BPA System Operating Limits Methodology
for the Planning Horizon

Bonneville Power Administration
Transmission Services
Transmission Planning

February 29, 2008

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I. Introduction

NERC Standard FAC-010-1 requires that each Planning Authority "shall have a documented System Operating Limits (SOL) Methodology for use in developing SOL's within its Planning Authority Area" for the planning horizon. This document describes the Bonneville Power Administration's (BPA's) System Operating Limits Methodology for the Planning Horizon.

II. Definitions

The NERC Glossary of Terms Used in Reliability Standards provides the following definitions:

System Operating Limit (SOL):

> *The value (such as MW, MVar, Amperes, Frequency or Volts) that satisfies the most limiting of the prescribed operating criteria for a specified system configuration to ensure operation within acceptable reliability criteria. System Operating Limits are based upon certain operating criteria. These include, but are not limited to:*
>
> • ***Facility Ratings*** *(Applicable pre - and post - Contingency equipment or facility ratings)*
> • ***Transient Stability Ratings*** *(Applicable pre - and post - Contingency Stability Limits)*
> • ***Voltage Stability Ratings*** *(Applicable pre - and post - Contingency Voltage Stability)*
> • ***System Voltage Limits*** *(Applicable pre - and post - Contingency Voltage Limits)*

Interconnection Reliability Operating Limit (IROL):

> *The value (such as MW, MVar, Amperes, Frequency or Volts) derived from, or a subset of the System Operating Limits, which if exceeded, could expose a widespread area of the Bulk Electric System to instability, uncontrolled separation(s) or cascading outages.*

Bulk Electric System

> *As defined by the Regional Reliability Organization, the electrical generation resources, transmission lines, interconnections with neighbouring systems, and associated equipment, generally operated at voltages of 100 kV or higher. Radial transmission facilities serving only load with one transmission source are generally not included in this definition.*

The definition of System Operating Limit lists units of measure (MW, MVAr, Amperes, Frequency or Volts). BPA typically expresses System Operating Limits in MW.

Section III of this report addresses BPA's SOL Methodology for the planning horizon. This methodology references the following table from the NERC Planning Standards:

III. SOL Methodology for the Planning Horizon (NERC FAC-010-1)

A. Introduction

This SOL Methodology is applicable for determining System Operating Limits in the planning horizon within BPA's Planning Authority Area (ref R1). Since this methodology addresses the planning horizon (typically extending beyond one year to a maximum of ten years), it is assumed to be long enough that the portfolio of facilities can be changed during that time (ref 1.1). Also, the SOL Methodology as described in Section IV and Table 1 - indicates that SOLs shall not exceed associated Facility Ratings (i.e. Applicable Rating) (ref R1.2).

In addition, the WECC operating philosophy is to operate only in conditions that have been studied. Therefore, under these normal operating conditions, there are never IROL conditions (only SOL). An IROL condition may be created by the occurrence of one or more unanticipated contingencies. When this occurs, under WECC Reliability Standards, BES Operators are required to resolve the IROL condition within 20 minutes (stability) or 30 minutes (thermal) (ref R1.3).

B. Contingencies

Details of contingencies considered and required system performance are addressed below under section D, Determining System Operating Limits for the Planning Horizon.

C. System Performance

System performance within BPA's Planning Authority Area shall be determined based on pre-contingency and contingency states and system response as described in Section IV and Table 1 – Transmission System Standards – Normal and Contingency Conditions (ref R2).

Pre-Contingency: In the pre-contingency state and with All Facilities in service, system performance shall have all facilities within their Facility Ratings and within their thermal, voltage and stability limits (ref R2.1).

Single Contingency: Following single contingencies, system performance shall have all facilities within their Facility Ratings and within their thermal, voltage and stability limits; and Cascading Outages or uncontrolled separation shall not occur (ref R2.2). The BES response to a Single Contingency, may include the following (ref R2.3):

- **Planned or controlled interruption of electric supply to radial customers or some local network customers connected to or supplied by the Faulted Facility or by the affected area (ref R2.3.1).**
- **System reconfiguration through manual or automatic control or protection actions (ref R2.3.2).**
- **To prepare for the next Contingency, system adjustments may be made, including changes to generation, uses of the transmission system, and the transmission system topology (ref R2.3.3).**

Multiple Contingency: Following multiple contingences identified in Reliability Standard TPL-003, system performance shall have all facilities within their Facility Ratings and within thermal, voltage and stability limits; and Cascading Outages or uncontrolled separation shall not occur (ref R2.4).

D. Determining System Operating Limits for the Planning Horizon

BPA's Planning Authority Area will be screened using the following methodologies as applicable to determine System Operating Limits. The most limiting methodology will determine the System Operating Limit for the Planning Horizon. The following steps are taken regardless of how the path or area is defined (ref R3):

- **Power Flow Base Case will include the following (ref R3.1, R3.3, R3.5):**
  - Study model includes the entire Western Electricity Coordinating Council (WECC) system which reflects an anticipated system configuration, generation dispatch, and load level (peak and/or off-peak) for seasonal (i.e. winter, spring, summer, and/or fall) system conditions
  - Study model assumes "All Facilities In Service" - No planned outages
  - Appropriate voltage profile and equipment loaded within the rating of facility

- **Remedial Action Schemes (RAS) are modeled if applicable, including (ref R3.4):**
  - Dropping generation
  - Switching shunt reactive devices
  - Switching series capacitors
  - Switching resistive devices (i.e. braking resistor)
  - Adjusting phase shifters
  - Tripping lines and/or loads
  - Ramping DC lines
  - Area separation schemes

Thermal Limits – BPA's Planning Authority Area is screened using power flow tools such as PowerWorld, PSS/E, and PSLF for limitations caused by thermal equipment limits with all lines in service and following outage conditions using the following methodology:

- **Contingencies for screening, are defined as category B and C contingencies in the NERC Transmission System Standards (reference Table 1) and those selected for detailed study are the ones most pertinent to the area or path of concern (ref R3.2).**

- Time versus temperature analysis can be used to maximize limits, ensuring that the maximum operating temperature is not reached for at least 30 minutes. This allows adequate time for manual dispatcher response to reduce system loading problems.

- Contingencies with Power Transfer Distribution Factors (PTDF) and Outage Transfer Distribution Factors (OTDF) below 2% may be ignored. This prevents outages that are relatively insensitive to power transfers on a path, from limiting that path.

- Remedial Action Schemes (RAS) are modeled when applicable.

- System performance for outages must meet the NERC Transmission System Standards – Normal and Contingency Conditions (reference Table 1).

Voltage Stability Limits – BPA's Planning Authority Area is screened using power flow tools such as PowerWorld, PSS/E, and PSLF for voltage stability limits if previous studies have shown that the area or path is sensitive to voltage stability problems or the path has not been previously studied.

If the area or path is sensitive to voltage stability problems, a selected list of the worst performing contingencies is used. If the area or path has not been previously studied for voltage stability performance, the full list of relevant contingencies is used for screening (ref R3.2).

- Remedial Action Schemes (RAS) are modeled when applicable.

- BPA follows the WECC voltage stability analysis documented in the "Guide to WECC/NERC Planning Standards I.D. – Voltage Support and Reactive Power to ensure positive reactive margin is maintained for all of the contingencies studied.

Transient Stability Limits – BPA's Planning Authority Area is screened using dynamic simulation tools (GE-PSDS, PTI-PSS/E) for transient stability limits if previous studies have shown the area or path is sensitive to transient stability problems or has not been studied before, using the following methodology.

- **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 the following criteria (ref R3.2**):
    - Any contingency that would set the SOL based on voltage stability criteria.
    - Additional contingencies based on historical system response, previous study results or the judgement of the study engineer.

- Remedial Action Schemes (RAS) are modeled when applicable.

- Each contingency is run for at least a 10 second simulation.

- Results are compared to the criteria in the WECC Disturbance Performance Table as defined in the NERC/WECC Planning Standards for acceptability.
  Acceptable performance is based on but not limited to:
    - Maximum first swing voltage dip and duration
    - Low frequency dip, and
    - System damping

E. Availability of SOL Methodology for Comments

BPA shall make available its SOL Methodology, and any changes to that methodology, to all of the following prior to the effectiveness of the change (ref R4):

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

F. Response to Comments on SOL Methodology

If a recipient of the SOL Methodology provides documented technical comments on the methodology, BPA shall provide a documented response to that recipient within 45 calendar days of receipt of those comments. The response shall indicate whether a change will be made to the SOL Methodology and, if no change will be made to that SOL Methodology, the reason why (ref R5).

IV. System Performance Standards

System Performance Standards within the BPA Planning Authority Area are defined in the following Table from the NERC Planning Standards:

> **Table 1 – Transmission System Standards – Normal and Contingency Conditions**: Conditions on the power system that are planned for with all facilities in service and during contingencies.

Table 1

NERC Transmission System Standards –Normal and Contingency Conditions

Table I. Transmission System Standards – Normal and Emergency Conditions

Category	Contingencies	System Limits or Impacts		
	Initiating Event(s) and Contingency Element(s)	System Stable and both Thermal and Voltage Limits within Applicable Rating [a]	Loss of Demand or Curtailed Firm Transfers	Cascading [c] Outages
A No Contingencies	All Facilities in Service	Yes	No	No
B Event resulting in the loss of a single element.	Single Line Ground (SLG) or 3-Phase (3Ø) Fault, with Normal Clearing: 1. Generator 2. Transmission Circuit 3. Transformer Loss of an Element without a Fault.	Yes Yes Yes Yes	No [b] No [b] No [b] No [b]	No No No No
	Single Pole Block, Normal Clearing[d]: 4. Single Pole (dc) Line	Yes	No[b]	No
C Event(s) resulting in the loss of two or more (multiple) elements.	SLG Fault, with Normal Clearing[d]: 1. Bus Section 2. Breaker (failure or internal Fault)	Yes Yes	Planned/ Controlled[e] Planned/ Controlled[e]	No No
	SLG or 3Ø Fault, with Normal Clearing[d], Manual System Adjustments, followed by another SLG or 3Ø Fault, with Normal Clearing[d]: 3. Category B (B1, B2, B3, or B4) contingency, manual system adjustments, followed by another Category B (B1, B2, B3, or B4) contingency	Yes	Planned/ Controlled[e]	No
	Bipolar Block, with Normal Clearing[d]: 4. Bipolar (dc) Line Fault (non 3Ø), with Normal Clearing[d]: 5. Any two circuits of a multiple circuit towerline[f]	Yes Yes	Planned/ Controlled[e] Planned/ Controlled[e]	No No
	SLG Fault, with Delayed Clearing[d] (stuck breaker or protection system failure): 6. Generator 7. Transformer 8. Transmission Circuit 9. Bus Section	Yes Yes Yes Yes	Planned/ Controlled[e] Planned/ Controlled[e] Planned/ Controlled[e] Planned/ Controlled[e]	No No No No

Table 1

NERC Transmission System Standards –Normal and Contingency Conditions (continued)

D [d] Extreme event resulting in two or more (multiple) elements removed or Cascading out of service	3Ø Fault, with Delayed Clearing [e] (stuck breaker or protection system failure): 1. Generator 2. Transmission Circuit 3. Transformer 4. Bus Section 3Ø Fault, with Normal Clearing [e]: 5. Breaker (failure or internal Fault) 6. Loss of towerline with three or more circuits 7. All transmission lines on a common right-of way 8. Loss of a substation (one voltage level plus transformers) 9. Loss of a switching station (one voltage level plus transformers) 10. Loss of all generating units at a station 11. Loss of a large Load or major Load center 12. Failure of a fully redundant Special Protection System (or remedial action scheme) to operate when required 13. Operation, partial operation, or misoperation of a fully redundant Special Protection System (or Remedial Action Scheme) in response to an event or abnormal system condition for which it was not intended to operate 14. Impact of severe power swings or oscillations from Disturbances in another Regional Reliability Organization.	Evaluate for risks and consequences. • May involve substantial loss of customer Demand and generation in a widespread area or areas. • Portions or all of the interconnected systems may or may not achieve a new, stable operating point. • Evaluation of these events may require joint studies with neighboring systems.

a) Applicable rating refers to the applicable Normal and Emergency facility thermal Rating or system voltage limit as determined and consistently applied by the system or facility owner. Applicable Ratings may include Emergency Ratings applicable for short durations as required to permit operating steps necessary to maintain system control. All Ratings must be established consistent with applicable NERC Reliability Standards addressing Facility Ratings.

b) Planned or controlled interruption of electric supply to radial customers or some local Network customers, connected to or supplied by the Faulted element or by the affected area, may occur in certain areas without impacting the overall reliability of the interconnected transmission systems. To prepare for the next contingency, system adjustments are permitted, including curtailments of contracted Firm (non-recallable reserved) electric power Transfers.

c) Depending on system design and expected system impacts, the controlled interruption of electric supply to customers (load shedding), the planned removal from service of certain generators, and/or the curtailment of contracted Firm (non-recallable reserved) electric power transfers may be necessary to maintain the overall reliability of the interconnected transmission systems.

d) A number of extreme contingencies that are listed under Category D and judged to be critical by the transmission planning entity(ies) will be selected for evaluation. It is not expected that all possible facility outages under each listed contingency of Category D will be evaluated.

e) Normal clearing is when the protection system operates as designed and the Fault is cleared in the time normally expected with proper functioning of the installed protection systems. Delayed clearing of a Fault is due to failure of any protection system component such as a relay, circuit breaker, or current transformer, and not because of an intentional design delay.

f) System assessments may exclude these events where multiple circuit towers are used over short distances (e.g., station entrance, river crossings) in accordance with Regional exemption criteria.