Los Angeles Department of Water & Power

System Operating Limits (SOL) Methodology for the Planning Horizon

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Rev 1.0

Transmission Planning

Power System Planning & Development

Table of Contents

System Operating Limits (SOL) Methodology for the Planning Horizon

Purpose

As required by The North American Energy Reliability Corporation (NERC) Standard FAC-010-1, this document presents the methodology of determining the SOL for the Planning Horizon at the Los Angeles Department of Water and Power (LADWP).

Definitions

This document adopts the following NERC definitions:

Bulk Electric System (BES) - As defined by the Regional Reliability Organization, the electrical generation resources, transmission lines, interconnections with neighboring 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.

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) - 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. The WECC does not have any IROL under normal operation, but during SOL conditions, depending upon the operating conditions, could become an IROL condition, which would be determined post-analysis (see Appendix C).

SOL Methodology for the Planning Horizon

Applicability to LADWP

This methodology is applicable for determining SOLs for the Planning Horizon within LADWP's Planning Authority. The Planning Horizon extends beyond one year to a maximum of ten years. (R1.1)

This methodology requires that SOLs shall not exceed associated Facility Ratings[1]. (R1.2)

WECC operating procedures only allow system operation within the established SOL. Therefore, under normal operation, IROL conditions do not exist except during SOL conditions. (R1.3)

System Performance

In the planning horizon, the determination of SOLs follows the process and methodology outlined in section 4.0 of the WECC document entitled "Overview of Policies and Procedures for Regional Planning Project, and Progress Reports". Section 4.0, "the WECC Procedures for Project Rating Review" requires LADWP and other planning authorities to perform studies that conforms the following requirements:

1. Applicable reliability performance criteria and/or standards:
    a. All transmission facilities within their thermal ratings
    b. System transiently and dynamically stable
    c. System with adequate reactive margin to prevent post-transient voltage instability
2. Required Studies: Power flow, transient stability, and post-transient voltage stability shall be performed in accordance with the NERC/WECC Planning Standards, WECC Post-Transient Study Methodology and this document.
3. In the normal conditions or pre-contingency state with all Facilities in-service, BES is required to demonstrate that system shall meet requirement R2.1 of FAC-010-1
4. BES is required to demonstrate that the single contingencies shall meet requirement R2.2 and R2.3 of FAC-010-1
5. BES is required to demonstrate that the double contingencies shall meet the requirement R2.4 and R2.5, and Regional Difference E1 of FAC-010-1
6. Study Model: - Study models shall be based on the most recent WECC approved base cases available for the study time frame and conditions. Updates shall be made to reflect the most accurate system configuration, generation, and load representation for each pertinent individual balancing authority area for the study time period. The following guidelines for system representation in modeling shall be applied:
    a. Full loop representation is to be used with the entire WECC system modeled. (R3.1)
    b. System transfer levels for major WECC paths should be agreed upon and listed. Additional transfer paths should be included as appropriate. (R3.1)
    c. Voltage profile and equipment loading will be within the ratings of the facilities and will be determined using existing criteria. (R3.1)

[1] Facilities Ratings are defined by NERC as 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.

d. The phase shifter methodology to be followed for all applicable phase shifters should be identified. (R3.1)

e. A list of the series compensation assumptions for the major EHV lines should be provided. (R3.1)

f. Generation and load shedding may exceed the minimum requirement to ensure margin for system security. (R3.1)

g. The study model will assume all lines in service, with no planned outages (R3.5)

h. A WECC base case will be selected based on the generation dispatch, load level (peak/off-peak) and season. The generation and load level should be selected to appropriately stress the study are or path. The generation dispatch may vary due to wind, hydro or other conditions. (R3.5)

i. Residential, commercial, and industrial load models, with constant power, current and impedance should be included as appropriate. Transient stability models shall represent voltage and frequency characteristics, either actual load models when available, or accepted industry models. Loads shall be modeled as accurately as possible, including the appropriate load power factor. Margins provided to allow for load model uncertainty shall be explicitly stated. (R3.5)

7. Power Flow: Power flow shall be performed in accordance with the following criteria:

   a. Thermal Capacity Limits – No transmission element will be loaded above 100% of its continuous rating under normal conditions. Following a single contingency or a credible double contingency, no transmission element will be loaded above its emergency rating. The Project Review Group (PRG) should develop a list of continuous and emergency ratings for applicable facilities and include in the study documentation.

   b. System Voltage Limits – The PRG will provide, review and approve the list of pertinent buses for voltage monitoring. Voltage deviation of these buses caused by the loss of a system element will be measured against the NERC/WECC Planning Standards. All deviations from the WECC Reliability Criteria should be listed.

8. Transient Stability: Transient stability studies shall be performed for all contingencies provided, reviewed and approved by the PRG with the following criteria:

   a. System disturbances will be initiated by a three-phase fault on the EHV bus adjacent to the major interconnection point and/power plant of interest. If requested by PRG, a single-to-ground fault will be studies as sensitivity.

   b. Evaluating faults will be cleared in accordance with the guidelines provided by the appropriate members of the PRG. Backup clearing time for stuck breaker operation should be provided as well.

   c. The system deemed stable if post-disturbance system swing meet the WECC Planning Standards.

9. Post-Transient Governor Power Flow – Post transient governor power flow analysis shall be conducted when requested by the PRG and should be in accordance with the WECC "Voltage Stability Assessment Methodology". The results should demonstrate in compliance with the NERC/WECC Reliability Criteria

10. Special Protection Schemes (SPS)

All SPS required to obtain the Accepted Rating should be described in details and modeled as they will be applied in operation

11. Documentation

A Rating Report (Report) shall document the study findings and conclusions. The Report should demonstrate acceptable performances and meet all the NERC/WECC Reliability Criteria. The Report should also include a general background of the existing system or project such as: historical information, a general project description, project need and use, and project participation.

Version History

Version	Date	Action	By
0	7/1/08	First Version	Mohammed Beshir
1.0	10/27/08	Revised the discussion of IROL and added Appendix C for further explanation. Added reference to Regional Differences in discussion of multiple contingencies and added Appendix B for further explanation. The narrative was revised extensively but without additional substantive changes.	Ly Le

Review and Approval

Reviewed By	**Name**	**Date**
Transmission Planning	Tim Wu	10/28/08

Approved By	**Name**	**Date**
Power System Planning & Development	Mohammed Beshir	11/10/08

Appendix A. NERC/WECC Planning Standards

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 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[e]: 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[e]: 1. Bus Section 2. Breaker (failure or internal Fault)	Yes Yes	Planned/ Controlled[c] Planned/ Controlled[c]	No No
	SLG or 3Ø Fault, with Normal Clearing[e], Manual System Adjustments, followed by another SLG or 3Ø Fault, with Normal Clearing[e]: 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[c]	No
	Bipolar Block, with Normal Clearing[e]: 4. Bipolar (dc) Line Fault (non 3Ø), with Normal Clearing[e]: 5. Any two circuits of a multiple circuit towerline[f]	Yes Yes	Planned/ Controlled[c] Planned/ Controlled[c]	No No
	SLG Fault, with Delayed Clearing[e] (stuck breaker or protection system failure): 6. Generator 7. Transformer 8. Transmission Circuit 9. Bus Section	Yes Yes Yes Yes	Planned/ Controlled[c] Planned/ Controlled[c] Planned/ Controlled[c] Planned/ Controlled[c]	No No No No

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.

Appendix B. WECC Regional Differences

LADWP will apply the following Interconnection-wide Regional Differences from FAC-010-1 for the Western Interconnection while developing SOLs for the Planning Horizon:

1. As governed by the requirements of R2.4 and R2.5, starting with all Facilities in service, the following multiple Facility Contingencies shall be evaluated when establishing SOLs:

    a. Simultaneous permanent phase to ground Faults on different phases of each of two adjacent transmission circuits on a multiple circuit tower, with Normal Clearing. If multiple circuit towers are used only for station entrance and exit purposes, and if they do not exceed five towers at each station, then this condition is an acceptable risk and therefore can be excluded.

    b. A permanent phase to ground Fault on any generator, transmission circuit, transformer, or bus section with Delayed Fault Clearing except for bus sectionalizing breakers or bus-tie breakers addressed in 4.1.7

    c. Simultaneous permanent loss of both poles of a direct current bipolar Facility without an alternating current Fault.

    d. The failure of a circuit breaker associated with a Special Protection System to operate 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.

    e. A non-three phase Fault with Normal Clearing on common mode Contingency of two adjacent circuits on separate towers unless the event frequency is determined to be less than one in thirty years.

    f. A common mode outage of two generating units connected to the same switchyard, not otherwise addressed by FAC-010.

2. The loss of multiple bus sections as a result of failure or delayed clearing of a bus tie or bus sectionalizing breaker to clear a permanent Phase to Ground Fault

    a. All Facilities are operating within their applicable Post-Contingency thermal, frequency and voltage limits.

    b. Cascading Outages do not occur.

    c. Uncontrolled separation of the system does not occur.

    d. The system demonstrates transient, dynamic and voltage stability.

    e. 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 security of the interconnected transmission systems.

    f. Interruption of firm transfer, Load or system reconfiguration is permitted through manual or automatic control or protection actions.

    g. To prepare for the next Contingency, system adjustments are permitted, including changes to generation, Load and the transmission system topology when determining limits.

3. For multiple Facility Contingencies in 4.1.1 through 4.1.5, SOLs shall be established such that operation within the SOL shall provide system performance consistent with the following:

    a. Cascading Outages do not occur.

4. The Western Interconnection may make changes (performance category adjustments) to the Contingencies required to be studied and/or the required responses to Contingencies for specific facilities based on actual system performance and robust design

Appendix C. WECC Application of SOL and IROL

Source:http://www.wecc.biz/documents/meetings/OC/CMOPS/2007/August/WECC%20Philosophy%20of%20SOL-IROL.pdf

Issue: NERC Reliability Standards include references to System Operating Limit (SOL) and Interconnection Reliability Operating Limit (IROL) and WECC needs to determine how these definitions apply in the Western Interconnection.

NERC Definitions:
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)

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.

Background:
These are NERC (Eastern Interconnection) terms and definitions. Quite some time ago Bob Dintelman and Steve Rueckert argued at NERC against the need for two different definitions for an overload. The WECC position was an overload is an overload and should be avoided, and if it occurred, should be mitigated as soon as possible. It was argued that these two definitions are almost saying it is a little more OK to have an SOL violation than an IROL violation. WECC's position was we should avoid and mitigate all violations. WECC lost the argument and the heavily weighted Eastern Interconnection and NERC philosophy won out over those in the west, and now the NERC Reliability Standards have two ways or types of exceeding limits.

Discussion Points:
WECC doesn't have any IROLs under normal operation, but during SOL conditions (during the 30 minute thermal or 20 minute stability OTC overload timeframes) there may be IROL conditions. (IROL's would have to be an OTC studied path, but not all studied paths are IROLs.)

For example, during COI SOL violations (or some of the other limit violations in Table 2 from the RMS agreement) where the limit was exceeded by too much, and an event were to occur during the time the limit was being exceeded, the operator could run the risk of a cascading outage.

The only other way cascading outages should happen is either the operator didn't define the limits properly, operating in an unstudied state, or there were equipment failures. These conditions could be IROL conditions after studies later determine that the operator could run the risk of cascading outages.

WECC criteria prevent operating in IROLs under normal operating conditions.

Recommendation:
CMOPS to approve the following interpretation of the NERC Reliability Standards for SOLs and IROLs until further clarification is made by NERC:

"The WECC does not have any IROLs under normal operation, but during SOL conditions, depending upon the operating conditions, could become an IROL condition, which would be determined post-analysis."