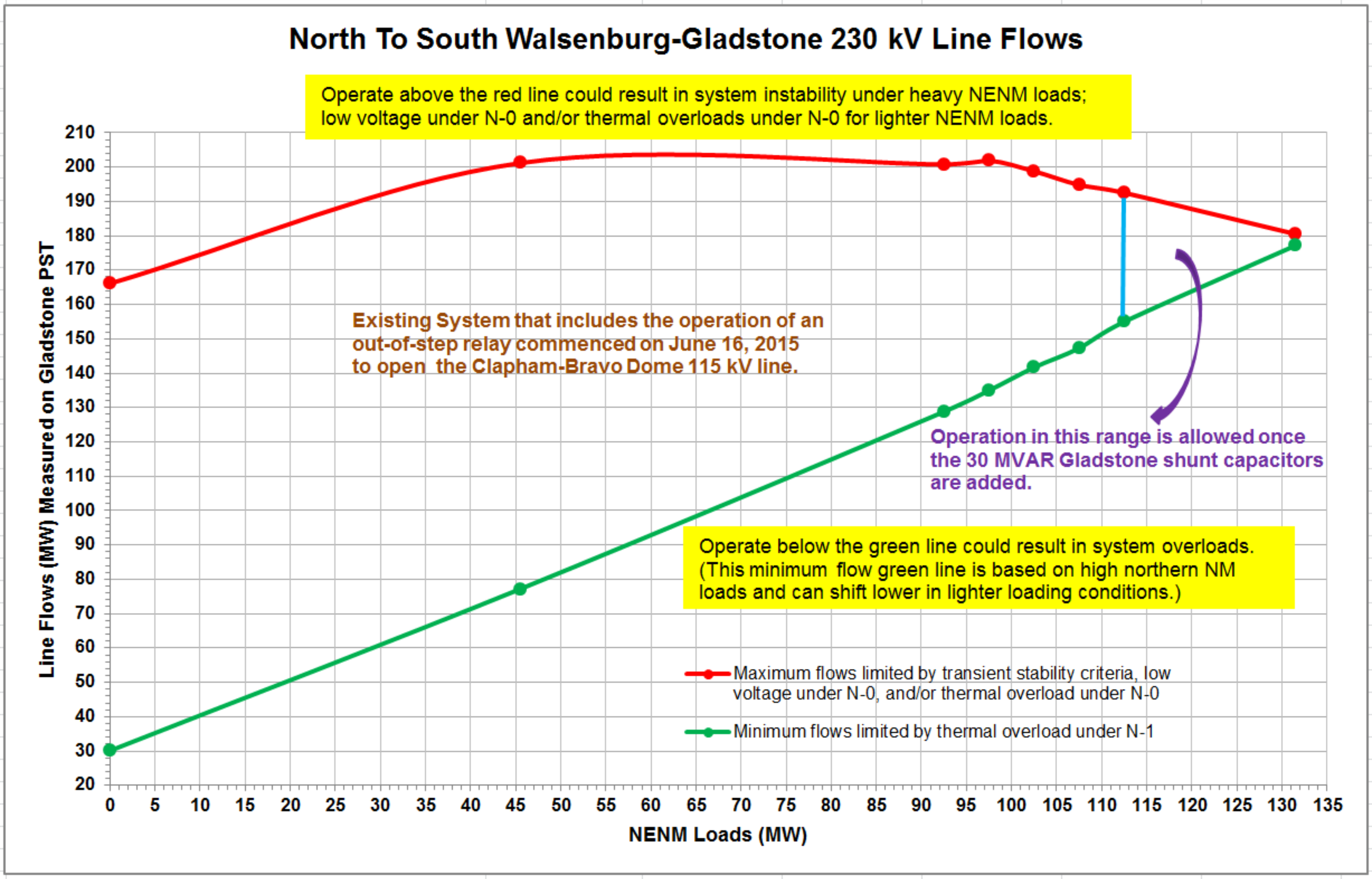

Figure 4: Walsenburg-Gladstone 230 kV Line Flows

Conclusion

By implementing an out-of-step protection scheme on the Clapham-Bravo Dome 115 kV line, higher Walsenburg-Gladstone 230 kV flows can be established from the transient stability and steady state study results. The allowable range of Walsenburg-Gladstone 230 kV line flows vary with NENM load levels. This is shown graphically on Figure 4.

A new 30 MVAR (2 x 15) shunt capacitor at Gladstone 115 kV bus is recommended to support the full NENM loads (NENM Load 0 scenario). The expected in service date is the fourth quarter of 2017. While adding a breaker to the existing 20 MVAR Gladstone 230 kV shunt line reactor does provide operational flexibility, line reactor switching alone will not provide adequate voltage support to the NENM transmission system.

It is recommended to minimize additional load increase in the NENM area. This is due to the weak transmission system already relying on the existing Walsenburg-Gladstone 230 kV line outage RAS and the Clapham-Bravo Dome 115 kV line out-of-step protection relay to mitigate the NENM transmission problems.

Appendix A: Planning Criteria

Consistent with the Western Electricity Coordinating Council (WECC) and the North American Electric Reliability Council (NERC).

Table A 1

Summary of Tri-State Steady-State Planning Criteria

System Condition	Operating Voltages [1] (per unit)		Maximum Loading [2] (Percent of Continuous Rating)	
	Maximum	Minimum	Transmission Lines	Other Facilities
Normal	1.05	0.95	80/100	100
N – k	1.10	0.90	100	100

(1) Exceptions may be granted for high side buses of Load-Tap-Changing (LTC) transformers that violate this criterion, if the corresponding low side busses are well within the criterion.

(2) The continuous rating is synonymous with the static thermal rating. Facilities exceeding 80% criteria will be flagged for close scrutiny. By no means, shall the 100% rating be exceeded without regard in planning studies.

Table A 2

Tri-State Voltage Criteria		
Conditions	**Operating Voltages**	**Delta-V**
Normal (P0 event)	0.95 - 1.05	
Contingency (P1 event)	0.90 - 1.10	8%
Contingency (P2-P7 event)	0.90 - 1.10	-

Table A 3

Steady State & Stability Performance Planning Events

Steady State & Stability:

a. The System shall remain stable. Cascading and uncontrolled islanding shall not occur.
b. Consequential Load Loss as well as generation loss is acceptable as a consequence of any event excluding P0.
c. Simulate the removal of all elements that Protection Systems and other controls are expected to automatically disconnect for each event.
d. Simulate Normal Clearing unless otherwise specified.
e. Planned System adjustments such as Transmission configuration changes and re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings.

Steady State Only:

f. Applicable Facility Ratings shall not be exceeded.
g. System steady state voltages and post-Contingency voltage deviations shall be within acceptable limits as established by the Planning Coordinator and the Transmission Planner.
h. Planning event P0 is applicable to steady state only.
i. The response of voltage sensitive Load that is disconnected from the System by end-user equipment associated with an event shall not be used to meet steady state performance requirements.

Stability Only:

j. Transient voltage response shall be within acceptable limits established by the Planning Coordinator and the Transmission Planner.

<table>
<tr><th>Category</th><th>Initial Condition</th><th>Event[1]</th><th>Fault Type[2]</th><th>BES Level[3]</th><th>Interruption of Firm Transmission Service Allowed[4]</th><th>Non-Consequential Load Loss Allowed</th></tr>
<tr><td>P0
No Contingency</td><td>Normal System</td><td>None</td><td>N/A</td><td>EHV, HV</td><td>No</td><td>No</td></tr>
<tr><td rowspan="2">P1
Single Contingency</td><td rowspan="2">Normal System</td><td>Loss of one of the following:
1. Generator
2. Transmission Circuit
3. Transformer[5]
4. Shunt Device[6]</td><td>3Ø</td><td rowspan="2">EHV, HV</td><td rowspan="2">No[9]</td><td rowspan="2">No[12]</td></tr>
<tr><td>5. Single pole of a DC line</td><td>SLG</td></tr>
<tr><td rowspan="6">P2
Single Contingency</td><td rowspan="6">Normal System</td><td>1. Opening of a line section w/o a fault[7]</td><td>N/A</td><td>EHV, HV</td><td>No[9]</td><td>No[12]</td></tr>
<tr><td rowspan="2">2. Bus Section Fault</td><td rowspan="2">SLG</td><td>EHV</td><td>No[9]</td><td>No</td></tr>
<tr><td>HV</td><td>Yes</td><td>Yes</td></tr>
<tr><td rowspan="2">3. Internal Breaker Fault (non-Bus-tie Breaker)[8]</td><td rowspan="2">SLG</td><td>EHV</td><td>No[9]</td><td>No</td></tr>
<tr><td>HV</td><td>Yes</td><td>Yes</td></tr>
<tr><td>4. Internal Breaker Fault (Bus-tie Breaker)[8]</td><td>SLG</td><td>EHV, HV</td><td>Yes</td><td>Yes</td></tr>
</table>

<table>
<tr><td rowspan="2">P3
Multiple Contingency</td><td rowspan="2">Loss of generator unit followed by System adjustments[9]</td><td>Loss of one of the following:
1. Generator
2. Transmission Circuit
3. Transformer[5]
4. Shunt Device[6]</td><td>3Ø</td><td rowspan="2">EHV, HV</td><td rowspan="2">No[9]</td><td rowspan="2">No[12]</td></tr>
<tr><td>5. Single pole of a DC line</td><td>SLG</td></tr>
<tr><td rowspan="3">P4
Multiple Contingency

(Fault plus stuck breaker[10])</td><td rowspan="3">Normal System</td><td rowspan="2">Loss of multiple elements caused by a stuck breaker[10] (non-Bus-tie Breaker) attempting to clear a Fault on one of the following:
1. Generator
2. Transmission Circuit
3. Transformer[5]
4. Shunt Device[6]
5. Bus Section</td><td rowspan="2">SLG</td><td>EHV</td><td>No[9]</td><td>No</td></tr>
<tr><td>HV</td><td>Yes</td><td>Yes</td></tr>
<tr><td>6. Loss of multiple elements caused by a stuck breaker[10] (Bus-tie Breaker) attempting to clear a Fault on the associated bus</td><td>SLG</td><td>EHV, HV</td><td>Yes</td><td>Yes</td></tr>
<tr><td rowspan="2">P5
Multiple Contingency

(Fault plus relay failure to operate)</td><td rowspan="2">Normal System</td><td rowspan="2">Delayed Fault Clearing due to the failure of a non-redundant relay[13] protecting the Faulted element to operate as designed, for one of the following:
1. Generator
2. Transmission Circuit
3. Transformer[5]
4. Shunt Device[6]
5. Bus Section</td><td rowspan="2">SLG</td><td>EHV</td><td>No[9]</td><td>No</td></tr>
<tr><td>HV</td><td>Yes</td><td>Yes</td></tr>
<tr><td rowspan="2">P6
Multiple Contingency

(Two overlapping singles)</td><td rowspan="2">Loss of one of the following followed by System adjustments[9].
1. Transmission Circuit
2. Transformer [5]
3. Shunt Device[6]
4. Single pole of a DC line</td><td>Loss of one of the following:
1. Transmission Circuit
2. Transformer[5]
3. Shunt Device[6]</td><td>3Ø</td><td>EHV, HV</td><td>Yes</td><td>Yes</td></tr>
<tr><td>4. Single pole of a DC line</td><td>SLG</td><td>EHV, HV</td><td>Yes</td><td>Yes</td></tr>
<tr><td>P7
Multiple Contingency
(Common Structure)</td><td>Normal System</td><td>The loss of:
1. Any two adjacent (vertically or horizontally) circuits on common structure[11]
2. Loss of a bipolar DC line</td><td>SLG</td><td>EHV, HV</td><td>Yes</td><td>Yes</td></tr>
</table>

Basic WECC Dynamic Criteria:

Tri-State's dynamic reactive power and voltage control / regulation criteria are in accordance with the NERC/WECC dynamic performance criteria and are as follows:

- Transient stability voltage response at applicable BES buses should recover to 80 percent of pre-contingency voltage within 10 seconds of the initiating event.

- Oscillations should show positive damping within a 30-second time frame.

Table A 4

Table 1

WSCC VOLTAGE STABILITY CRITERIA[*]

Performance Level	Disturbance (1)(2)(3)(4) Initiated By: Fault or No Fault DC Disturbance	MW Margin (P-V Method) (5)(6)(7)	MVAR Margin (V-Q Method) (6)(7)
A	Any element such as: One Generator One Circuit One Transformer One Reactive Power Source One DC Monopole	≥ 5%	Worst Case Scenario (8)
B	Bus Section	≥ 2.5%	50% of Margin Requirement in Level A
C	Any combination of two elements such as: A Line and a Generator A Line and a Reactive Power Source Two Generators Two Circuits Two Transformers Two Reactive Power Sources DC Bipole	≥ 2.5%	50% of Margin Requirement in Level A
D	Any combination of three or more elements such as: Three or More Circuits on ROW Entire Substation Entire Plant Including Switchyard	> 0	> 0

(1) This table applies equally to the system with all elements in service and the system with one element removed and the system readjusted (see Section 2.2).

(2) For application of this criteria within a member system, controlled load shedding is allowed to meet Performance Level A (see Section 2.2 for a description of provisions for application of this criteria within a member system).

(3) The list of element outages in each Performance Level is not intended to be different than the Disturbance Performance Table in the WECC Reliability Criteria. Additional element outages have been added to this table to show more examples of contingencies. Determination of credibility for contingencies for each Performance Level is based on the definitions used in the existing WECC Reliability Criteria.

(4) Margin for N-0 (base case) conditions must be greater than the margin for Performance Level A.

(5) Maximum operating point on the P axis must have a MW margin equal to or greater than the values in this table as measured from the nose point of the P-V curve for each Performance Level.

(6) Post-transient analysis techniques shall be utilized in applying the criteria.

(7) Each member system should consider, as appropriate, the uncertainties in Section 2.3 to determine the required margin for its system.

(8) The most reactive deficient bus must have adequate reactive power margin for the worst single contingency to satisfy either of the following conditions, whichever is worse: (i) a 5% increase beyond maximum forecasted loads or (ii) a 5% increase beyond maximum allowable interface flows. The worst single contingency is the one that causes the largest decrease in the reactive power margin.

(*) Table 1 is an excerpt from the WSCC Reliability Criteria for Transmission System Planning in effect at the time of this document's approval. The most current version of the Council's Table of Allowable Effects on Other Systems should be referred to when conducting studies.

Table A 5

<table>
<tr><th colspan="2">Table A 6 – Steady State & Stability Performance Extreme Events</th></tr>
<tr><td colspan="2">Steady State & Stability
For all extreme events evaluated:
a. Simulate the removal of all elements that Protection Systems and automatic controls are expected to disconnect for each Contingency.
b. Simulate Normal Clearing unless otherwise specified.</td></tr>
<tr><td>Steady State
1. Loss of a single generator, Transmission Circuit, single pole of a DC Line, shunt device, or transformer forced out of service followed by another single generator, Transmission Circuit, single pole of a different DC Line, shunt device, or transformer forced out of service prior to System adjustments.

2. Local area events affecting the Transmission System such as:
a. Loss of a tower line with three or more circuits.[11]
b. Loss of all Transmission lines on a common Right-of Way[11].
c. Loss of a switching station or substation (loss of one voltage level plus transformers).
d. Loss of all generating units at a generating station.
e. Loss of a large Load or major Load center.

3. Wide area events affecting the Transmission System based on System topology such as:
a. Loss of two generating stations resulting from conditions such as:
i. Loss of a large gas pipeline into a region or multiple regions that have significant gas-fired generation.
ii. Loss of the use of a large body of water as the cooling source for generation.
iii. Wildfires.
iv. Severe weather, e.g., hurricanes, tornadoes, etc.
v. A successful cyber attack.
vi. Shutdown of a nuclear power plant(s) and related facilities for a day or more for common causes such as problems with similarly designed plants.
b. Other events based upon operating experience that may result in wide area disturbances.</td>
<td>Stability

1. With an initial condition of a single generator, Transmission circuit, single pole of a DC line, shunt device, or transformer forced out of service, apply a 3Ø fault on another single generator, Transmission circuit, single pole of a different DC line, shunt device, or transformer prior to System adjustments.

2. Local or wide area events affecting the Transmission System such as:
a. 3Ø fault on generator with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
b. 3Ø fault on Transmission circuit with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
c. 3Ø fault on transformer with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
d. 3Ø fault on bus section with stuck breaker[10] or a relay failure[13] resulting in Delayed Fault Clearing.
e. 3Ø internal breaker fault.
f. f. Other events based upon operating experience, such as consideration of initiating events that experience suggests may result in wide area disturbances</td></tr>
</table>

Table A6 – Steady State & Stability Performance Footnotes (Planning Events and Extreme Events)

1. If the event analyzed involves BES elements at multiple System voltage levels, the lowest System voltage level of the element(s) removed for the analyzed event determines the stated performance criteria regarding allowances for interruptions of Firm Transmission Service and Non-Consequential Load Loss.

2. Unless specified otherwise, simulate Normal Clearing of faults. Single line to ground (SLG) or three-phase (3Ø) are the fault types that must be evaluated in Stability simulations for the event described. A 3Ø or a double line to ground fault study indicating the criteria are being met is sufficient evidence that a SLG condition would also meet the criteria.

3. Bulk Electric System (BES) level references include extra-high voltage (EHV) Facilities defined as greater than 300kV and high voltage (HV) Facilities defined as the 300kV and lower voltage Systems. The designation of EHV and HV is used to distinguish between stated performance criteria allowances for interruption of Firm Transmission Service and Non-Consequential Load Loss.

4. Curtailment of Conditional Firm Transmission Service is allowed when the conditions and/or events being studied formed the basis for the Conditional Firm Transmission Service.

5. For non-generator step up transformer outage events, the reference voltage, as used in footnote 1, applies to the low-side winding (excluding tertiary windings). For generator and Generator Step Up transformer outage events, the reference voltage applies to the BES connected voltage (high-side of the Generator Step Up transformer). Requirements which are applicable to transformers also apply to variable frequency transformers and phase shifting transformers.

6. Requirements which are applicable to shunt devices also apply to FACTS devices that are connected to ground.

7. Opening one end of a line section without a fault on a normally networked Transmission circuit such that the line is possibly serving Load radial from a single source point.

8. An internal breaker fault means a breaker failing internally, thus creating a System fault which must be cleared by protection on both sides of the breaker.

9. An objective of the planning process should be to minimize the likelihood and magnitude of interruption of Firm Transmission Service following Contingency events. Curtailment of Firm Transmission Service is allowed both as a System adjustment (as identified in the column entitled 'Initial Condition') and a corrective action when achieved through the appropriate re-dispatch of resources obligated to re-dispatch, where it can be demonstrated that Facilities, internal and external to the Transmission Planner's planning region, remain within applicable Facility Ratings and the re-dispatch does not result in any Non-Consequential Load Loss. Where limited options for re-dispatch exist, sensitivities associated with the availability of those resources should be considered.

10. A stuck breaker means that for a gang-operated breaker, all three phases of the breaker have remained closed. For an independent pole operated (IPO) or an independent pole tripping (IPT) breaker, only one pole is assumed to remain closed. A stuck breaker results in Delayed Fault Clearing.

11. Excludes circuits that share a common structure (Planning event P7, Extreme event steady state 2a) or common Right-of-Way (Extreme event, steady state 2b) for 1 mile or less.

12. An objective of the planning process is to minimize the likelihood and magnitude of Non-Consequential Load Loss following planning events. In limited circumstances, Non-Consequential Load Loss may be needed throughout the planning horizon to ensure that BES performance requirements are met. However, when Non-Consequential Load Loss is utilized under footnote 12 within the Near-Term Transmission Planning Horizon to address BES performance requirements, such interruption is limited to circumstances where the Non-Consequential Load Loss meets the conditions shown in Attachment 1. In no case can the planned Non-Consequential Load Loss under footnote 12 exceed 75 MW for US registered entities. The amount of planned Non- Consequential Load Loss for a non-US Registered Entity should be implemented in a manner that is consistent with, or under the direction of, the applicable governmental authority or its agency in the non-US jurisdiction.

13. Applies to the following relay functions or types: pilot (#85), distance (#21), differential (#87), current (#50, 51, and 67), voltage (#27 & 59), directional (#32, & 67), and tripping (#86, & 94).

Attachment A: NERC Standard FAC-010-2.1
(See the attached pdf file.)

Attachment B: NERC Standard FAC-014-2
(See the attached pdf file.)