# RELIABILITY COORDINATOR AREA SYSTEM OPERATING LIMIT METHODOLOGY

0820EXT00129

By SPP Operations Staff

Effective on 04/01/2024

Version 2.0

# REVISION HISTORY

| DATE OR VERSION NUMBER | Date | CHANGE DESCRIPTION | COMMENTS |
|---|---|---|---|
| 1.0 | 10/19/2018 | Initial Creation with the Approval of RR309 | |
| 1.1 | 10/1/2021 | Update generator contingency definition to remove 150 MW generator threshold. | |
| 1.2 | 6/1/2022 | Addition of an Introduction, addition of Section - Instability, Cascading, Uncontrolled Separation and IROLs & IROL establishment section (both due to compliance obligations). | |
| 2.0 | 04/01/2024 | Changes applied per the recommendation of the SOLMTF that reviewed changes to FAC-011-4 and FAC-014-3. Additional updates were made to sections 1.2, 2.0.3, and 5.0 for clarity | |

# CONTENTS

# 1.0 INTRODUCTION

This document is SPP's 'System Operating Limits Methodology for the Operations Horizon' for the Eastern Interconnection. This document establishes the methodology for use in the SPP RC Area - Eastern Interconnection for developing System Operating Limits (SOLs) and Interconnection Reliability Operating Limits (IROLs) for use in the Operations Horizon pursuant to NERC Reliability Standards FAC-011 and FAC-014. All requirements for establishing SOLs and IROLs are contained in the body of this document.

TOPs and the RC continually assess and evaluate projected system conditions within the Operations Horizon with the objective of ensuring acceptable system performance in Real-time. These assessments are performed in an iterative fashion, typically beginning as part of seasonal studies, followed by assessments performed as part of the IRO-017 Outage Coordination Process, followed by Operational Planning Analyses (OPAs), and ultimately concluding with Real-time Assessments (RTAs). Accordingly, these studies use anticipated transmission system configuration, generation dispatch, and load levels, which are expected to improve in accuracy through the iterative assessments as Real-time approaches.

## 1.0.1 METHODOLOGY FOR THE DETERMINATION OF OPERATING HORIZON SOLS

SPP's methodology establishes System Operating Limits (SOLs) for all BES and applicable non-BES Facilities, as well as interfaces, in the Operating Horizon utilizing the study methods identified in section 1.0. These SOLs are equal to Facility Ratings unless a more limiting rating, such as those associated with voltage or stability, have been identified. Refer to section 1.4 for additional information on Facility Ratings, section 1.5 for System Voltage Limits, and 1.6.7 for Stability Limits. Each Transmission Operator shall provide its SOL established in accordance with this methodology to its Reliability Coordinator.

## 1.0.2 SYSTEM MODELING AND CONTINGENCY DEFINITION

- All SPP RC models shall be based on a coordinated model of the Eastern Interconnect and any necessary Facilities in other Interconnections. The model shall include all Transmission Operator (TOP) Areas within the SPP RC footprint as well as Facilities in adjacent TOP Areas that have been determined to have impact on the SPP RC footprint. SPP preforms an annual analysis to identify external contingencies based on

LODF thresholds for adjacent TOP areas.

- Loads served over radial lines may be modeled as aggregate at the delivery transmission bus. Distribution capacitors can be modeled as aggregate at a load bus.
- At a minimum, the contingency list used in the operating horizon shall include all identified in section 1.0.3. Additional contingencies may be identified in Reliability Standard TPL-001, provided by other applicable registered entities or deemed necessary by the RC, PC or TP. **Note**: SPP publishes a contingency list on the secure transfer site, Globalscape (\Studies\Report Tools\RTCA). TOPs shall annually review contingent facilities on the secure SPP RC site to verify all requested facilities within its area are included.

## 1.0.3 CONTINGENCIES APPLICABLE FOR OPERATIONS HORIZON

The Contingencies that shall be studied for assessments (seasonal studies, special studies, outage coordination studies, OPAs, RTAs) within the Operations Horizon include the following:

- Single-line-to-ground (SLG) or three-phase Fault (whichever is more severe), with Normal Clearing, on any Faulted B E S generator, transmission circuit, transformer or shunt device. Note: It is up to the TOP to determine when a SLG is an appropriate Fault type to study.
- Loss of any BES generator, transmission circuit, transformer, or shunt device without a Fault.
- Single pole block, with Normal Clearing, in a monopolar or bipolar high voltage direct current system.
- Additional single or multiple contingency events may be identified by the TOP or RC to be included in analysis.
- Additional contingencies identified by the Planning Coordinator or Transmission Operator may be submitted to PlanningAssessmentsSPPRC@spp.org.
- The RC shall consider any of the contingencies that have been determined by its PC to result in Stability Limits.

These Contingencies are the minimum that must be studied but are not necessarily the only Contingencies that are studied. It may be appropriate that a subset of contingencies be

evaluated due to the nature of the study such as stability analysis. Contingencies will be selected in the vicinity of the study area in order to provide meaningful results based on previous analysis results, TOP input, and engineering judgement. Note that not all Contingencies within a TOP are expected to be included in certain types of analyses. For example, time-domain, PV/QV and transfer studies are not conducive to analyzing as many Contingencies as can be done in steady-state Contingency analyses performed as part of a power flow. For studies such as time-domain analyses and PV/QV analyses, TOPs and the RC are expected to include those Contingencies that are the most severe to the situation based on experience, engineering judgment and historical analysis.

### 1.0.4 CONTINGENCIES EXTERNAL TO THE TOP AREA

TOPs are responsible for determining any contingencies external to the TOP Area that are known to impact the TOP Area or system under study. These external contingencies could reside in a TOP area outside the SPP RC area. At the request of a TOP, the SPP RC can facilitate coordination with a neighboring RC where necessary. If the SPP RC or any other RC identifies any contingencies external to the TOP Area that are known to impact the TOP Area or system under study, the SPP RC will provide such information to the affected SPP RC area TOPs.

### 1.0.5 CONTINGENCIES INTERNAL TO THE TOP AREA

TOPs are responsible for determining any contingencies internal to the TOP Area that are known to impact the TOP Area or system under study. These internal contingencies may include impactful shunt contingencies or multiple contingencies that are not already evaluated.

## 1.1 ACCEPTABLE SYSTEM PERFORMANCE

In the SPP RC Area, the BES is expected to be operated such that acceptable system performance is being achieved in both the pre- and post-Contingency state. This section describes acceptable system performance for the pre- and post-Contingency state.

In determining the system's response to Contingencies, the following actions shall be acceptable:

- 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.
- Interruption of other network customers:
    - Only if the system has already been adjusted, or is being adjusted, following at least one prior unplanned outage, or
    - If the Real-time operating conditions are more adverse than anticipated in the corresponding studies.
- System reconfiguration through manual or automatic control or protection actions. Adequate time must be allowed for manual reconfiguration actions. **Note**: Planned manual load shedding is acceptable only after all other available System adjustments have been made.

In the event that reliability studies performed by the RC and TOPs do not agree on the severity of an identified reliability issue, the most limiting (severe) study result will be acted upon until the cause of the difference can be determined.

It is not the intent of this SOL Methodology to require more stringent BES performance criteria than that stipulated in the prevailing NERC Transmission Planning (TPL) Reliability Standards; However, this SOL Methodology may prescribe specific performance criteria where the corresponding performance criteria in planning is non-specific.

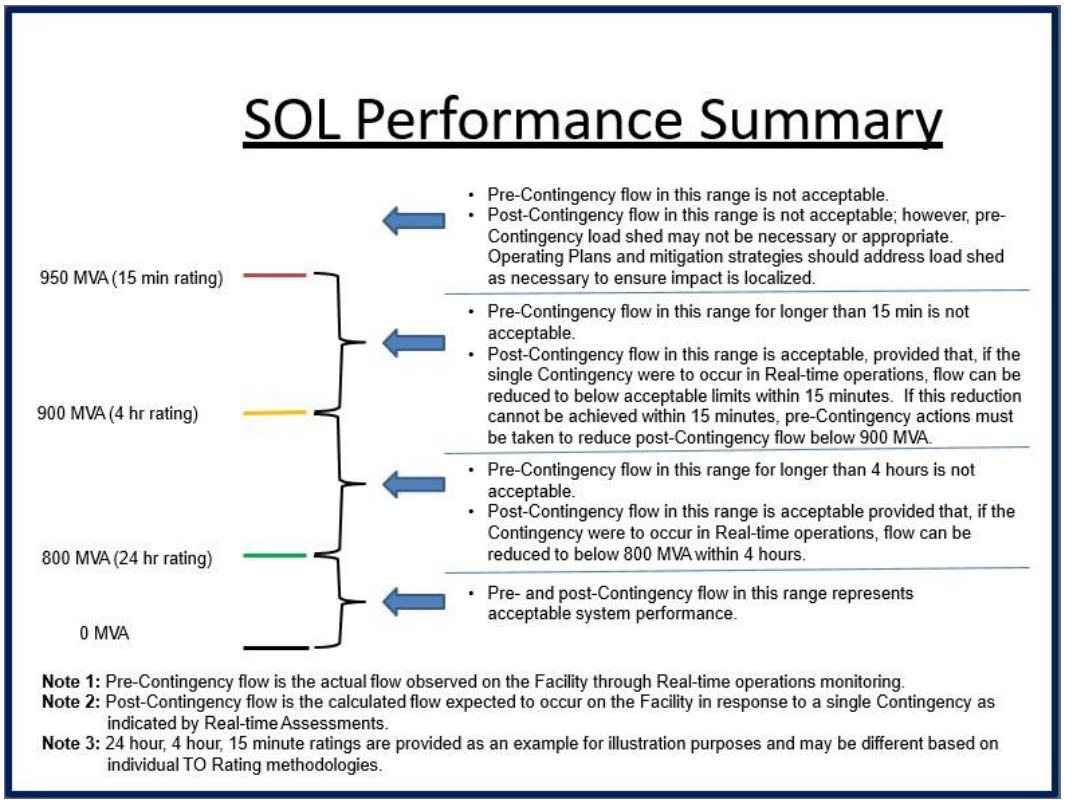



Figure 1 - SOL Performance Summary for Facility Ratings provides an example of acceptable pre- and post-Contingency performance for a sample set of Facility Ratings. The Facility Ratings shown in the example are selected for illustration purposes only.

## 1.1.1 PRE-CONTINGENCY

Acceptable system performance for the pre-Contingency state in the Operations Horizon is characterized by the following:

- The BES shall be operated within any identified transient, angular and steady-state voltage Stability limit.
- All Facilities shall be within their normal Facility Ratings or Emergency Facility Rating within the specified duration (Refer to Figure 1 – SOL Performance Summary for thermal Facility Ratings above for acceptable SOL pre-contingency operational time components).
- Steady state flow through Facilities are within Normal Ratings; however, Emergency Ratings may be used when System adjustments to return the flow within its Normal Rating could be executed and completed within the specified time duration of those Emergency Ratings.

- All Facilities shall be within their normal System Voltage Limits or within their Emergency Voltage limit within the specified duration (Refer to Figure 1) acceptable SOL pre-contingent time components.

### 1.1.2 POST-CONTINGENCY

Acceptable system performance for the post-Contingency state in the Operations Horizon is characterized by the following:

- The BES shall be operated within any identified transient, angular and steady-state voltage Stability limit.
- All Facilities shall be within their Emergency Facility Ratings within the specified duration (Refer to Figure 1 – SOL Performance Summary for Facility Ratings above).
- All Facilities shall be within their Emergency System Voltage Limits.
- Instability, cascading or uncontrolled separation shall not occur.

### 1.1.3 PREPARATION FOR NEXT CONTINGENCY

To prepare for the next Contingency, system adjustments may be made, including changes to generation, and the transmission system topology.

## 1.2 SOL EXCEEDANCE

Actual and potential SOL exceedances occur when the acceptable system performance criteria, as described in Section 1.1 of this document, are not being met as determined by Real-time monitoring, RTAs or OPAs. Should it be determined that these criteria cannot be met, the exceedance shall be mitigated as soon as possible by TOP and/or RC. Mitigation techniques may include the use of flowgates through the Congestion Management process, implementation of other TOP or RC developed Operating Plans, or any combination as required up to, and including load shedding. Pre-contingent load shed may not be appropriate for localized issues; however, plans should be in place and ready for use should the contingency occur. Planned manual load shedding is acceptable only after all other available System adjustments have been made.

If the TOP identifies a mitigation plan for an SOL exceedance then the TOP will coordinate the plan with the RC before the time threshold in Table 1 is met. In some instances the

mitigation plan will be implemented on a post-contingent basis. The mitigation plan will identify communication requirements between the TOP and the SPP RC.

## 1.2.1 PRIORITIZATION IN COMMUNICATING SOL EXCEEDANCES

Real-time operators in the SPP RC area are constantly monitoring and performing Real-time Assessments in order to identify and mitigate SOL exceedances. While it is important to coordinate when mitigating SOL exceedances, it is equally important to prioritize the necessary communication when System Operators are addressing multiple SOL Exceedances. The communication timeframes can be divided into two distinct groups based on expected occurrence frequency and risk level:

- Less frequent, higher risk: IROL exceedances, SOL exceedances of stability limits, post-contingency SOL exceedances that are identified to have a validated risk of instability, cascading outages, and uncontrolled separation and pre-contingency SOL exceedances of Facility Ratings and pre-contingency Minimum System Voltage Limits will always be communicated as soon as possible and within 15 minutes of validated identification.

- More frequent, lower risk: Post-contingency SOL exceedances of Facility Ratings and System Voltage limits and pre-contingency Normal Maximum System Voltage Limits must be communicated within 30 minutes, if not resolved beforehand.

Nothing prohibits a Real-time System Operator from communicating beyond what is required or in line with other good utility practice (e.g. troubleshooting or communicating). The provisions in the following table are meant to ensure that a risk based approach can be applied to prevent low risk or after the fact communications from distracting System Operators from other higher priority tasks. Additionally, certain SOL Exceedance types may slide up or down the list based on exceedance magnitude or other considerations specific to the situation. The Communication Timeframe starts at the first time instance that the SOL exceedance is identified. The Communication Timeframe refers to the SOL exceedance identification. It does not require that an SOL exceedance is resolved in the specified timeframe.

Table 1 – Communication Timeframe for SOL/IROL Exceedances

| Priority | SOL Exceedance Type | Communication Timeframe | Associated Risk |
|---|---|---|---|
| **Highest** | IROL exceedances | 15 minutes | Interconnection Reliability |
| | Post Contingency SOL exceedance or unsolved contingency with validated risk of instability, cascade, and/or uncontrolled separation | 15 minutes | Interconnection Reliability |
| | SOL exceedance of stability limit | 15 minutes | Localized Reliability |
| | Pre-Contingency SOL exceedance of Facility Ratings - Emergency | 15 minutes | Imminent Equipment Damage or Degradation |
| | Pre-Contingency SOL exceedance of Facility Ratings - Normal | 15 minutes | Imminent Equipment Damage or Degradation |
| | Pre-Contingency SOL exceedance of minimum System Voltage Limit - Normal | 15 minutes | Localized Reliability |
| | Pre-Contingency SOL exceedance of maximum System Voltage Limit - Normal | 30 minutes if not resolved | Potential Equipment Damage or Degradation |
| | Post-Contingency SOL exceedance of Facility Ratings - Emergency | 30 minutes if not resolved | Potential Equipment Damage or Degradation |
| | Post-Contingency SOL exceedance of minimum System Voltage Limits - Emergency | 30 minutes if not resolved | Localized Reliability |

| | | | |
|---|---|---|---|
| **Lowest** | Post-Contingency SOL exceedance of maximum System Voltage Limits - Emergency | 30 minutes if not resolved | Potential Equipment Damage or Degradation |

# 1.3 ALLOWED USE OF AUTOMATIC MITIGATION SCHEMES IN THE OPERATIONS HORIZON

The following items describe the allowed use of automatic mitigation schemes in the Operations Horizon, including both non-load-shed automatic schemes and load-shed automatic schemes (note that the use of UFLS programs and UVLS Programs are not allowed in the establishment of stability limits):

- If a TOP relies upon an automatic scheme for providing acceptable performance for contingencies, then the actions of the automatic scheme must be modeled in assessment tools or otherwise included in the TOP's analysis and the RC's analysis as applicable.
- If at any time RTAs or OPAs or other prior analyses indicate that the automatic scheme either fails to mitigate the reliability issue, potentially causes other reliability issues or could result in a more significant reliability risk, or if the automatic scheme is expected to be unavailable, an Operating Plan must be developed as appropriate in coordination with impacted TOPs and the RC, that contains pre-Contingency or post-Contingency mitigation actions to address the reliability issue.
- Automatic schemes that have a single point of failure may not be utilized to prevent instability, Cascading or uncontrolled separation from occurring in response to contingencies. Exceptions may be made only for conditions that would otherwise require pre-Contingency load shedding. If operational situations arise where an automatic scheme that has a single point of failure must be relied upon to avoid pre-Contingency load shedding, such conditions must be coordinated and approved for use by the RC.
- If an automatic scheme is relied upon to prevent instability, Cascading or uncontrolled separation in the transient or post-transient timeframe, the TOP/RC studies must assess those timeframes to ensure that the automatic action occurs in time to prevent

instability, Cascading or uncontrolled separation.

# 1.4 FACILITY RATINGS

Facility Ratings are determined by the Transmission Owner (TO), in accordance with their respective Facility Rating methodology, considering such impacts such as ambient temperatures, seasonal variances, normal/Emergency operations, etc.

Normal and Emergency Ratings are to be utilized when available, with acceptable timing requirements identified for all unique Emergency Ratings.

- Emergency Facility Ratings with a time value less than 30 minutes (as determined by the TOs) can only be used if acceptable by both the TOP and the RC and documented in an approved Operating Plan. SPP uses a default time value of 30 minutes unless notified by the TOP of a variance.

## 1.4.1 FACILITY RATINGS FOR THERMAL-BASED SOLS USED IN THE SPP RC'S NETWORK MODEL

- SPP RC's network model uses the ratings submitted by TOs and approved by TOPs through the Rating Submission Tool.
- SPP RC's analysis tools are also able to utilize dynamic Facility Ratings in Real-time operations. If a TO establishes dynamic Facility Ratings, the TO shall coordinate with their TOP and SPP RC to facilitate SPP RC's implementation of those dynamic Facility Ratings in SPP RC's models. Dynamic Facility ratings will not be utilized in forward looking studies.

## 1.4.2 COMMUNICATION OF FACILITY RATINGS FOR THERMAL-BASED SOLS

- TOs are responsible for communicating to the TOP and RC any changes to the Facility Ratings used in operations. This includes any temporary Facility Ratings that may be implemented and changes to seasonal Facility Ratings (e.g., when the TO stops using summer seasonal ratings and begins using fall seasonal ratings).

### 1.4.3 COORDINATION RESPONSIBILITIES

- TOPs are expected to establish all SOLs in accordance with the RCs methodology for use in the Operations Horizon in coordination with pertinent adjacent TOPs.
- If TOPs are unable to reach a resolution on matters related to TOP-to-TOP collaboration and coordination, the most limiting value shall be utilized, refer to the Dispute Resolution process in Section 4.0 for additional details.

### 1.4.4 MONITORING OF SOL AND IROL LIMITS

All BES Facilities are monitored at their normal and Emergency SOL and IROL ratings in seasonal studies, outage coordination studies, special studies, OPAs and RTAs. Non-BES facilities and tie-lines are monitored if requested by the TOP. TOPs shall annually review monitored facilities on the secure SPP RC site (\Studies\Report Tools\RTCA) to verify all requested facilities within its area are currently monitored. Certain Facility Ratings can be further adjusted due to dynamic line ratings with coordination between the TOP and RC.

## 1.5 SYSTEM VOLTAGE LIMITS

System Voltage Limits are defined as the maximum and minimum steady-state voltage limits (both normal and Emergency) that provide for acceptable System performance.

It is important that the TOPs and the RC use the same set of System Voltage Limits for assessments within the Operations Horizon, including seasonal studies, outage coordination studies, special studies, OPAs and RTAs. While it is acceptable to use general or more stringent voltage limits to flag potential reliability issues, the established System Voltage Limits must ultimately be used for assessments within the Operations Horizon.

Operating above the Low System Voltage Limits ensures that the system does not operate at unacceptably low voltage levels, and that the equipment connected to the bus is not subjected to voltages that drop below the system voltage rating.

Operating below the High System Voltage Limits ensures that the equipment does not operate at unacceptably high voltage levels, and that the equipment connected to the bus is not subjected to voltages that exceed the equipment voltage rating.

## 1.5.1 ESTABLISHING SYSTEM VOLTAGE LIMITS

- TOPs are responsible for the establishment of System Voltage Limits for all of the BES substation buses and applicable non-BES that exist within their TOP Area unless an exclusion is provided based on this SOL methodology. TOPs have flexibility to modify these limits as necessary based on actual or expected conditions within the bounds of the subsequent requirements listed below, provided the changes are justified for reliability and a technically sound rationale can be provided.

- System Voltage Limits must respect voltage-based Facility Ratings.

- While it is expected that TOPs take steps to coordinate the development of System Voltage Limits as described in the Coordination Responsibilities section of this SOL Methodology, it is the specific responsibility of TOPs to agree on the System Voltage Limits for buses with facilities that connect to buses owned by adjacent TOPs. The System Voltage Limit at each bus shall reflect voltage-based Facility Ratings from each adjacent bus. If the TOPs cannot agree, the most limiting System Voltage Limits (designated in kV) will apply as a default. If this default poses an unacceptable restriction or a reliability issue for the interconnecting TOPs, the TOPs must collaborate with SPP RC to reach a resolution.

- System Voltage Limits must enable reliable BES operations. If a TOP provides System Voltage Limits that SPP RC determines to be detrimental to the reliable operation of the BES, SPP RC may request a technical justification for the use of such limits and may assign different System Voltage Limits if it is more conservative.

- System Voltage Limits must be greater than or equal to in-service BES relay settings for undervoltage load shedding systems and Undervoltage Load Shedding Programs. For all BES substation buses without UVLS, the Low System Voltage limits shall not be lower than 0.8 pu.

- Normal High System Voltage Limits must not exceed the voltage ratings of the connected equipment.

- Emergency High System Voltage Limits must not exceed Protection Systems that trip BES Facilities in response to high voltages.

- For any applicable substation bus, System Voltage Limits must include the following:

    - A Normal Low System Voltage Limit – the low voltage limit that is used and monitored for actual/pre-Contingency operations. An actual/pre-Contingency voltage below a Normal Low System Voltage Limit is an SOL

exceedance and requires TOPs and RC implementation of an Operating Plan, to increase the actual/pre-Contingency voltage above the limit. SPP will use minus five percent of nominal voltage unless a more limiting criteria is provided by the TOP.

- An Emergency Low System Voltage Limit – the low voltage limit that is used for Emergency operations and is otherwise monitored for the post- Contingency state. A calculated post-Contingency voltage below an Emergency Low System Voltage Limit is an SOL exceedance and requires implementation of an Operating Plan to increase the post-Contingency voltage above the limit. SPP will use minus ten percent of nominal voltage unless a more limiting criteria is provided by the TOP.
- A Normal High System Voltage Limit – the high voltage limit that is used and monitored for actual/pre-Contingency operations. An actual/pre-Contingency voltage above a Normal High System Voltage Limit is an SOL exceedance and requires TOPs and RC action to decrease the actual/pre-Contingency voltage below the limit. SPP will use plus five percent of nominal voltage unless a different criteria is provided by the TOP.
- An Emergency High System Voltage Limit – the high voltage limit that is used for Emergency operations and is otherwise monitored for the post-Contingency state. A calculated post- Contingency voltage above an Emergency High System Voltage Limit is an SOL exceedance and requires implementation of an Operating Plan to reduce calculated post-Contingency voltage to within the limit. SPP will use plus five percent of nominal voltage unless a different criteria (as determined by the TOs) is provided to the TOP and SPP RC.

Table 2 – System Voltage Limits Monitor and Study Summary

| **Normal High/Low** | **Emergency High/Low** |
|---|---|
| Real-time:<br>• Monitored in SCADA or State Estimation for actual exceedance. | Real-time:<br>• Monitored in SCADA or State Estimation for actual exceedance.<br>• Monitored in RTCA (or equivalent) for calculated post- Contingency exceedance. |

| | |
|---|---|
| Study:<br>• Monitored for pre- Contingency exceedance | Study:<br>• Monitored for pre-Contingency exceedance<br>• Monitored in Contingency Analysis for calculated post- Contingency exceedance |

### 1.5.2 COMMUNICATION OF SYSTEM VOLTAGE LIMITS

- TOPs shall review their System Voltage Limits annually at a minimum and document changes to their System Voltage Limits. TOPs must use the template posted to the secure SPP RC site titled "System Voltage Limits TEMPLATE.xlsx" to communicate their System Voltage Limits. TOPs shall post the populated template for its TOP Area in the "System Voltage Limits" folder on the secure SPP RC site. TOPs shall submit the completed spreadsheet with the filename "System Voltage Limits – TOP.xlsx" as detailed in the SPP RC and BA Required Data Specification.
- Note that the SPP RC requires each System Voltage Limit variance and exclusion to be accompanied by a supporting rationale.

## 1.6 STABILITY LIMITS

The SPP RC and TOPs shall coordinate on studies that are performed to establish stability-based SOLs based on the methods identified in the subsequent sections of the Methodology. The SPP RC in coordination with the TOP(s) will establish stability limits when an identified instability scenario impacts adjacent Reliability Coordinator Areas or more than one Transmission Operator in its Reliability Coordinator Area in accordance with its SOL methodology. Real-time applications are utilized to confirm pre-established limits and to identify new limits that arise from unanticipated system conditions.

The SPP RC and TOP will coordinate when it is appropriate to use Stability limits established in prior studies, or whether expected system conditions warrant performing new studies to revise those Stability limits used in Real-time operations.

Both methods must meet the performance criteria specified in this SOL Methodology.

When interface Stability limits are established, they should be established in a manner that most accurately and directly addresses the instability risk. Neither historical presumptions/practices regarding system monitoring nor commercial/contractual arrangements

should influence where Stability limits are established to most accurately and directly monitor for reliability.

## 1.6.1 STEADY-STATE VOLTAGE STABILITY

### STEADY-STATE VOLTAGE STABILITY ANALYSIS METHODOLOGY

- SPP utilizes the EMS model for establishing, calculating and monitoring SOLs/IROLs in the operating horizons. These models are updated periodically to reflect expected system topology changes based on reported facility outages or upgrades.
- Monitored scenarios will be identified using available reliability studies, real-time system information, outage schedules, and other relevant sources. During the different Operating Horizons, the pre- and post-contingency operating conditions being studied may require mitigation. The SPP RC and TOPs must determine and coordinate which Contingencies within the TOP areas are to be utilized for study in the operating horizon.
- If the TOP or the SPP RC determine that changes are required for a pre- or post-contingency operating condition, such changes shall be communicated to the affected entities. The SPP RC will coordinate with all applicable impacted TOPs or neighboring RCs.
- The use of proxy flowgate limits for stability will be communicated in the same manner as other flowgate limits and information.
- The SPP RC will perform a voltage stability assessment for identified areas and paths that have a reasonable potential to cause real-time and post-contingency voltage instability.
- A voltage stability limit more restrictive than an existing SOL will be identified as the revised SOL and communicated to affected entities prior to implementation in congestion management procedures.
    - The RC will coordinate with the impacted TOPs to establish necessary mitigations and Operating Plans.
- The SPP RC may identify and establish voltage stability limits based on the voltage stability assessment results and will coordinate the voltage stability limits with the affected TOP(s). Voltage stability limits may require development of new temporary flowgates.
- No BES bus, or non-BES bus as deemed necessary, shall exceed the threshold set by an

identified point of steady-state voltage instability including applicable margins.

### STEADY-STATE VOLTAGE STABILITY ANALYSIS

- Voltage Stability Limits are SOLs and can become IROLs. Reference Figure 2 – Sample P-V Curve as an example of a MW power transfer approach to defining a voltage Stability Limit.
- SOLs established from steady-state voltage stability limits shall include a minimum 5% margin (MW/MVA) from the voltage stability limit ('knee of the curve'). Operating Plans shall specify the margin utilized.

Reference Figure 2 – Sample P-V Curve below for an example of a PV curve for determining voltage Stability Limits.

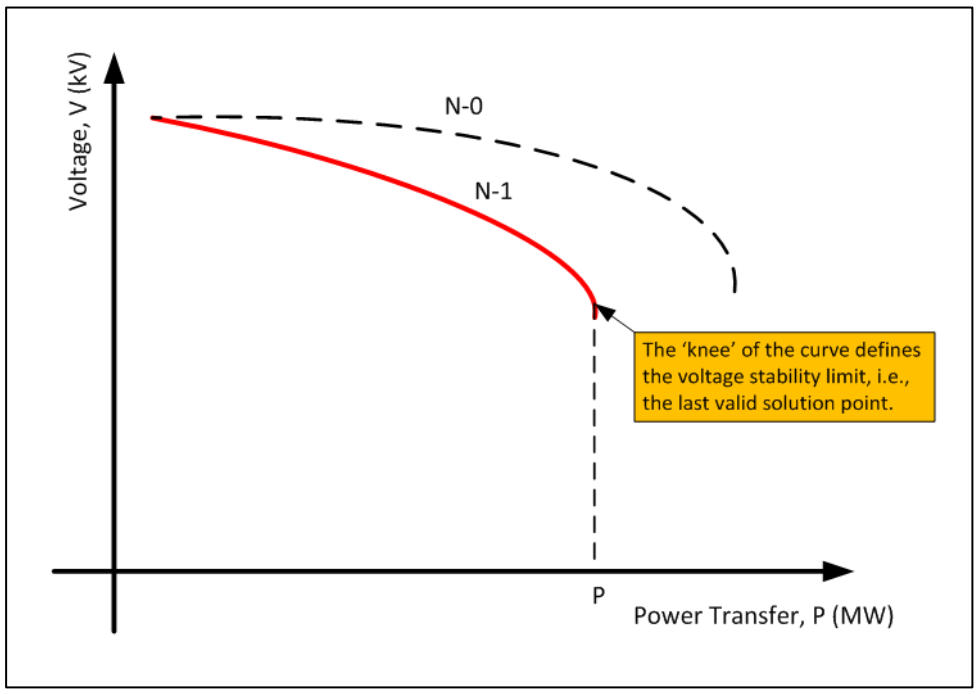



Figure 2 – Sample P-V Curve

## 1.6.2 TRANSIENT ANALYSIS METHODOLOGY

- The RC and TOP will coordinate to determine if and what types of operational transient studies are required for a given season, planned outage or operational scenario. For example, if a TOP or the RC determines, based on experience,

engineering judgment and knowledge of the system, that a planned transmission or generation outage might pose a risk of transient instability for the next worst contingency, the TOP and RC shall perform the appropriate transient analyses to identify those risks.

- The RC will consider expected levels of transfers, load and generation dispatch, and System conditions including any changes to System topology such as Facility outages in RC assessments (seasonal studies, special studies, outage coordination studies, OPAs, RTAs) when applying performance criteria in 1.7.3.

- The RC will use updated modeling that includes monitored lists, contingency lists, and RAS from the EMS. Dynamic modeling from internal and external sources will utilize the most updated version available.

- The use of Underfrequency load shedding (UFLS) and Undervoltage Load Shedding (UVLS) programs will not be considered in establishing stability limits.

- When transient studies have been performed, the RC and TOPs will coordinate to verify performance criteria in Section 1.7.3 has been met for all expected pre/post contingent operational scenarios utilizing those applicable contingencies identified in Section 1.0.3.

- Methods utilizing worst case studies, most severe contingencies, and monitoring of critical or weakest parts of the system can be leveraged to ensure the most severe impacts to the BES are being identified.

- If an allowable RAS is relied upon to address a transient instability phenomenon, the transient studies must simulate the actions of these schemes to ensure that the schemes adequately address the reliability issues. Associated study reports or Operating Plans must include a description of the actions and timing of these schemes.

- Transient studies must model applicable Facility outages that are planned for the period of the study and must use appropriate load levels.

- Expected loading conditions shall be screened for the period under study to determine the conditions under which instabilities occur. The TOP and/or the RC may run studies on only those specific set of loading conditions under which instabilities occur for subsequent studies.

- Single Contingencies shall be simulated as the more severe of single line-to-ground Faults or three-phase Faults as determined by the TOP or RC. The more severe

Faults will be simulated:

- At each point of connection with bus; or
- The most severe of the high or low side of an autotransformer.

- The Fault duration applied shall be based on the total known Fault clearing times or as specified in the corresponding planning studies for the applicable voltage level.
- Transient studies must extend for at least 10 seconds following the initiating event or longer if swings are not damped.
- The dynamics parameter file used for transient studies in all phases of assessments in the Operations Horizon shall be based upon the approved MDAG dynamics file for the applicable season or other modeling that may be more updated.
- The buses monitored for transient system performance are determined based on experience, engineering judgment and knowledge of the system.

# 1.6.3 TRANSIENT ANALYSIS PERFORMANCE REQUIREMENTS

Table 3 – Transient System Performance Requirements

| **Transient System Performance** | **Criteria Threshold** |
|---|---|
| The system must demonstrate positive damping. The signals used generally include transient voltage and/or frequency. An example of damping ratio calculation is provided in Section 1.7.7. | 0.8%,<br>Greater than SPPR1 of 5%<br>Greater than SPPR5 of 22.6% |
| All rotor angles must demonstrate positive damping. | 0.8%,<br>Greater than SPPR1 of 5%<br>Greater than SPPR5 of 22.6% |
| The BES must remain transiently stable, and must not Cascade or experience uncontrolled separation. System frequency in the interconnected system as a whole must not trigger UFLS. Any controlled islands formed must remain stable.<br><br>No BES generating unit shall pull out of synchronism or Inverter Based Resource (IBR) units show signs of instability | Yes |
| Bus Voltages on the Bulk Electric System shall recover to acceptable levels<br>Known generator trip settings (or generator ride-though capabilities as specified by PRC-024-3 Attachments 1 and 2 or its successor if trip settings are unknown) must be accounted for in any transient studies.<br>Under frequency generator tripping (UFLS) shall not be triggered | Minimum .7 pu 2.5 seconds after the fault is cleared<br><br>Maximum 1.2 pu after the fault is cleared |

General Notes:

1. A generator being disconnected from the system by Fault clearing action or by a RAS is not considered losing synchronism. Additionally, small (<20 MVA) non-BES generators that may trip are not considered as losing synchronism.

For generators that the GO has identified as not being able to meet the PRC-024-3 requirements, either the unit must be tripped, or the Point of Interconnection (POI) frequency verified against the unit established trip values and the appropriate action taken.

**Transient Voltage Recovery Requirement**

Bus voltages on the Bulk Electric System shall recover above 0.70 per unit, 2.5 seconds after the fault is cleared. Bus voltages shall not swing above 1.2 per unit after the fault is cleared, unless affected transmission system elements are designed to handle the rise above 1.2 per unit.

# 1.6.4 ESTABLISHMENT OF TRANSIENT STABILITY LIMITS

- Transient Stability Limits are established to meet the transient system performance requirements in Table 3 – Transient System Performance Requirements.
- Transient Stability limited SOLs do not include margins.

# 1.6.5 ANGULAR STABILITY

Machine Rotor Angles shall exhibit well damped angular oscillations following a disturbance on the Bulk Electric System as described in Section 1.7.6 System Damping.

# 1.6.6 SYSTEM DAMPING

Measuring damping is best performed a) after all significant automatic schemes have operated; and b) should measure damping over oscillations toward the end of the simulation rather than at the beginning of the simulation. As an example, a good trigger for measuring signal damping switched and the fault should be fully cleared.

Well damped angular oscillations shall meet one of the following two requirements when calculated directly from the rotor angle:

Successive Positive Peak Ratio One (SPPR1) must be less than or equal to 0.95 where SPPR1 is calculated as follows:

$$SPPR1 = \frac{\text{Peak Rotor Angle of 2nd Positive Peak minus Minimum Value}}{\text{Peak Rotor Angle of 1st Positive Peak minus Minimum Value}} \leq 0.95$$

-or- Damping Factor % = (1 – SPPR1) x 100% ≥ 5%

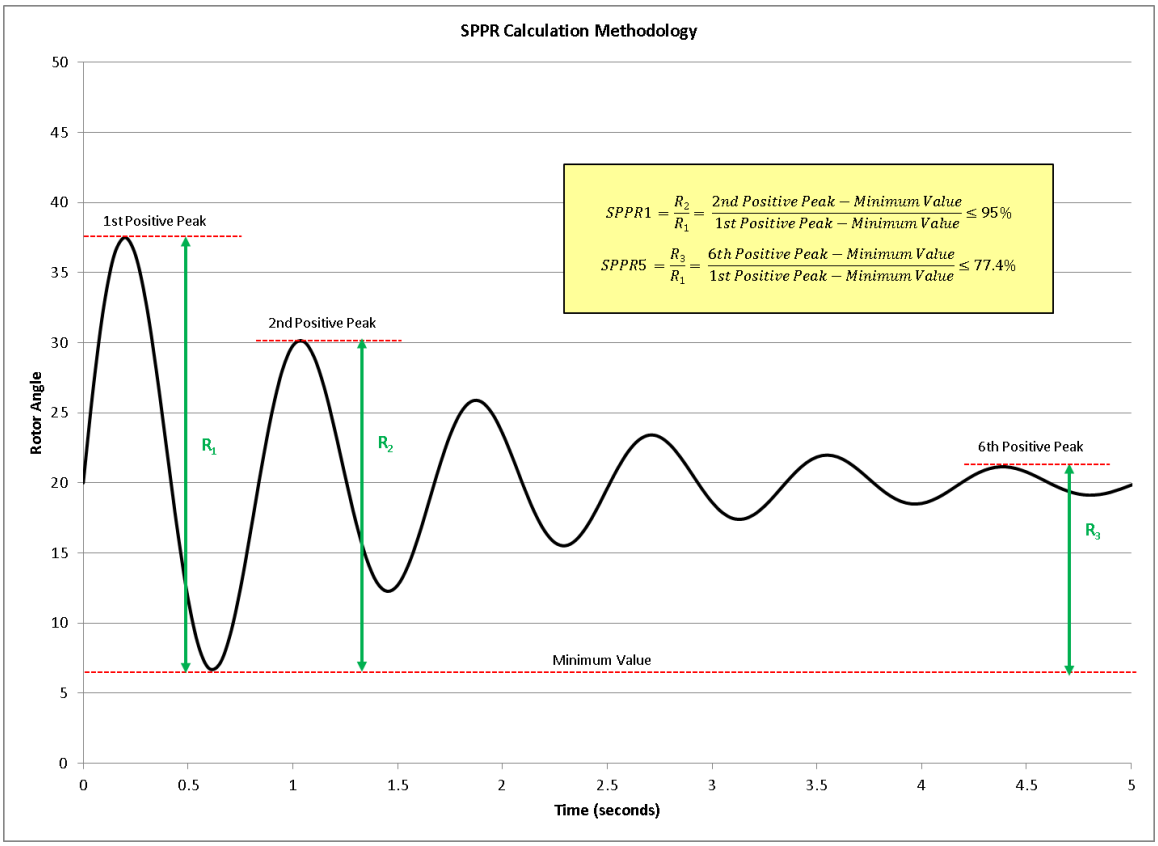
Successive Positive Peak Ratio Five (SPPR5) must be less than or equal to 0.774 where SPPR5 is calculated as follows:

$$SPPR5 = \frac{\text{Peak Rotor Angle of 6th Positive Peak minus Minimum Value}}{\text{Peak Rotor Angle of 1st Positive Peak minus Minimum Value}} \leq 0.774$$

-or- Damping Factor % = (1 – SPPR5) x 100% ≥ 22.6%

The machine rotor angle damping ratio may be determined by appropriate modal analysis (i.e. Prony Analysis) where the following equivalent requirement must be met:

Damping Ratio ≥ 0.008




# 1.6.7 COMMUNICATION OF TRANSIENT AND VOLTAGE STABILITY LIMITS

- When studies indicate the presence of transient or voltage instability risks (whether contained or uncontained) for planned outages or expected system conditions, the identifying entity shall communicate the study results to SPP RC and to impacted TOPs for further coordination and review. This communication should occur in a timely manner to allow for proper coordination and preparation prior to Real-time operations.

- The following information for any identified transient or voltage Stability limit shall be communicated to impacted parties:
    - Instability Risk – a description of the instability risk that is addressed with the Stability limit.
    - Contingencies – the Contingency(ies) that the Stability limit is protecting against.
    - Outages – any transmission or generation outages associated with the Stability limit.
    - Stability Limit Values – any pre-determined fixed value(s) for the Stability

limit. Describe if the Stability limit established in real-time or calculated dynamically. In instances where there is no Stability Limit established to address the instability risk, RC still needs to know about the risk and how that risk is being addressed.

- Example, a forced transmission line outage has rendered a condition where a small load pocket is now served by two transmission lines instead of the usual three lines. A Contingency on either of the remaining two lines will result in local voltage collapse on the small load pocket. The only way of preventing the voltage collapse is to shed load pre-Contingency. The TOP and the RC agree not to shed load pre-Contingency to prevent the single Contingency from resulting in local, contained voltage collapse.

- Monitoring Method – description of the method System Operators use for monitoring the Stability limit.
- Other Pertinent Information – any other pertinent operating conditions associated with the Stability limit, e.g., applicable to a certain season, a period of weeks/days/hours, certain loading conditions or other conditions, etc.

- Transient or voltage Stability Limit(s) identified as part of seasonal studies or special studies shall be communicated to SPP RC via PlanningAssessmentsSPPRC@spp.org. The subject line of the email shall clearly indicate that the communication contains an identified Stability limit.

- Transient or voltage Stability limit(s) identified as part of outage studies or OPA studies shall be communicated to SPP RC.

- Transient or voltage Stability limit(s) identified as part of Real-time studies shall be communicated to SPP RC via phone.

- Non-static transient or voltage Stability limit(s) are typically communicated to SPP RC via ICCP.

# 2.0 INSTABILITY, CASCADING, UNCONTROLLED SEPARATION AND IROLS

## 2.0.1 INSTABILITY

An IROL, as defined by NERC, is an SOL that, if exceeded, could result in instability, uncontrolled separation, or Cascading outages that adversely impact the reliability of the BES.

There are many forms of instability, each with a wide spectrum of reliability impacts – from minimal impact, such as losing a single unit due to its own "instability," to a major and devastating impact, such as losing a significant portion of the BES.

It is recognized that not all instability events pose the same degree of risk to the reliability of the BES. However, it is critical that studies/assessment determine how – or if – the instability would be contained, and to understand the impact that the instability may have on the BES.

Accordingly, if a transient or voltage instability event has demonstrated through studies to have wide-area BES impact, then the establishment of an IROL may be warranted.

## 2.0.2 UNCONTROLLED SEPARATION

Uncontrolled separation (which includes uncontrolled islanding) occurs when studies indicate that a Contingency is expected to result in rotor angle instability or to trigger relay action which causes the system to break apart into major islands in an unintended (non-deliberate) manner. The determination of uncontrolled separation takes into consideration transient instability phenomena and relay actions that cause islands to form.

It is recognized that transient instability may result in the loss of small pockets of generation and load, or radially connected subsystems that do not warrant establishment of an IROL. In such scenarios, the loss of a unit (or group of units) may have little to no impact on the reliable operation of the interconnected system.

# 2.0.3 CASCADING

Cascading can occur when studies indicate that a Contingency results in severe loading on a Facility, triggering a chain reaction of Facility disconnections by relay action, equipment failure or forced immediate manual disconnection of the Facility (for example, due to line sag or public safety concerns). Per the definition, when Cascading occurs, the electric service interruption cannot be restrained from sequentially spreading beyond an area pre-determined by studies.

Cascading test – If powerflow studies indicate that the successive tripping of Facilities stops before the case diverges, then by definition, the phenomenon is not considered to be Cascading, because the studies have effectively defined an "area predetermined by studies." However, if the system collapses during the Cascading test, the area cannot be "predetermined by studies," and therefore it is concluded that the extent of successive tripping of elements cannot be determined. Valid cascading events identified in real-time are assessed for potential IROL establishment.

## POWERFLOW CASCADING TEST:

A. The RC will run Contingency analysis and flag Contingencies that result in post-Contingency loading in excess of the lower of:
    a) The Facility(ies)'s trip setting
    b) 115 percent of the highest Emergency Rating
B. For each flagged Contingency, open the contingent element(s) that cause(s) the post- Contingency loading and all consequent Facilities that overload in excess of (A) (a) or (b) above. Run powerflow without simulating any manual system adjustments.
C. Repeat step (B) for any newly overloaded Facility (ies) in excess of (A) (a) or (b) above. Continue with this process until no more Facilities are removed from service or until the powerflow solution diverges.
D. If the subsequent tripping of Facilities stops prior to case divergence, then it can be concluded that the area of impact is predetermined by studies, and thus Cascading does not occur. If the case diverges during the Cascading test using the 115 percent of the highest Emergency Rating, then further investigation into post-Contingency loading may occur (if time allows) before declaring that Cascading occurs.

# 2.1 IROL ESTABLISHMENT

Interconnection Reliability Operating Limits (IROLs) are a subset of the SOLs that, if violated, could lead to instability, uncontrolled separation, or cascading outages that adversely impact the reliability of the Bulk Electric System.

IROLs are identified through RC assessments (seasonal studies, special studies, outage coordination studies, or OPAs).

An IROL may be established when Instability, Uncontrolled Separation, and/or Cascading meet any of the following criteria:

- thermal overload in excess of 115% of the Emergency rating of the monitored facility that creates a cascading event, or
- valid diverged or valid non-converged contingency, or
- causes the loss of 500 MW or more of firm load or greater, or
- causes the pre- and/or post-contingent voltage of 5 or more BES buses to fall below 0.9 p.u., or
- causes the successive tripping of 5 or more BES Transmission and/or generating Facilities (no system adjustments allowed), or
- causes the formation of one or more stable or unstable islands.

All affected TOPs and the RC can agree an event is localized (and not classified as an IROL), but it must be a unanimous consensus.

This condition will be reviewed further by evaluating the system response to the loss of the SOL violated facility. An IROL will be established if the evaluation reveals that the ensuing SOL violated facility may cause instability, uncontrolled separation, or cascading.

## 2.1.1 MANAGING IROL EXCEEDANCES

The RC is responsible for declaring IROLs. However, both the RC and TOPs are responsible for communicating and collaborating with each other to address the risks when studies (seasonal studies, special studies, outage studies or OPAs) identify the potential for instability (whether contained or uncontained), Cascading or uncontrolled separation.

In the event of an IROL violation, the Bulk Electric System is vulnerable to instability, uncontrolled separation, and/or widespread cascading outages. All efforts, up to and including

shedding of firm load, shall be made to mitigate the IROL exceedance within the defined Tv timeframe. In order to be best prepared for this situation, SPP has created relief guides that will assist the Reliability Coordinator in the relief of any flowgate with an IROL.

IROL limits are only applicable in the defined direction of flowgate unless specifically stated in an IROL relief guide. The defined direction will measure flow starting at the "From" bus across the monitored facility ending at the "To" bus.

# 2.2 IROL TV IN THE SPP RC AREA

The IROL $T_V$ in the SPP RC Area shall be less than or equal to 30 minutes. The default IROL $T_V$ value is 30 minutes. However, shorter duration IROL $T_v$ values may be established in coordination with the impacted TOPs based on relay/protection settings and other considerations.

# 2.3 TYPES OF IROLS

Since IROLs are a subset of SOLs, the following provides a brief characterization of each type of IROL that if exceeded could lead to instability, uncontrolled separation, or Cascading:

## 2.3.1 TRANSIENT STABILITY IROLS

Establish to prevent:

- The loss of synchronism (from rotor angle instability or associated relay action) that results in subsequent uncontrolled tripping of BES Facilities (Cascading), or in uncontrolled separation.
- Widespread voltage collapse that occurs in the transient timeframe.

A transient Stability IROL is not warranted to prevent one or more units from losing synchronism and tripping offline, provided that studies demonstrate that the transmission system remains stable after the units are lost.

### 2.3.2 VOLTAGE STABILITY IROLS

Establish to prevent:

- An undeterminable area or a wide area of the BES experiencing voltage instability.
- Voltage instability that consequently leads to Cascading or uncontrolled separation.

### 2.3.3 FACILITY RATING-BASED IROLS

Establish to prevent:

- Non-stability related Cascading due to excessive post-Contingency loading of Facilities that consequently leads to instability or uncontrolled separation.

# 3.0 SPP RC ROLES AND RESPONSIBILITIES

### 3.0.1 ADHERENCE TO THIS SOL METHODOLOGY

The RC must ensure that SOLs and IROLs for its RC Area are established and that the SOLs and IROLs are consistent with its SOL Methodology. SPP RC performs the following functions to meet this requirement:

- SPP RC ensures that Facilities in SPP's network model reflect the Facility Ratings as established by the TOs and provided to SPP by the TOs/TOPs, consistent with this SOL Methodology.
- SPP RC ensures that during the determination of SOLs, the BES condition used reflects current or expected system conditions and reflects changes to system topology such as Facility outages.
- SPP RC ensures that buses in the network model are associated with the System Voltage Limits as provided by TOPs, consistent with this SOL Methodology.
- SPP RC reviews the Stability limits provided by TOPs to ensure they are established consistent with this SOL Methodology. SPP RC will establish an IROL once criteria in section 2.1 is met.

- SPP RC ensures RC System Operators and engineers have awareness of identified Stability limits and IROLs.
- When assessments indicate that the system is at risk of instability, uncontrolled separation, or Cascading for the next contingency, the RC is expected to bring the system to a secure state with no intentional delay as it would address an IROL utilizing the applicable Operating Plans.
- SPP RC's Real-time Contingency Analysis (RTCA) application provides indication of whether acceptable steady-state system performance is being achieved for the post- Contingency state given actual system conditions. SPP RC shall post its RTCA results in a format that is mutually agreed upon by the SPP RC and SPP RC Area TOPs.
- SPP RC utilizes a real-time voltage stability analysis tool and communicates the results of this tool to impacted TOPs.

# 4.0 DISPUTE RESOLUTION

## 4.0.1 DISPUTES BETWEEN ENTITIES

The SPP RC shall make a final determination on the appropriate course of action if a dispute should arise between two or more entities in the SPP RC area in any situations pertaining to this methodology. The SPP RC will coordinate with neighboring RCs if a dispute on the application of applicable SOL Methodology(s) should arise between two or more entities in separate RC footprints.

## 4.0.2 MOST CONSERVATIVE OPERATING APPROACH

If in the application of this methodology, an operational situation should arise where two entities (BAs, TOPs, and GOPs) do not agree on actions necessary to maintain reliability of the Bulk Electric System, the most conservative approach will be implemented until such time that additional study evidence can alleviate the dispute. The SPP RC will coordinate with neighboring RCs if entities in dispute reside in multiple RC footprints.

# 5.0 RC COMMUNICATION OF SOL/IROL INFORMATION TO OTHER ENTITIES

SPP RC shall provide its SOL methodology to those entities that indicate a reliability-related need within 30 days of a request or prior to the effective date of the SOL methodology. These entities include:

- Adjacent Reliability Coordinators and Reliability Coordinators with a reliability-related need for those limits.
- Transmission Operators within the SPP RC Area.
- Generator Owners or Transmission Owners within the SPP RC Area.
- Transmission Planners within the SPP RC Area.
- Transmission Service Providers within the SPP RC Area.
- Planning Authorities/Planning Coordinators within the SPP RC Area.

SPP RC provides SOLs and IROLs to those entities listed below that have provided a written request that includes a schedule for delivery of those limits or at least once every twelve calendar months. These entities include:

- Adjacent Reliability Coordinators and Reliability Coordinators with a reliability-related need for those limits.
- Transmission Operators within the SPP RC Area.
- Transmission Planners within the SPP RC Area.
- Transmission Service Providers within the SPP RC Area.
- Planning Authorities/Planning Coordinators within the SPP RC Area.

SPP RC provides the following supporting information for each IROL as part of the corresponding IROL Relief Guide:

- Identification and status information of the associated Facility (or group of Facilities) that is critical to the derivation of the IROL.
- The value of the IROL and its associated $T_V$.
- The associated Contingency(ies).

- The description of system conditions associated with the IROL.
- The type of limitation represented by the IROL (e.g., voltage collapse, transient Stability).

# TERMS AND ACRONYMS

| ACRONYM | TERM |
|---|---|
| SPP | Southwest Power Pool |
| Contingency | The unexpected failure or outage of a system component, such as a generator, transmission line, circuit breaker, switch or other electrical element. |
| Facility Rating | The maximum or minimum voltage, current, frequency, or real or reactive power flow through a facility that does not violate the applicable equipment rating of any equipment comprising the facility. |
| Normal Rating | The rating as defined by the equipment owner that specifies the level of electrical loading, usually expressed in megawatts (MW) or other appropriate units that a system, facility, or element can support or withstand through the daily demand cycles without loss of equipment life. |
| Emergency Rating | The rating as defined by the equipment owner that specifies the level of electrical loading or output, usually expressed in megawatts (MW) or Mvar or other appropriate units, that a system, facility, or element can support, produce, or withstand for a finite period. The rating assumes acceptable loss of equipment life or other physical or safety limitations for the equipment involved. |

| | |
|---|---|
| Operations Horizon | A rolling 12-month period starting at Real-time (now) through the last hour of the twelfth month into the future. |
| System Operating Limit | 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:<br>• Facility Ratings (applicable pre- and post-Contingency Equipment Ratings or Facility Ratings) •<br>• transient stability ratings (applicable pre- and post- Contingency stability limits)<br>• voltage stability ratings (applicable pre- and post-Contingency voltage stability)<br>• system voltage limits (applicable pre- and post-Contingency voltage limits) |
| System Voltage Limit | The maximum and minimum steady-state voltage limits (both normal and Emergency) that provide for acceptable System performance. |