



FOR GENERATIONS

**BC Hydro System Operating Limits
Methodology for Planning Horizon**

Report No. SPA2008-02

REV. 3

Transmission and Station Planning

BC Hydro and Power Authority

4 January 2008

Revised: 24 June 2014

BC Hydro System Operating Limits Methodology for Planning Horizon

Prepared by: Performance Planning

Reviewed by: Guihua Wang

Approved by: Ajay Kumar

TABLE OF CONTENTS

I. Introduction	1
II. Glossary of Terms.....	1
III. SOL Methodology in the Planning Horizon (Reference FAC-010-2.1).....	3
A. Introduction	3
B. System Performance for Planned Firm Load and Planned Firm Transfers.....	3
C. Study Methodology	4
IV. Identification of SOLs that Qualify as IROLs (ref R1.3)	5
A. General	5
B. Impact Containment and IROL Load Impact.....	5
C. Determining Transient Stability Limited IROLs	6
D. Determining Steady State (Post-Transient) Voltage Stability Limited IROLs	6
E. Determining Thermally Limited IROLs	8
F. IROL TV	8
V. System Performance Standards.....	9
Table 1 - Contingency/Performance Requirements	12

Revision History

Rev. No.	Date	Description
1	11 April 2008	Clarified that SOLs can be determined by interpolation of study results. Clarified voltage and voltage stability margins for ESA customers.
2	15 December 2009	Clarified that post-contingency steady state voltage deviations up to 10% are acceptable in BC Hydro's regional transmission network.
3	23 June 2014	<ol style="list-style-type: none"> 1. Removed the portion of SOL for Operations Horizon. For Operations Horizon, WECC (PEAK)'s SOL methodology will be followed. 2. Added description how to determine IROL for Planning Horizon. 3. Replaced BCTC with BC Hydro.

BC Hydro System Operating Limits Methodology

I. Introduction

This document describes BC Hydro's System Operating Limits (SOL) Methodology including documentation of BC Hydro's System Performance Standards to respond to the following NERC Standard.

NERC Standard **FAC-010-2.1** requires that each Planning Authority "shall have a documented SOL Methodology for use in developing SOLs within its Planning Authority Area" for the planning horizon.

NERC Standard FAC-010 -2.1 requires certain elements to be addressed in these methodologies, including contingencies to be addressed and the required system response. In addition to the types of contingencies identified by NERC, the BC Hydro System Operating Limits Methodology considers additional contingencies and has specific quantified System Limits and Allowed Impacts.

The definition of System Operating Limit lists units of measure (MW, MVar, Amperes, Frequency or Volts). BC Hydro expresses System Operating Limits in MW.

Throughout this document, text in bold is intended to respond to the specific Requirements in the NERC standards.

II. Glossary of Terms

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

System Operating Limit (SOL):

The value (such as MW, MVar, Amperes, Frequency or Volts) that satisfies the most limiting of the prescribed operating criteria for a specified system configuration to ensure operation within acceptable reliability criteria. System Operating Limits are based upon certain operating criteria. These include, but are not limited to:

- *Facility Ratings (Applicable pre- and post- Contingency equipment or facility ratings)*
- *Transient Stability Ratings (Applicable pre- and post-Contingency Stability Limits)*
- *Voltage Stability Ratings (Applicable pre- and post- Contingency Voltage Stability)*
- *System Voltage Limits (Applicable pre- and post- Contingency Voltage Limits)*

Interconnection Reliability Operating Limit (IROL):

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.

Interconnection Reliability Operating Limit Tv

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.

Bulk Electric System

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

III. SOL Methodology in the Planning Horizon (Reference FAC-010-2.1)

A. Introduction

This SOL Methodology is applicable for determining System Operating Limits in the planning horizon within the BC Hydro Planning Authority Area (ref R1.1).

Details of contingencies considered and required system performance are addressed below in System Performance, subsections B and C. **In no case shall an SOL exceed an associated Facility Rating (ref R1.2).**

B. System Performance for Planned Firm Load and Planned Firm Transfers

For planned firm load and planned firm transfers in the planning horizon, system performance shall be determined based on precontingency and contingency states and system response as described in Section III and as specified in Section IV performance standards Table 1 – Contingency/Performance Table – All Lines in Service or Planned Maintenance Outages (ref R2).

Table 1 addresses FAC-010-2.1 Requirements as follows:

R2.1	Category A – No Contingencies
R2.2 and R2.3	Category B – Event resulting in the loss of a single element.
R2.4 and R2.5	Category C – Event resulting in the loss of two or more (multiple) elements.

C. Study Methodology

SOLs shall be determined in consideration of the items listed below.

- 1. The study model shall be based on an approved BC Hydro base case relevant for the study. The study model shall have a full representation for the BC Hydro Planning Authority Area system, but which may be modified by the study. In addition, it shall have load representation modeling relevant to the region of study (e.g. Lower Mainland/Vancouver Island, Northern Region, South Interior), the period of the year (e.g. peak winter, summer, or other) and the type of study (e.g. power flow, stability). No margins shall be included in the study model. Representation of other Planning Authority Areas will be provided in the approved base case, based on WECC base cases. When studying interconnections to other Planning Authority Areas, representation of the other Planning Authority Area shall be reviewed with the applicable Planning Authority. (Ref R3.1, R3.3, portion of R3.5.)**
- 2. All contingencies potentially impacting the SOL shall be considered. Prior study results may be considered to determine the contingencies for which simulations are required. Margins provided in the System Performance Standards are discussed in the Section IV. No additional margins shall be included in meeting these Standards. (Ref R3.2)**
- 3. In addition to the requirements outlined in item 1, the study model detail shall include residential, commercial, and industrial load models, with constant power, current and impedance as appropriate and where available. 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. Any margins provided to allow for load model uncertainty shall be explicitly stated. (Ref R3.3)**
- 4. Allowed use of SPS or RAS is addressed in Section IV (ref R3.4). Generation and load shedding may exceed the minimum requirement to ensure margin for system security.**
- 5. The transmission system shall include all facilities planned to be in-service, taking into account planned outages. Load level shall be representative of the period of the year and time of day under consideration. For the investment planning horizon, generation dispatch shall be determined in conjunction with the Resource Planners. Prior studies and/or determination of reasonable assumptions may be used to refine the range of generation dispatch to be simulated, with documentation of the foregoing (ref R3.5). Where a range of generation dispatch may impact on SOLs, sensitivity studies shall assess the potential impact on SOLs and no additional margins shall be provided.**

6. **When an SOL for a specific set of conditions has not been determined by study simulation, it is acceptable to determine the SOL by interpolation between SOLs that have been determined by study simulation.**
7. **Unless more restrictive limitations are present, SOLs shall equal the applicable Facility Ratings, voltage limits, voltage stability limits, transient stability limits, and WECC Path Ratings. The most limiting of these shall determine the SOL.**

IV. Identification of SOLs that Qualify as IROLs (ref R1.3)

When an IROL is exceeded, the Interconnection has entered into an insecure state, i.e., the most limiting Credible or Regionally Critical Contingency could result in instability, uncontrolled separation, or Cascading outages which adversely impact the reliability of the BES.

SOLs that qualify as IROLs shall be established consistent with the following requirements: [R3.6]

A. General

BC hydro shall identify the subset of SOLs that qualify as IROLs consistent with this SOL Methodology. When BC Hydro identifies an SOL that qualifies as an IROL, then BC Hydro will communicate the results of its analysis with impacted Planning Authorities (PAs) and Reliability Coordinator (RC).

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.

For each determined IROL, BC Hydro will work with RC and the impacted PAs to develop plans, processes, and procedures that identify actions that RC and others shall take (up to and including load shedding) in time to prevent exceeding the IROL and to mitigate the magnitude and duration of exceeding that IROL such that the IROL is relieved within the IROL's T_v .

B. Impact Containment and IROL Load Impact

When studies in the Planning Horizon indicate pre- or post-contingency instances of instability, uncontrolled separation, or cascading, a potential IROL condition is

present. The presence of an SOL that qualifies as an IROL will be determined based on

- i. whether impact containment is demonstrated, and
- ii. the level of load impact.

BC Hydro will consider impact containment to be adequately demonstrated when all of 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 PA, studies have been coordinated and all concerns resolved.
- d. Impacted PAs 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.

BC Hydro in coordination with the RC shall identify SOLs that qualify as IROLs when studies indicate that instability, cascading outages, or uncontrolled separation may occur resulting in uncontrolled interruption of load equal to or greater than 1000 MW. This threshold represents an upper bound for load loss regardless of demonstrated containment, but excludes load loss due to intended RAS/SPS actions. The 1000 megawatt threshold is intended to restrict the applicability of IROLs to large-area impacts rather than small-load areas.

C. Determining Transient Stability Limited IROLs

This section addresses transient stability limited IROLs based on dynamic time domain simulations. It is not intended to address small signal stability.

BC Hydro, working with RC, shall 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.

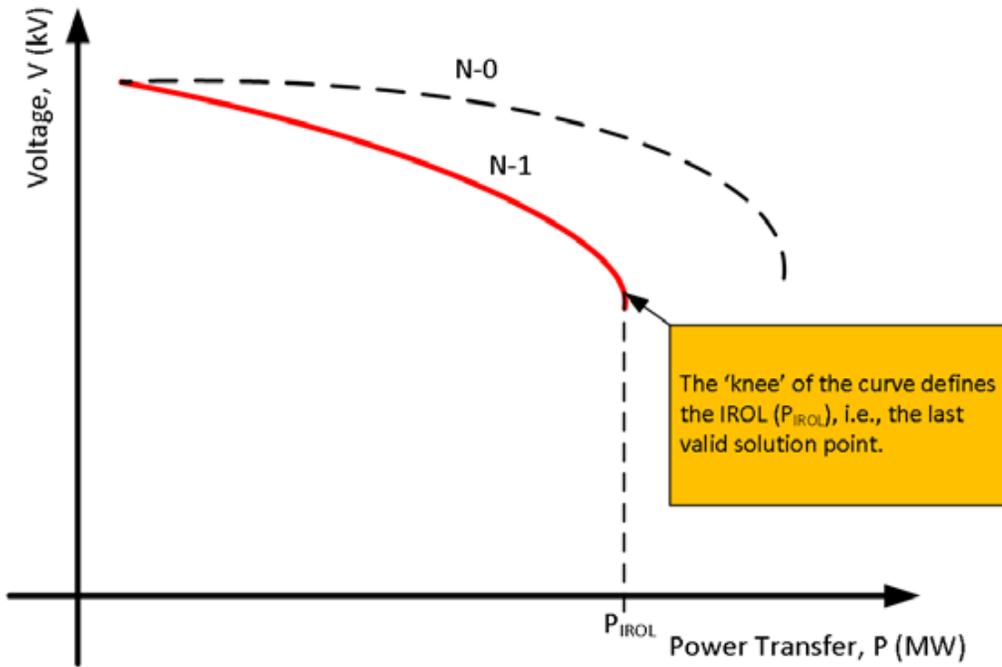
Where transient simulations show loss of synchronism due to disturbances, BC Hydro will coordinate with the impacted PAs and with the RC to make a determination of whether an IROL exists.

D. 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. Applicable operating margins shall be addressed in the related IROL plans, processes, and procedures. See the illustration below.

Figure 1: An IROL Example based on P-V Analysis:



E. 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).

BC Hydro shall 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.

F. IROL TV

IROL Tv shall be based on WECC RMS Agreement requirements: 20 minutes for stability, 30 minutes for thermal. No margins are applied. (Ref R3.6)

V. System Performance Standards

System Performance Standards within the BC Hydro Planning Authority Area are defined in

Table 1 – Contingency/Performance Table – All Lines in Service or Planned Maintenance Outages: Conditions on the power system that are planned for with all facilities in service and during planned outages.

The following clarifications are provided with respect to Table 1.

1. Generation dispatch shall be modeled according to transmission service agreement commitments by the generator owner/operator, including provisions of ancillary services (e.g. generator reactive and voltage support) or in consultation with Resource Planners as appropriate.
2. Contingencies shall be considered to be permanent outages which cannot be returned to service within the timeframe required for manual system adjustments. For facilities with automatic reclosing, the performance requirements shall apply assuming unsuccessful reclosing.
3. Facility rating limits, determined in accordance with BC Hydro's Facility Ratings Methodology, include continuous and emergency limits. Emergency limits are applicable for short durations as required to permit operating steps, including manual system adjustments, necessary to maintain control and restore the system to a secure operating state.
4. Steady state voltage stability is required with the system modeled at a minimum of 105% of the System Operating Limit for system normal conditions (Category A) and for single contingencies (Category B). For multiple contingencies (Category C), steady state voltage stability is required with the system modeled at a minimum of 102.5% of the System Operating Limit.
5. System studies may consider Category C.4 and C.5 events to be Category D events where multiple circuit towers or adjacent circuits are used over short distances (e.g., station entrance, river crossings).
6. Non-Firm Loads and Non-Firm Transfers shall not reduce the reliability of the system. Interruption of Non-Firm Loads and curtailment of Non-Firm Transfers is permitted for all contingencies.
7. System Limits or Allowed Impacts for Transient Voltage Dip, Minimum Transient Frequency, Post Contingency Steady State Voltage, and Voltage Stability Margin are proxies for avoiding system instability, loss of load, and cascading. These proxies have been established by WECC and, with respect to performance of the BC Hydro system, may include margins. System studies may determine that different standards

could be applied for internal impacts and apply these standards¹. If these standards are less stringent, other systems are permitted to have the same impact on that part of the system for the same category of disturbance. If these standards are more stringent, these standards may not be imposed on other systems. The WECC proxies apply with respect to impacts on other systems unless modified by that other system.

8. In determining System Operating Limits for Planned System Conditions, response to a Category B single contingency may include any of the following:
 - a) System reconfiguration through manual or automatic control or protection actions to meet the System Limits and Allowed Impacts and to return the system to within continuous ratings is permitted, except shedding of firm load and curtailment of firm transfers is not permitted.
 - b) Consequential loss of load or transfers: Planned/controlled interruption, consequential loss of electric supply to radial customers or some local network customers, connected to or supplied by the faulted element or by the affected area, or consequential loss of firm transfers is permitted provided the impacts are contained to this part of the system.
 - c) All control actions in response to the contingency and to ensure reliable system operation shall be practical to complete within 20 minutes for stability limits and 30 minutes for thermal limits. Control actions in response to contingencies shall also consider whether a faster response is necessary to address facility specific limits.
9. In determining System Operating Limits for Planned System Conditions, response to a Category C contingency, and Unplanned System Conditions, response to a Category B or Category C contingency, may include the following:
 - a) System reconfiguration through manual or automatic control or protection actions to meet the System Limits and Allowed Impacts and to return the system to within continuous ratings is permitted, including shedding of firm load and curtailment of firm transfers. For unplanned load levels, shedding/curtailment of firm obligations shall not exceed an amount equal to unplanned firm load and unplanned firm transfers.
 - b) Generation shedding is permitted.
 - c) All control actions in response to the contingency and to ensure reliable system operation for the new SOL shall be practical to complete within 20 minutes for stability limits and 30 minutes for thermal limits. Control actions in response to contingencies shall also consider whether a faster response is necessary to address facility specific limits.
10. A number of extreme contingencies that are listed under Category D and judged to be critical shall be selected for evaluation. It is not expected that all possible facility outages under each listed contingency of Category D will be evaluated. Category D events are addressed in the planning horizon in anticipation of extreme unforeseen operating conditions.
11. ESA (Electricity Supply Agreement) customers are a special class of customers for which system limits and allowed impacts are determined on a case by case basis according to customer requirements and connection point, as addressed in BC Hydro

Table 1 - Contingency/Performance Requirements

Pre-Existing Conditions	Category	Contingencies	System Limits or Allowed Impacts									
			Elements Forced Out of Service	Facility Rating Limits	Transient Voltage Dip	Minimum Transient Frequency	Post Contingency Steady State Voltage	Voltage Stability Margin	System Stable	Loss of Firm Load or Curtailed Firm Transfers	Cascading Outages	
Planned System Conditions	A - No Contingencies	No Contingencies - All Facilities in Service , Planned Outages	None	Continuous				Normal Operating Range	105% of the SOL	Yes	No	No
Planned System Conditions	B – Event resulting in the loss of a single element.	Single Line Ground (SLG), 3-Phase (3Ø) Fault with Normal Clearing, or loss of element without a fault (including failure to operate and inadvertent operation of related protection): 1. Generator 2. Transmission Circuit 3. Transformer 4. Shunt device (e.g. reactor, capacitor, SVC, synchronous condenser) Single Pole Block, Normal Clearing : 5. Single Pole (dc) Line	Single	Before Operator Action – Emergency Limits After Operator Action – Continuous Limits	Not to exceed 25% at load buses or 30% at non-load buses. Not to exceed 20% for more than 20 cycles at load buses.	Not below 59.6 Hz for 6 cycles or more at a load bus.	Non-ESA busses: Deviation not to exceed 5% at any bus. (note 1) ESA customer POD: per ESA.	Non-ESA busses: 105% of the SOL ESA customers : 100% of forecast load.	Yes	No loss of firm load or firm transfers, except consequential loss. Generator tripping permitted only for special circumstances and WECC’s MORC must be met.	No	
Planned System Conditions	C – Event(s) resulting in the loss of two or more (multiple) elements.	SLG Fault, with Normal Clearing : 1. Bus Section 2. Breaker (failure or internal fault) – internal system impacts	Multiple	Before Operator Action – Emergency After Operator Action – Continuous	Not to exceed 30% at any bus. Not to exceed 20% for more than 40 cycles at load buses.	Not below 59.0 Hz for 6 cycles or more at a load bus. Internal exception for conditions resulting in islanding: Minimum 57.9 Hz	Non-ESA busses: Deviation not to exceed 10% at any bus. ESA customer POD: not considered.	Non-ESA busses: 102.5% of the SOL ESA customer POD: not considered.	Yes	Planned/Controlled	No	
		SLG or 3Ø Fault, with Normal Clearing, Manual System Adjustments, followed by another SLG or 3Ø Fault, with Normal Clearing: 3. Category B (B1, B2, B3, or B4) contingency, manual system adjustments, followed by another Category B (B1, B2, B3, or B4) contingency										
		Bipolar Block, with Normal Clearing : 4. Bipolar (dc) Line										
		Fault (non 3Ø), with Normal Clearing, excluding short distance situations: 5. Any two circuits of a multiple circuit towerline, or Two adjacent circuits										
		SLG Fault, with stuck breaker or primary protection system failure: 6. Generator 7. Transformer 8. Transmission Circuit 9. Bus Section - internal system impacts										
Failure to operate or inadvertent operation of protection: 10. Protection related to any Category C event.	Multiple					Yes	Controlled	No				
		Other common mode failures and external impacts 11. Common mode loss of two generating units connected to the same switchyard not addressed above,										

