System Operating Limit (SOL) Methodology for the Planning Horizon

(FAC-010-3)

Western Area Power Administration

Planning Authorities

Version 5

Effective

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1. Purpose

The North American Electric Reliability Corporation (NERC) Standards FAC-0l0-2.l and FAC-014-2 require that each Planning Authority "shall have a documented System Operating Limits (SOL) Methodology for use in developing SOLs within its Planning Authority Area" for the planning horizon. This document describes the System Operating Limits Methodology utilized for all Western Area Power Administration (Western) Planning Authority areas. This methodology is only applicable to the planning horizon, the timeframe one to ten years out. [R1.1]

This document is updated periodically as needed to maintain consistency with current NERC Reliability Standards, Peak RC System Operating Limits Methodology for the Operating Horizon and WECC Regional Business Practices.

2. Definitions

This document is based on the following definitions from the NERC Glossary of Terms Used in Reliability Standards:

2.1. ***Bulk Electric System (BES)*** - Unless modified by [list of inclusions and exclusions], all Transmission Elements operated at 100 kV or higher and Real Power and Reactive Power resources connected at 100 kV or higher. This does not include facilities used in the local distribution of electric energy.

2.2. ***Cascading*** - The uncontrolled successive loss of system elements triggered by an incident at any location. Cascading results in widespread electric service interruption that cannot be restrained from sequentially spreading beyond an area predetermined by studies.

2.3. ***Facility*** - A set of electrical equipment that operates as a single Bulk Electric System Element (e.g., a line, a generator, a shunt compensator, transformer, etc.)

2.4. ***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.

2.5. ***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.

2.6. ***Interconnection Reliability Operating Limit T_V (IROL T_V)*** - The maximum time that an Interconnection Reliability Operating Limit can be violated before the risk to the interconnection or other Reliability Coordinator Area(s) becomes greater than acceptable. Each Interconnection Reliability Operating Limit's Tv shall be less than or equal to 30 minutes.

2.7. ***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)

3. SOL Methodology for the Planning Horizon

3.1. SOL Applicability and Requirements

Western performs annual transmission planning assessments and numerous studies throughout the year. When these studies indicate that there are potential reliability performance violations during certain scenarios, corrective action plans are established. These corrective action plans could include system upgrades, but other alternatives might be more effective or efficient. Sometimes it is best to place restrictions on the system which must be adhered to in establishing long term plans.

For example, a flow limit could be placed on a specific set of lines to avoid potential load tripping due to under-voltages after a contingency. This limit could in turn be used to develop operating procedures, coordinate protection systems, determine the maximum transmission capacity that can be sold, provide stipulations for generator dispatch levels in interconnection agreements, assist in procurement of adequate reactive service, and many other activities that take place in the planning horizon. Utilizing this limit throughout the planning horizon will ensure that the system does not reach a scenario with potential reliability performance violations.

In general terms, a value that ensures operation within acceptable reliability criteria for a given configuration is an SOL. In addition to limits developed through studies, all Facility Ratings are SOLs. SOLs shall not exceed associated Facility Ratings [R1.2].

This methodology is applicable for determining System Operating Limits for the planning horizon within Western Planning Authority areas. The planning horizon is assumed to be beyond one year to a maximum of ten years [R1.1]. This methodology does not apply to the operating horizon, the time period less than one year out.

3.2. System Performance

In performing studies to establish SOLs, BES performance shall be based on the NERC System Performance Table provided in Appendix 1, titled "Transmission System Standards - Normal and Emergency Conditions." [R2]

Pre-contingency State - In the pre-contingent state, with all Facilities in service, this methodology requires that the BES demonstrate transient, dynamic, and voltage stability; all Facilities shall be within their thermal, voltage, and stability limits for system intact and planned (i.e. prior) outage conditions. The requirements for the pre-contingent state are also summarized under Category P0 of Table 1 - Steady State & Stability Performance Planning Events in Appendix 1. [R2.1]

Thermal Facility Ratings are shared through WECC base case coordination.[1] The thermal ratings may vary from current operating procedures or from season to season. This is because the thermal ratings are provided for the corresponding season and timeframe for which the case is modeled. In the pre-contingent state, all normal thermal Facility Ratings in WECC base cases will be SOLs for the planning horizon.

Unless specified otherwise Western bus voltage limits for any bus in pre-contingent conditions will be +/- 5% of the nominal voltage (0.95 to 1.05 per unit). Note that "500 kV" elements normally have a nominal voltage of 525 kV and are thus operated between 1.00 and 1.10 per unit of the 500 kV baseline. In the pre-contingent state, all normal bus voltage limits will be SOLs.

Regional criteria are used as proxies to establish what constitutes "transient, dynamic, and voltage stability" in planning studies.[2] However, there are not defined criteria for the pre-contingent state, and thus there are no stability limits on facilities in the pre-contingent state. Steady state and dynamic simulations must converge prior to contingencies, and no elements should be out of synchronism prior to simulating contingencies in dynamic analysis.

Additionally, WECC annually posts a Path Rating Catalog.[3] The ratings in this catalog are thermal, voltage, and/or stability limits which constitute SOLs.

Contingencies - Following the contingencies described in Category P1-P7 of the NERC Steady State & System Stability Performance Planning Events Table in Appendix 1, the system shall demonstrate transient, dynamic and voltage stability; all Facilities shall be within their thermal, voltage, and stability limits; Cascading outages or uncontrolled separation shall not occur. The requirements for the post-contingent state are also summarized in the Table. Additionally, Western uses WR4 of WECC Criterion – TPL-001-WECC-CRT-3 in Appendix

[1] For the cases with ratings see: http://www.wecc.biz/committees/StandingCommittees/PCC/TSS/BaseCases/Pages/default.aspx

[2] Order No. 693 at P1819 states, "The Commission agrees with SoCal Edison that, if an entity models overload relays, undervoltage relays, all remedial action schemes including those of neighboring systems and has a good load representation, then proxies are not required. However, due to modeling and simulation limitations this is often not the case and planners invariably use proxies. Recognizing this and the range of proxies currently in use, the Transmission Issues Subcommittee of the NERC Planning Committee recommended that proxies used in simulations be defined until such time as improved analytical tools and models are available to simulate cascading events."

[3] http://www.wecc.biz/library/Pages/Path%20Rating%20Catalog.aspx

1 as indicators of possible transient, dynamic, and voltage stability limits following single and multiple contingencies within the Western Interconnection. [R2.2, R2.2.1, R2.2.2, and R2.2.3]. The proxies to identify possible "Cascading" are given in WR4 of WECC Criterion – TPL-001-WECC-CRT-3 in Appendix 1. [R2.5]

Emergency thermal Facility Ratings will be used as the applicable post-contingent limits. These ratings have a limited duration. Typically, a 30 minute Emergency Rating is used, but this can be adjusted on a case-by-case basis. Simulations must prove that the system can be readjusted to bring facilities within their next lowest rating before the applicable timeframe expires. For example, some facilities have been given a 15 minute emergency rating greater than their 30 minute rating. If simulations show that the facility will exceed its 30 minute rating after a contingency but remain within its 15 minute rating, the limit has not been violated as long as the facility can be brought below the 30 minute rating within 15 minutes and there is an operating procedure to state how that will be done.

Unless specified otherwise in operating procedures, the applicable voltage limits for any bus after single and multiple contingencies will be +/- 10% of the nominal voltage (0.90 to 1.10 p.u.). Note that "500 kV" elements normally have a nominal voltage of 525 kV and are thus limited between 0.95 and 1.15 per unit of the 500 kV baseline. Post-contingency bus voltage limits cannot exceed 30 minutes in duration. Simulations must prove that the system can be readjusted to bring buses within their normal voltage ratings before this timeframe expires.

Additionally, the following proxy will be used to assess whether the system demonstrates voltage stability:

- When studying transmission paths/interfaces, the simulation must converge after single contingencies with the pre-contingency path/interface transfer modeled at a minimum of 105 percent of the simulated transfer level. For multiple contingencies, the simulation must converge with the pre-contingency transfer path/interface transfer modeled at a minimum of 102.5 of the simulated transfer level.
- When studying load areas, the simulation must converge after single contingencies at a minimum of 105 percent of the simulated load level. For multiple contingencies, the simulation must converge with the area modeled at a minimum of 102.5 percent of the simulated load level.

The BES response to a single contingency may include the following [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. [R2.3.1]

- System reconfiguration through manual or automatic control or protection actions. [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. [R2.4]

The BES response to a multiple contingency may include the following [R2.6]:

- 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. [R2.3.1]
- System reconfiguration through manual or automatic control or protection actions. [R2.3.2]
- Planned or controlled interruption of electric supply to customers (load shedding), the planned removal from service of certain generators, and/or curtailment of contracted Firm (non-recallable reserved) electric power Transfers [R2.6.1]. Several methods might be used to model curtailment of contracted Firm Transfers in a simulation. These include, but are not limited to, generation redispatch, opening of lines or transformers, adjusting phase shifters, or other methods to reduce flow across a path.

3.3. Determining SOLs

The following describes Western's considerations to be addressed when determining SOLs in the planning horizon:

Study Model [R3.1, R3.5] - Study models shall be based on the most recent WECC approved base cases available for the study time frame and conditions unless otherwise noted and justified. Models shall reflect an adequate range of system stressing scenarios.

- Full loop representation is to be used with the entire WECC topology modeled. [R3.1]
- Anticipated system configurations such as planned outages, generation dispatch and seasonal load levels will be modeled. Generation and load levels will be selected to appropriately stress the study area and any associated transmission paths. Generation dispatch may vary due to wind, hydro, or other conditions. [R3.5]
- 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, actual load models when available, or accepted industry modeling. Loads shall include appropriate power factor representation and demand uncertainty margins of 5% for Categories P0 and P1, and 2.5% for Categories P2-P7. [R3.5]

- System transfer level limits for transmission paths defined within the WECC Path Rating Catalog. Additional transfer paths should be included if appropriate. [R3.1]

- Voltage profiles and equipment loadings within all accepted BES Facility Ratings and WECC Reliability Criteria. [R3.1]

- Applicable AC-DC-AC converter operating criteria. [R3.1]

- Applicable Phase Shifter operating criteria. [R3.1]

- Applicable series compensation assumptions for existing Extra High Voltage (EHV) lines. [R3.1]

- Applicable generation and load shedding necessary to ensure system security and reliability. [R3.1]

Selection of Contingencies [R3.2] – When performing simulations to determine SOLs, Western models Category P2-P7 contingencies. Effects of contingencies within Western and in other areas shall be considered. The contingencies selected for a detailed study will be the ones that are most pertinent to the area or path of concern. Contingencies of facilities above and below 100 kV shall be considered. Generally, the contingency list shall include:

- Any contingencies that have been previously studied and set or significantly impact a System Operating Limit.

- Additional contingencies based on historical system response or judgment of the engineer.

- New outages, resulting from changes in the system configuration, that have not yet been studied.

Thermal and Voltage Limits [R3.2] - The single contingencies must meet and exceed requirements R2.2, R2.3 and R2.4 of FAC-010-2. Multiple contingencies must meet and exceed the requirements R2.5, R2.6, and WECC Regional Difference E.l. of FAC-010-2 (see Appendix 2).

Voltage Stability Limits [R3.2] –Contingency cases that will not solve, or evidence difficulty solving, are analyzed for potential voltage problems.

Transient Stability Limits [R3.2] – The following methodology shall be used to determine transient stability limits:

- The contingency list for transient stability determination is a subset of the contingencies used for the thermal and voltage stability studies. This contingency list includes:

    - Any contingencies that have been previously studied that set or significantly impacted a SOL.

    - Additional contingencies based on historical system response and/or engineering judgment.

    - New outages, resulting from changes in the system configuration, that have not yet been studied.

- Each contingency will be simulated for at least 10 seconds.

Acceptable transient performance will be determined using WECC System Performance Criteria and Disturbance Performance Table (see Appendix 1). Performance is based on, but not limited to, system damping, low frequency dip and maximum first swing voltage dip and duration.

Model Detail [R3.3] - A detailed system representation of the study area should be modeled when appropriate. During simulation, monitoring criteria will be set to adequately analyze the impacts on BES facilities and other critical facilities below 100 kV. Facilities both inside and outside of Western will be considered for monitoring if included in the WECC approved base case model.

Remedial Action Schemes [R3.4] - Remedial Action Schemes will be modeled as they are known to operate.

System Configuration [R3.5] - A WECC base case will be selected based on the generation dispatch, load level (peak/off-peak) and season. The study model will assume all lines in service, with known planned outages. The base load level will be updated with the latest forecast. Loads shall be modeled as accurately as possible, including the appropriate load power factor. The generation and load level should then be adjusted to appropriately stress the study area or path.

IROL Criteria [R1.3, R3.6] –
An IROL is an SOL, that if violated, could lead to instability, uncontrolled separation, or Cascading Outages that adversely impact the reliability of the BES. SOLs qualify as IROLs when impact containment cannot be demonstrated as described in the 'Impact Containment and IROL Load Impact' section below or when studies indicate that instability, Cascading, or uncontrolled separation may occur resulting in uncontrolled interruption of load equal to or greater than 1000 MW.

Impact Containment and IROL Load Impact
Impact containment is considered to be adequately demonstrated when all the following are accomplished:

a. Impacted area is predefined by studies.
b. Cascading is restrained from sequentially spreading beyond the impacted area.
c. If the impacted area has been identified to involve more than one Planning Authority area, studies have been coordinated and all concerns resolved.
d. Impacted Planning Authorities have developed and documented agreed upon coordinated plans, processes, and procedures to ensure adequate containment within the impacted area and have provided this documentation to the RC.

Determining Transient Stability Limited IROLs
Western will identify Transmission Path/Interface SOLs that qualify as IROLs to prevent intra-area or inter-area instability or uncontrolled tripping of BES Facilities due to out-of-step conditions. Where transient simulations show loss of synchronism due to disturbances

internal or external to its Planning Authority Area, Western will coordinate with the impacted Planning Authorities to make a determination of whether an IROL exists.

Determining Steady State (Post-Transient) Voltage Stability Limited IROLs
The maximum pre-contingency megawatt power transfer or area load for which a post-contingency solution can be achieved for the limiting (critical) Contingency qualifies as an IROL unless impact containment can be demonstrated as described in the 'Impact Containment and IROL Load Impact' section above and the level of uncontrolled load interruption is less than 1000 MW.

Determining Thermally Limited IROLs
Cascading potentially occurs 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 public safety concerns). Western will identify the subset of SOLs that qualify as thermally limited IROLs when studies indicate post-contingency overloading and subsequent loss of BES Facility(ies) resulting in Cascading outages beyond an area pre-determined by studies. The process outlined below shall be followed:

a. Run Contingency analysis and flag Credible Contingencies that result in post-contingency loading in excess of the lower of:
    i. The Facility(ies)'s trip setting.
    ii. 125 percent of the highest Facility(ies) Rating.

b. For each flagged Credible Contingency, open both the contingent element(s) that cause(s) the post contingency loading and all consequent Facilities that overload in excess of (a) (i) or (ii) above. Rerun Contingency analysis.
c. Repeat step (b) for any newly overloaded Facility(ies) in excess of (a) (i) or (ii) above. Continue with this process until Cascading stops within a predefined area or the solution diverges.
d. Evaluate results to identify thermally limited SOLs that qualify as IROLs.

IROL T_V
A goal of the long term planning process is to ensure that the system will not exceed IROLs in pre-contingency conditions. Furthermore, if planning simulations show a potential for an IROL to be exceeded post-contingency, the planning simulations must demonstrate that the system can be brought below the IROL within its corresponding IROL T_V. The default IROL T_V shall be 30 minutes in Western areas for the planning horizon.[4] However, shorter duration IROL Tv may be established in coordination with other impacted Planning Authorities based on relay/protection settings and other considerations.

4. Availability

[4] The Peak Reliability and Western TOPs might implement an IROL T_V of different duration in the operating horizon.

4.1. **Issuance of Methodology [R4] –** Prior to the effectiveness of any change, Western will issue this methodology on its OASIS website and notify the following applicable entities of such posting. [R4]:

- Each adjacent Planning Authority and each Planning Authority that indicates it has a reliability-related need for the methodology. [R4.l]

- Each Reliability Coordinator and Transmission Operator that operates in any portion of Western's Planning Authority Areas. [R4.2]

- Each Transmission Planner that works in Western's Planning Authority Areas. [R4.3]

Revision History

WAPA-DSW			
Revision	**Date**	**Action**	**Name of Editor**
0	5/24/07	Original document	Nick Saber
WAPA-RMR			
Revision	**Date**	**Action**	**Name of Editor**
0	12/23/2008	1.Drafted and published original document	Bob Easton
1	7/24/2009	1. Changed title page from Balancing Authority to Planning Authority	Jared Griffiths
WAPA-UGP			
Revision	**Date**	**Action**	**Name of Editor**
A	5/5/10	Original Document	Frank Jarvenpaa
2	3/25/13	Updates relative to FAC-010, Version 2.1 and WECC RC SOL Methodology for the Operations Horizon, Version 6.1	Frank Jarvenpaa
WAPA-DSW and WAPA-RMR Combined			
Revision	**Date**	**Action**	**Name of Editor**
2	9/30/2013	Combined WAPA-DSW and WAPA-RMR methodologies and redrafted to better align with WECC RC "Phase II" SOL Methodology	Patrick Harwood
2.1	4/30/2014	Periodic review and errata changes	Patrick Harwood
WAPA All Regions Combined			
Revision	**Date**	**Action**	**Name of Editor**
3	8/17/2014	Combined Western methodologies	James Hirning
4	4/1/2016	Updated Referenced NERC/WECC Criteria	James Hirning/Patrick Harwood
5	3/24/2017	Updated for most recent FAC-010 version Replaced Special Protection System with Remedial Action Scheme	James Hirning

Approval:

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Manager, Transmission Planning – South, RMR

Appendix 1 - System Performance Table

Table I. Transmission System Standards - Normal and Emergency Conditions

NERC Standard TPL-001-4 — Transmission System Planning Performance Requirements (Fully in effect on 1/1/2016)

Table 1 – Steady State & Stability Performance Planning Events

Steady State & Stability:

a. The System shall remain stable. Cascading and uncontrolled islanding shall not occur.

b. Consequential Load Loss as well as generation loss is acceptable as a consequence of any event excluding P0.

c. Simulate the removal of all elements that Protection Systems and other controls are expected to automatically disconnect for each event.

d. Simulate Normal Clearing unless otherwise specified.

e. Planned System adjustments such as Transmission configuration changes and re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings.

Steady State Only:

f. Applicable Facility Ratings shall not be exceeded.

g. System steady state voltages and post-Contingency voltage deviations shall be within acceptable limits as established by the Planning Coordinator and the Transmission Planner.

h. Planning event P0 is applicable to steady state only.

i. The response of voltage sensitive Load that is disconnected from the System by end-user equipment associated with an event shall not be used to meet steady state performance requirements.

Stability Only:

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

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

Category	Initial Condition	Event [1]	Fault Type [2]	BES Level [3]	Interruption of Firm Transmission Service Allowed [4]	Non-Consequential Load Loss Allowed
P3 Multiple Contingency	Loss of generator unit followed by System adjustments[9]	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6]	3Ø	EHV, HV	No[9]	No[12]
		5. Single pole of a DC line	SLG			
P4 Multiple Contingency *(Fault plus stuck breaker[10])*	Normal System	Loss of multiple elements caused by a stuck breaker [10](non-Bus-tie Breaker) attempting to clear a Fault on one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
		6. Loss of multiple elements caused by a stuck breaker[10] (Bus-tie Breaker) attempting to clear a Fault on the associated bus	SLG	EHV, HV	Yes	Yes
P5 Multiple Contingency *(Fault plus relay failure to operate)*	Normal System	Delayed Fault Clearing due to the failure of a non-redundant relay[13] protecting the Faulted element to operate as designed, for one of the following: 1. Generator 2. Transmission Circuit 3. Transformer [5] 4. Shunt Device [6] 5. Bus Section	SLG	EHV	No[9]	No
				HV	Yes	Yes
P6 Multiple Contingency *(Two overlapping singles)*	Loss of one of the following followed by System adjustments.[9] 1. Transmission Circuit 2. Transformer [5] 3. Shunt Device[6] 4. Single pole of a DC line	Loss of one of the following: 1. Transmission Circuit 2. Transformer [5] 3. Shunt Device [6]	3Ø	EHV, HV	Yes	Yes
		4. Single pole of a DC line	SLG	EHV, HV	Yes	Yes

Category	Initial Condition	Event [1]	Fault Type [2]	BES Level [3]	Interruption of Firm Transmission Service Allowed [4]	Non-Consequential Load Loss Allowed
P7 Multiple Contingency *(Common Structure)*	Normal System	The loss of: 1. Any two adjacent (vertically or horizontally) circuits on common structure [11] 2. Loss of a bipolar DC line	SLG	EHV, HV	Yes	Yes

Appendix 1 - System Performance Table (cont.)

WECC Criterion – TPL-001-WECC-CRT-3

Transmission System Planning Performance

A. Introduction

1. **Title:** **Transmission System Planning Performance**

2. **Number:** TPL-001-WECC-CRT-3

3. **Purpose:** **T**o facilitate coordinated near-term and long-term transmission planning within the Interconnection of the Western Electricity Coordinating Council (WECC), and to facilitate the exchange of the associated planning information for normal and abnormal conditions.

   This document applies to all transmission planning studies conducted within the Interconnection of the Western Electricity Coordinating Council (WECC).

   This is a planning criterion. This document does not designate the entity responsible for system remediation.[5]

4. **Applicability:**

   4.1. Functional Entities:

   4.1.1. Planning Coordinator

   4.1.2. Transmission Planner

   4.2. Facilities

   4.2.1. This document applies to Bulk Electric System (BES) Facilities.

   4.2.2. The following buses are specifically *excluded* from this WECC Criterion:

   4.2.2.1. Non-BES buses

   4.2.2.2. Line side series capacitor buses

   4.2.2.3. Line side series reactor buses

   4.2.2.4. Dedicated shunt capacitor buses

   4.2.2.5. Dedicated shunt reactor buses

[5] TPL-001-WECC-2.1, System Performance, WECC's Disturbance Performance Table (Table W-1) of Allowable Effects Other System (Table) was retired by the WECC Ballot Body on October 8, 2015 with WECC Board of Director approval on December 5, 2013.

4.2.2.6. Metering buses, fictitious buses, or other buses that model point of interconnection solely for measuring electrical quantizes; and,

4.2.2.7. Other buses specifically excluded by each Planning Coordinator or Transmission Planner internal to their system

5. Effective Date: The Effective Date is the later of January 1, 2016 or the Effective Date of TPL-001-4, Transmission System Planning Performance, Requirements R2-R6 and R8, subject to approvals.

B. Requirements and Measures

WR1. Each Transmission Planner and Planning Coordinator shall use the following default base planning criteria, unless otherwise specified in accordance with Requirements WR2 and WR3:

1.1. Steady-state voltages at all applicable Bulk-Electric System (BES) buses shall stay within each of the following limits:

1.1.1. 95 percent to 105 percent of nominal for P0[6] event (system normal pre-contingency event powerflow);

1.1.2. 90 percent to 110 percent of nominal for P1-P7[7] events (post-contingency event powerflow).

1.2. Post-Contingency steady-state voltage deviation at each applicable BES bus serving load shall not exceed 8% for P1 events.

1.3. Following fault clearing, the voltage shall recover to 80% of the pre-contingency voltage within 20 seconds of the initiating event for all P1 through P7 events, for each applicable BES bus serving load.

1.4. Following fault clearing and voltage recovery above 80%, voltage at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds, for all P1 through P7 events.

1.5. For Contingencies without a fault (P2.1 category event), voltage dips at each applicable BES bus serving load shall neither dip below 70% of pre-contingency voltage for more than 30 cycles nor remain below 80% of pre-contingency voltage for more than two seconds.

1.6. All oscillations that do not show positive damping within 30-seconds after the start of the studied event shall be deemed unstable.

[6] P0 through P7 refers to the categories of contingencies identified in Table 1 of NERC Standard TPL-001-4, Transmission System Planning Performance Requirements.

[7] Previously cited.

WM1. Each Transmission Planner and Planning Coordinator will have evidence that it used the base criteria in its Planning Assessment specified in Requirement WR1, unless otherwise allowed in accordance with Requirements WR2 and WR3.

WR2. Each Transmission Planner and Planning Coordinator that uses a more stringent criterion than that stated in Requirement WR1 shall apply that criterion only to its own system, except where otherwise agreed upon by all other planning entities to which the more stringent criterion was applied.

WM2. Each Transmission Planner and Planning Coordinator that uses a more stringent criterion in its planning assessment than that stated in Requirement WR1 and applied that criterion to other systems will have evidence of agreement from all other planning entities to which the more stringent criteria was applied.

WR3. Each Transmission Planner and Planning Coordinator that uses a less stringent criterion than that stated in Requirement WR1 shall allow other Transmission Planners and Planner Coordinators to have the same impact on that part of the system for the same category of planning events (e.g., P1, P2).

WM3. Each Transmission Planner and Planning Coordinator that uses a less stringent criterion than that stated in Requirement WR1 will have evidenced that it allowed other Transmission Planners and Planner Coordinators to have the same impact on that part of the system for the same category of planning events (e.g., P1, P2).

WR4. Each Transmission Planner and Planning Coordinator shall use the following threshold criteria to identify the potential for Cascading or uncontrolled islanding. An entity is allowed to use these criteria to identify instability due to Cascading or uncontrolled islanding as long as it does not impose it on others:

- When a post contingency analysis results in steady-state facility loading that is either in excess of a known BES facility trip setting, or exceeds 125% of the highest seasonal facility rating for the BES facility studied. If the trip setting is known to be different than the 125% threshold, the known setting should be used.
- When transient stability voltage response occurs at any applicable BES bus outside of the criteria stated in Requirement WR1.3 of this document.
- When either unrestrained successive load loss occurs or unrestrained successive generation loss occurs.

WM4. Each Transmission Planner and Planning Coordinator will have evidence that it used the indicators of Requirement WR4 to identify the potential for Cascading or uncontrolled islanding.

WR5. Each Transmission Planner and Planning Coordinator shall use the following minimum criteria when identifying voltage stability:

5.1. For transfer paths, all P0-P1 events shall demonstrate a positive reactive power margin at a minimum of 105 percent of transfer path flow.

5.2. For transfer paths, all P2-P7 events shall demonstrate a positive reactive power margin at a minimum of 102.5 percent of transfer path flow.

5.3. For load areas, all P0-P1 events shall demonstrate a positive reactive power margin at a minimum of 105 percent of forecasted peak load.

5.4. For load areas, all P2-P7 events shall demonstrate a positive reactive power margin at a minimum of 102.5 percent of forecasted peak load.

WM5. Each Transmission Planner and Planning Coordinator will have evidenced that it used the minimum criteria identified in Requirement WR5 to identify voltage stability.

WR6. Each Transmission Planner and Planning Coordinator that uses study criteria different from the base criteria in Requirement WR1 shall make its criteria available upon request within 30 days.

WM6. Each Transmission Planner and Planning Coordinator that uses study criteria different from the base criteria in Requirement WR1 will have evidence that it made its criteria available upon request, as required in Requirement WR6.

Rationale

Rationale for Requirement WR1

This is a planning criterion.

WR1 addresses NERC TPL R5 and R6.

WR1 is designed to state the base planning criteria the system must meet – unless an individual entity or group of entities has different criteria. WECC Requirements WR2 and WR3 allow for entities to have different criteria.

Neither WR2 nor WR3 changes the WR1 default; rather, WR2 and WR3 allow for deviation from the WR1 default. WR2 allows for a more stringent approach without changing the WR1 default. A more stringent approach may be used in accordance with WR2 so long as all the affected parties agree. Similarly, WR3 allows deviation from the default with the additional protection that when used, other Transmission Planners and Planning Coordinators are allowed to use the same criteria on that part of the system for the same category of planning events (e.g., P1 and P2).

In the context of Requirement WR1, the word "nominal" carries its common definition and could be, for example, either the base voltage or the operating voltage as established in the entity's Planning Assessment. This means that nominal may have a varying definition or use from one entity to the next. If an entity does not specify what is nominal, the default use of the term nominal defaults to the kilo-volt class that is specified in the WECC Base Case, with the exception of the 500 kilo-vote class, in which case the default nominal would be specified as 525 kilo-volt.

Requirement WR1.1.2 refers to the post automatic equipment adjustment effect prior to manual adjustment.

Rationale for Requirement WR1.2

For purposes of this document, a BES bus that is serving load is the bus with direct transformation from BES-level voltage to distribution-level voltage that serves load.

In developing WR1.2, the drafting team was aware that eight percent is not the only practical percentage for use. Historically, stakeholders reported successfully using percentages between five and ten whereas others reported being under a regulatory mandate to use eight percent. To accommodate both positions the team selected the eight percent.

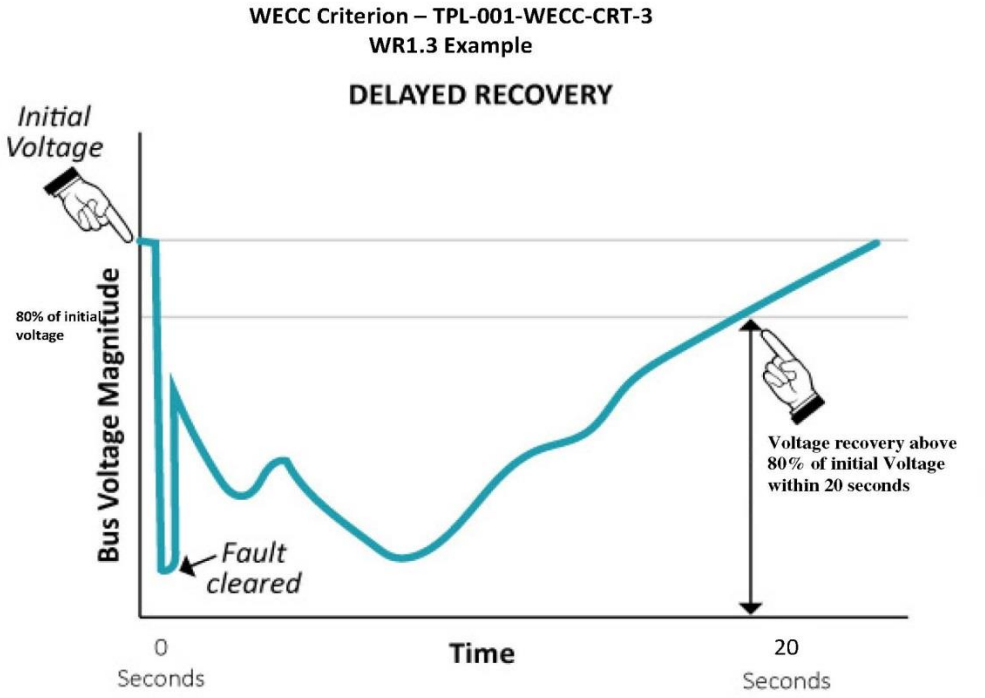
By default, only automatic post-contingency actions occurring in the studied timeframe are considered when calculating voltage deviation. This would include, among other things, capacitor or reactor switching. For purposes of WR1.2, automatic generally means a programmed response not manually initiated.

For P1 there is no high voltage deviation requirement. For P2-P7, there is no low or high voltage deviation requirement. It is implied that P2 through P7 events don't require a voltage deviation beyond meeting the requirements in WR1.1.2.

For purposes of this document, a BES bus that is serving load is the bus with direct transformation from BES-level voltage to distribution-level voltage that serves load.

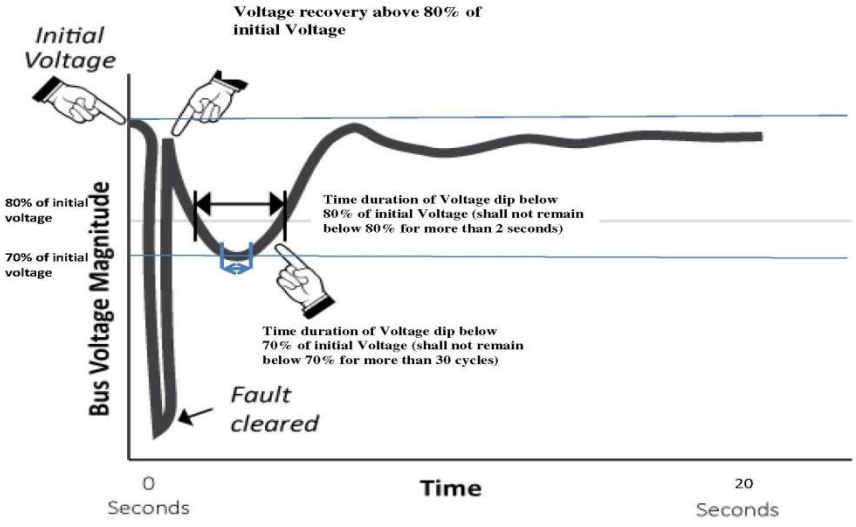
The following illustrations apply to WR1.3 and WR1.4, and not WR1.2.

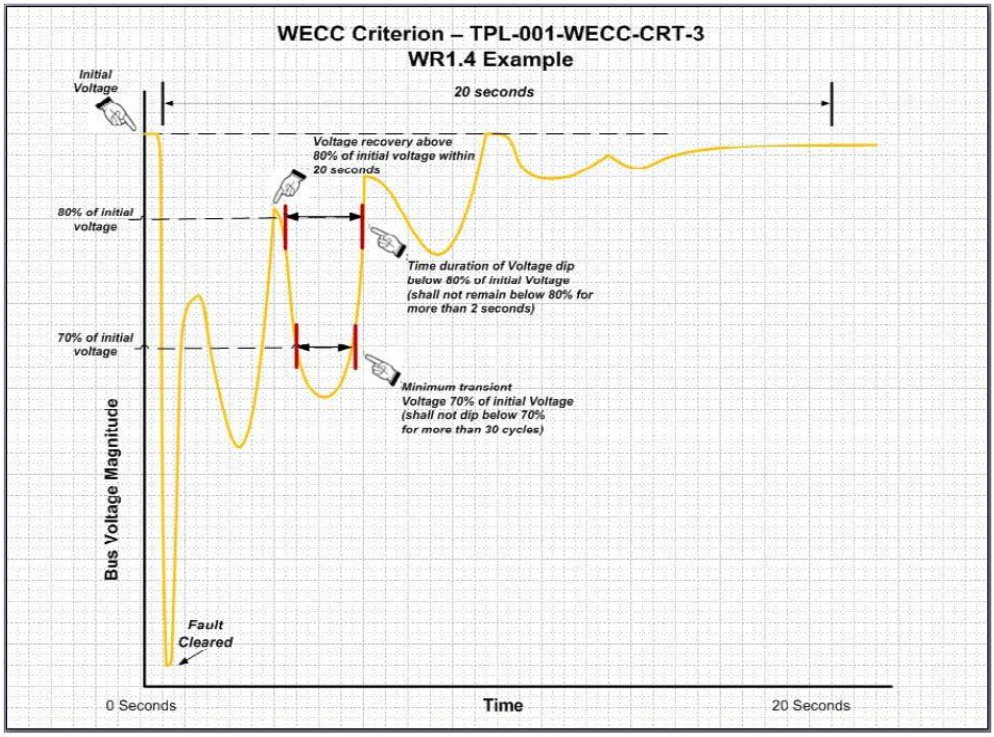
The following diagrams are offered for illustrative purposes. They are not designed to depict all possible voltage trajectories.



WECC Criterion – TPL-001-WECC-CRT-3
WR1.4 Example

NORMAL RECOVERY





Rationale for Requirement WR1.5 and 1.6
For purposes of this document, a BES bus that is serving load is the bus with direct transformation from BES-level voltage to distribution-level voltage that serves load.
The intent is not to require that transient stability simulations be run out to 30-seconds in all cases in order to ensure the system is stable and positively damped. Shorter runs are permissible if it can be shown that applicable criteria can be met within a shorter time frame.

For purposes of Requirement WR1.6, positive damping in stability analysis is demonstrated by showing that the amplitude of power angle or voltage magnitude oscillations after a minimum of 10 seconds is less than the initial post-contingency amplitude. In any case, results that do not show positive damping within a 30-second time frame are considered to be undamped.

The 30-second window is a general reference and does not refer to any specific time window.

Rationale for Requirement WR2

Planning Assessment is a NERC defined term. As stated in the Purpose statement, this document applies to all transmission planning studies conducted within the Interconnection of the Western Electricity Coordinating Council (WECC).

The rationale for Requirement WR2 is to ensure that the each planning entity does not impose more stringent requirements on systems other than their own. It may use more stringent criteria on its own system but may not impose more stringent criteria on others.

Transmission Planners and Planning Coordinators may mutually agree to use study criteria that is more stringent than that described in this document.

Rationale for Requirement WR3

The rationale is to ensure equity between planning entities. (Availability of differing criteria is addressed in Requirement WR6.)

Rationale for Requirement WR4
Requirement WR4 is designed to establish screening criteria that when exceeded may require further investigation of instability. The Requirement is not intended to show the presence of Cascading or instability. An entity is allowed to use these criteria for instability if they choose without imposing it on others.
The term Cascading in WR4 is the NERC defined term.
In WR4, Bullet 1, the 125% threshold is imported from the Peak RC System Operating Limits Methodology. The 125% threshold should only be used for facilities where the trip setting is not known. If the trip setting is known that known setting should be used. For example, if the known trip setting is 150% of the continuous rating, this should take precedence over the 125% of the highest rating.
The specific amounts of unrestrained load loss addressed in WR4, Bullet three, are not specified in this document. Because of the breadth of the possible permutations, the amount should be left to the sound engineering judgment of the planning entity.
Rationale for Requirement WR5

Requirement WR5 addresses "what" must be achieved and does not address "how" to do it.

For a review of "how" to achieve the goals, please refer to:

- The WECC Voltage Stability Assessment Methodology
- WECC Guide to WECC/NERC Planning Standards I.D: *Voltage Support and Reactive Power,* Prepared by: Reactive Reserve Working Group (RRWG), Under the auspices of Technical Studies Subcommittee (TSS); Approved by TSS, March 30, 2006
- Additional guidance is contained in Section 2.2 Voltage Stability of the Guide to WECC/NERC Planning Standards 1.D, Voltage Support and reactive Power, March 30, 2006.

The intent of Requirement WR5 is to ensure the voltage stability of transfer paths as well as the system as a whole during peak load or peak transfer conditions. A margin on real power flow is

used as a test for voltage stability. A positive reactive power margin can be demonstrated by a valid steady state power flow solution.

Power flow solutions refer to post contingency conditions where the actions of reactive devices and load tap changers should be modeled for the appropriate time frame being studied.

There is a higher likelihood of occurrence of a P0 to P1 category event; therefore, a higher margin (105%) is used. For P2-P7, there is a lower likelihood of occurrence; therefore, the lower margin (102.5%) is used.

Rationale for Requirement WR6

Requirement WR6 ensures the free flow of information between entities.

Appendix 2 – Contingencies Based on WECC Regional Differences

The following Interconnection-wide Regional Differences for the Western Interconnection shall be applied when developing SOLs for the Planning Horizon:

A2.1 Starting with all Facilities in service, the following multiple Facility Contingencies shall be evaluated when establishing SOLs:

A2.1.1 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.

A2.1.2 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 A2.1.7.

A2.1.3 Simultaneous permanent loss of both poles of a direct current bipolar Facility without an alternating current Fault.

A2.1.4 The failure of a circuit breaker associated with a Remedial Action Scheme 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.

A2.1.5 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.

A2.1.6 A common mode outage of two generating units connected to the same switchyard, not otherwise addressed by FAC-010.

A2.1.7 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.

A2.2 For multiple Facility Contingencies in A2.1.1 through A2.1.5, SOLs shall be established such that operation within the SOL shall provide system performance consistent with the following:

A2.2.1 All Facilities are operating within their applicable Post-Contingency thermal, frequency and voltage limits.

A2.2.2 Cascading does not occur.

A2.2.3 Uncontrolled separation of the system does not occur.

A2.2.4 The system demonstrates transient, dynamic and voltage stability.

A2.2.5 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.

A2.2.6 Interruption of firm transfer, Load or system reconfiguration is permitted through manual or automatic control or protection actions.

A2.2.7 To prepare for the next Contingency, system adjustments are permitted, including changes to generation, Load and the transmission system topology when determining limits.

A2.3 For multiple Facility Contingencies in A2.1.6 through A2.1.7, SOLs shall be established such that operation within the SOL shall provide system performance consistent with the following with respect to impacts on other systems:

A2.3.1 Cascading does not occur.

A2.4 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. Such changes will be applied in determining SOLs.