AESO System Operating Limit Methodology for the Operations Horizon

Version 5.0

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Foreword

The AESO is responsible for reliability coordination functions within the province of Alberta, which includes the Interconnected Electric System in Alberta (AIES). Alberta Reliability Standards (ARS) FAC-011-AB requires that the ISO must have a documented methodology for use in developing System Operating Limits (SOLs) within its area. This document provides the details of the AESO's SOL methodology for the Operations Horizon[1]. The AESO performs operations planning analysis and assessments over a 4 year horizon, starting at Real-time (now) up to the end of year 4, including the following sub-horizons: Seasonal, Outage Planning, Next-day, Same-day, and Real-time sub-horizons. The AESO SOL methodology for the Operations Horizon is applicable across all the sub-horizons within the Operations Horizon.

[1] The Operations Horizon, Seasonal sub-horizon and Outage Planning sub-horizon have different definitions in Alberta from their definitions in other jurisdictions. See Appendix I for details.

Contents

Definitions and Descriptions of Terms

The capitalized terms used in this SOL methodology generally have meanings set forth in the Alberta Electric System Operator (AESO) Consolidated Authoritative Document Glossary (January 1, 2019) (CADG) and in Appendix I of this document.

A. Purpose

This document is the AESO System Operating Limit (SOL) Methodology for the Operations Horizon. The document establishes the methodology to be used in Alberta for determining SOLs and Interconnection Reliability Operating Limits (IROL) for use in the Operations Horizon pursuant to Alberta Reliability Standards (ARS) FAC-011-AB and ARS FAC-014-AB. In the event of any discrepancy between this SOL methodology and applicable ARS, the ARS governs.

The use of this SOL methodology in the Operations Horizon will ensure the reliable operation of the Bulk Electric System (BES) in Alberta. It is not the intent of this SOL methodology to limit in any way the nature and range of studies and analyses performed to ensure acceptable system performance throughout the Operations Horizon.

One task of the AESO is to assess and evaluate projected system conditions as real time approaches with the objective of ensuring acceptable system performance in real time. For example, acceptable system performance can be achieved by establishing operating limits such as SOLs and IROLs, and by developing plans, processes, and procedures to prevent and mitigate SOL/IROL exceedance.

B. Applicability

This SOL methodology is applicable to Alberta for developing SOLs and IROLs to be used in the Operations Horizon where the studies commence on the effective date of this methodology.

C. Effective Date

The effective date for this revision of this AESO SOL methodology is October 15, 2019.

D. Minimum Acceptable System Performance

SOLs in Alberta are established such that operating within these boundaries provides BES acceptable pre- and post-contingency performance consistent with this documented methodology [FAC-011-AB-2 R2].

In Alberta, the BES is expected to be operated such that acceptable system performance is achieved in both the pre- and post-contingency states. The AESO may rely on real-time tools or rely on prior studies provided that the prior studies demonstrate acceptable performance for the current or expected system conditions.

It is not the intent of this SOL methodology to require more stringent BES performance than that stipulated in the prevailing AESO transmission planning (TPL) Reliability Standards and applicable WECC TPL Criteria and Practices, or to expect the BES to perform in any way better than it was designed.

SOLs (including SOLs that qualify as IROLs) are to be established to ensure acceptable BES performance throughout the Operations Horizon (including the Real-time sub-horizon). If any of the acceptable pre- or post-contingency system performance criteria stipulated in this methodology is not met, an SOL is exceeded.

Acceptable Pre-Contingency Performance: Acceptable pre-contingency system performance is characterized as follows [Ref: FAC-011-AB-2 R2.1]:

1. The BES must demonstrate transient, dynamic and voltage stability.
2. All Facilities must be within their applicable Facility Ratings. Refer to illustration in Appendix II.
3. All Facilities must be within their normal System Voltage Limits.
4. All Facilities must be within their stability limits.
5. In the determination of System Operating Limits, the Bulk Electric System condition used must reflect current or expected system conditions and must reflect changes to system topology such as facility outages;

Acceptable Post-Contingency Performance for Single Contingencies: Acceptable post-contingency system performance is characterized as follows [Ref: FAC-011-AB-2 R2.2]:

1. The BES must demonstrate transient, dynamic and voltage stability.
2. All Facilities must be within their applicable Emergency Ratings or Temporary Emergency Ratings, as provided by the appropriate facility owner. Refer to illustration in Appendix II.
3. All Facilities must be within their emergency System Voltage Limits.
4. All Facilities must be within their stability limits.
5. Cascading or uncontrolled separation must not occur.

Acceptable System Response for Single Contingencies: In determining the system's response to a single contingency, the following actions are acceptable [Ref: FAC-011-AB-2 R2.3]:

1. Planned or controlled interruption of electric supply to radial customers or some local network customers connected to or supplied by the Faulted Facility or by the affected area [Ref: FAC-011-AB-2 R2.3.1].

2. Interruption of other network customers [Ref: FAC-011-AB-2 R2.3.2]:
   i. Only if the system has already been adjusted, or is being adjusted, following at least one prior outage, or
   ii. If the real-time operating conditions are more adverse than anticipated in the corresponding studies.

3. System reconfiguration through manual or automatic control or protection actions [Ref: FAC-011-AB-2 R2.3.3]. Adequate time must be allowed for manual reconfiguration actions.

Acceptable Post-Contingency Performance for Credible Multiple Contingencies: Acceptable post-contingency system performance is characterized as follows:

1. In the Seasonal sub-horizon, acceptable system performance is characterized by:

   i. The BES is to demonstrate transient, dynamic and voltage stability.
   ii. All Facilities are to be within their applicable Emergency Ratings, or Temporary Emergency Ratings, as provided by the appropriate facility owner (unless this level of BES performance is more stringent than Reliability Standard requirements applicable to the Planning Horizon).

iii. All Facilities are to be within their emergency System Voltage Limits (unless this level of BES performance is more stringent than Reliability Standard requirements applicable to the Planning Horizon).
iv. All Facilities are to be within their stability limits.
v. Cascading or uncontrolled separation is not to occur.

2. Due to equipment outages, topology changes and other conditions for which the system was not designed, it may not always be possible to meet the same level of acceptable system performance in shorter term sub-horizons (i.e., Outage Planning, Next-day, Same-day, Real-time) as in the Seasonal sub-horizon. When studies indicate that prevailing impacting outages do not allow for the same level of system performance as described in item **Acceptable Post-Contingency Performance for Credible Multiple Contingencies** section 1 (ii) and (iii) above, the AESO is to establish adequate plans, processes, and procedures to contain and mitigate Credible Multiple Contingencies impacts.

The BES is to demonstrate acceptable pre- and post-contingency system performance throughout the Operations Horizon for the following Contingencies as a minimum [FAC-011-AB-2 R3.2]:

- Single Contingencies internal to Alberta
- Credible Multiple Contingencies internal to Alberta
- any Single Contingencies and Credible Multiple Contingencies external to Alberta that is known to or may impact Alberta

Conditions that expose the system to unacceptable BES performance cannot be allowed to continue indefinitely. As such, when the system is experiencing unacceptable pre- or post-contingency performance, the system must be adjusted as soon as practical to prepare for the next contingency.

When system studies conducted throughout the Operations Horizon (including Real-time Assessments) indicate that any of the acceptable post-contingency system performance criteria are not met, the AESO is to take pre-contingency actions to achieve acceptable performance. To prepare for the next Contingency, system adjustments may be made, including changes to generation, uses of the Transmission System, and the Transmission System topology. [Ref: FAC-011-AB-2 R2.4]

It should be noted that there are no firm transfers via interties to Alberta.

In addition to the System Voltage Limits described above, it is also acceptable in Alberta to include a “desired range” to flag potential reliability issues when system voltage is approaching the low/high normal System Voltage Limits.

E. Process for Selecting Applicable Contingencies

This section describes the AESO process for selecting applicable Contingencies for use in the Operations Horizon, and determining which of the Multiple Contingencies developed by the AESO transmission planning department in accordance with FAC-014-AB1-2 R6 are applicable for use in the Operations Horizon, given the actual or expected system conditions. The process addresses the need to modify SOLs, the subset of SOLs that qualify as IROLs, and the associated list of Multiple Contingencies. [FAC-011-AB-2 R3.2 and R3.3].

Applicable Single Contingencies for use in the Operations Horizon

The system is to demonstrate acceptable BES performance throughout the Operations Horizon following the Single Contingencies identified below. [Ref: FAC-011-AB-2 R2.2]

- Single-line-to-ground (SLG) or 3-phase Fault (whichever is more severe), with Normal Clearing, on any Faulted generator, line, transformer, or shunt device.
- Loss of any generator, line, transformer, or shunt device without a Fault.
- Single pole block, with Normal Clearing, in a monopolar or bipolar high voltage direct current system.

Applicable Multiple Contingencies for Use in the Seasonal Sub-Horizon

The AESO is responsible for identifying Multiple Contingencies (MCs) within its area. The inability to prevent or mitigate adverse impacts of a Multiple Contingency is not considered an acceptable reason for changing credibility of the Multiple Contingencies at any time in the Operations Horizon.

This SOL methodology does not require that all Multiple Contingencies that were studied in the Planning Horizon be studied in all sub-horizons within the Operations Horizon. Some of these MCs may not be deemed credible for use in the Seasonal sub-horizon (which is defined as 12 months up to 4 years) due to differences in system topology and/or load or generation levels.

In determining the credibility of Multiple Contingencies in its area, the AESO operations planning team will apply engineering judgment and system operating experience, consult with AESO transmission planning department, transmission operators, transmission owners, generator owners, and utilize the following references:

- List of MCs studied by the transmission planning department in the Planning Horizon.
- Category C of 'Appendix 1 of the Transmission System Standards – Normal and Emergency Conditions' in TPL-003-AB-0.

The AESO operations planning must assess whether any of the MCs, that have been determined by the AESO system planning team to result in stability limits (provided per FAC-014-AB1-2 R6) and provided to AESO operations planning team, are Credible and thus applicable for use in the Seasonal sub-horizon. The AESO must modify applicable SOLs (including SOLs that qualify as IROLs) based on the revised list of Credible MCs.

Applicable Multiple Contingencies for Use in the Outage Planning, Next-day, Same-day and Real-time Sub-horizons

While this methodology introduces levels of flexibility that allow the AESO to revise the list of Credible MCs, the AESO recognizes that the impact of an MC may go beyond Alberta. Therefore, as much as practicable, when the AESO revises the list of Credible MCs and if the AESO determines there is a potential impact on a neighboring Balancing Authority or Reliability Coordinator (RC), the AESO will allow time for adequate coordination of studies with neighboring Balancing Authorities or RCs that may be necessary to verify acceptable BES performance and establish or revise SOLs/IROLs.

The AESO must determine which MCs from the Seasonal sub-horizon shall remain Credible and applicable for use in the Outage Planning, Next-day, Same-day, and Real-time sub-horizons, until the rationale for the MC credibility is changed and documented.

If the AESO expects that an MC may become Credible in the shorter sub-horizons due to, for example, an upcoming storm season, the AESO will communicate such information in a timely manner. As much as practicable, the AESO will develop pre-established outage limits (SOLs/IROLs) that can be applied should that particular MC become Credible.

If the AESO determines that the list of Credible Multiple Contingencies must be changed, the AESO is to communicate the changes to affected entities including the ones listed in FAC-014-AB1-2 R5.

Other Multiple Contingency Considerations

Items below apply to those Multiple Contingencies that have already been deemed Credible by the AESO. While these requirements are applicable for the entirety of the Operations Horizon, they are not intended to require that these analyses be performed in any specific sub-horizon.

When performing studies, it is acceptable to analyze only those Credible Contingencies that would produce the more severe system results or impacts. The selection of these Contingencies is based on prior or current studies. The rationale for the Contingencies selected is to be available as supporting evidence.

Where common tower circuits (i.e., any two adjacent BES circuits on a single tower) are deemed Credible Multiple Contingencies, the analysis is to include simultaneous loss of the two circuits.

Where two Adjacent Transmission Circuits that are both greater than or equal to 240 kV share a common right-of-way for a total of 5 kilometers or more and are deemed Credible Multiple Contingencies (excluding – but not limited to – substation entrances, pinch points, and river crossings), the analysis is to include simultaneous loss of the two adjacent circuits.

Where bipolar DC line Contingencies are deemed Credible, simultaneous permanent loss of both poles of a direct current bipolar Facility is to be analyzed.

F. Determining SOLs

AESO is expected to assess projected system conditions as necessary as real time approaches in order to establish SOLs (including SOLs that qualify as IROLs), plans, processes, and procedures to meet pre- and post- contingency acceptable system performance in real-time operations.

General

AESO is to establish seasonal SOLs (including SOLs that qualify as IROLs) and develop plans, processes, and procedures that support operation within the established SOLs. All post-contingency mitigation plans should reflect the time necessary to take mitigating actions, including control actions, to return the system to a secure state.

AESO is to establish SOLs, including IROLs, consistent with this SOL methodology [FAC-014-AB1-2 R1]. The AESO will ensure that:

- Facilities in the AESO energy management system (EMS) model contain Normal Ratings, Emergency Ratings, and Temporary Emergency Ratings as provided by generation facility owners and transmission facility owners.
- The AESO EMS model contains System Voltage Limits.
- Stability limits have been established consistent with this SOL methodology, and the AESO system operators and engineers have awareness of these limits.
- When performing operational planning analyses and Real-time Assessments, the AESO is to follow this SOL methodology to determine when SOLs qualify as IROLs.
- The AESO is to review SOLs that have been determined to qualify as IROLs and make a final

determination whether an identified SOL should be declared an actual IROL.

- The AESO's EMS real-time contingency analysis (RTCA) and real-time voltage stability analysis (RTVSA) applications provide indication of whether acceptable thermal and voltage system performance would be achieved in the post-contingency state for actual system conditions.

Unless more restrictive limitations are present, SOLs are to be equal to the applicable Facility Ratings, System Voltage Limits, voltage stability limits, and transient stability limits. The most limiting of these will determine the SOL used in real-time operations.

If an SOL is exceeded in real time, the AESO will bring the system back within limits in 30 minutes or less as defined by the facility owner.

The AESO is to use anticipated Transmission System configuration, generation Dispatch, and load levels when establishing SOLs (including SOLs that qualify as IROLs) [Ref: FAC-011-AB-2 R3.6]. At a minimum, AESO is to establish SOLs based on studies or analyses of reasonably expected maximum stressed BES conditions for the sub-horizon under study.

The AESO will determine when it is appropriate to use SOLs established in previous studies, or whether expected system conditions warrant performing new studies to:

- ensure acceptable BES performance;
- establish or update SOLs (including SOLs that qualify as IROLs);
- develop plans, processes, and procedures necessary to ensure acceptable BES performance

For any transient or voltage stability SOL that – while not qualifying as an IROL – has been identified by the AESO as impacting more than one Intertie, the AESO and the RCs/Interconnected Transmission Operator(s) are to develop and document agreed upon coordinated plans, processes, and procedures to mitigate SOL exceedances within a predefined time duration. If the AESO and RCs/Interconnected Transmission Operator(s) cannot agree on pre-defined time duration, then a default 30-minute time duration is to be used.

Transient Stability Limits

The AESO is to establish SOLs to prevent unit/intra-area instability, inter-area instability, or tripping of critical BES Facilities due to out-of-step conditions with the exception of controlled separation schemes from Western Interconnection on the interties between Alberta and Montana (Path 83), and Alberta and BC (Path 1).

AESO is to establish SOLs to prevent insufficiently damped system response. These SOLs are to be identified based on undamped and sustained system oscillations. Oscillations that do not show positive damping within a 30-second[2] time frame are deemed undamped.

To facilitate monitoring, AESO is to communicate established transient stability limited SOLs as pre-contingent MW flow limits on Transmission Paths/Interfaces consisting of single or multiple transmission elements.

AESO is to communicate transient stability limits and associated documentation per FAC-014-AB1-2.

System Voltage Limits

The AESO is to establish acceptable pre- and post-contingency voltage limits[3] for its area and

[2] This stipulation is not intended to require that transient stability simulations be run out to 30 seconds all the time in order to ensure the system is stable and positively damped. Shorter runs are permissible.
[3] The AESO has flexibility to modify these limits as necessary based on actual or expected conditions.

communicate these per FAC-014-AB1-2. Operating outside established voltage limits will constitute SOL exceedance. This requirement is applicable to all BES Facilities and any sub-100 kV Facilities that the AESO deems critical for BES reliability.

Post Transient Voltage Stability Limits

The process for establishing voltage stability limited SOLs in Alberta focuses on two aspects:

- Identifying the voltage stability limit (i.e., the maximum pre- contingency power transfer or load level for which a post-contingency solution can be reached) and applying minimum margins to determine the corresponding voltage stability-limited SOL.
- Ensuring that voltage stability is demonstrated for each established Transmission Path/Interface or area load SOL.

1. Identify the voltage stability limit

The AESO is to stress Transmission Paths/Interfaces or load areas to the reasonably expected maximum transfer conditions or area load levels to determine whether voltage stability limits exist[4]. If this voltage stability limit does not qualify as an IROL, the following minimum margins are to be applied to establish corresponding SOL expressed in megawatts:

- The Transmission Path/Interface SOL will be equal to or less than the maximum pre-contingency power transfer for which a post-contingency solution can be reached less a minimum 5 percent margin for Single Contingencies or a minimum 2.5 percent margin for Multiple Contingencies.
- The area load level SOL will be equal to or less than the maximum pre-contingency area load for which a post-contingency solution can be reached, less a minimum of 5 percent margin for Single Contingencies or a minimum 2.5 percent margin for Multiple Contingencies.

2. Demonstrate voltage stability

The AESO is to perform studies to ensure that SOLs for Transmission Paths/Interfaces or load areas demonstrate voltage stability with margins as described below:

- For Transmission Paths/Interfaces, voltage stability is required with the pre- contingency path/interface flow modeled at a minimum of 105 percent of the path/interface SOL (pre-contingency system conditions) for Single Contingencies. For Multiple Contingencies, post-transient voltage stability is required with the pre-contingency transfer path/interface flow modeled at a minimum of 102.5 percent of the path/interface SOL.
- For load areas, voltage stability is required for the area system modeled at a minimum of 105 percent of the reference load level SOL (pre-contingency system conditions) for Single Contingencies. For Multiple Contingencies, post-transient voltage stability is required with the area load modeled at a minimum of 102.5 percent of the reference load level.

The AESO is to communicate any identified voltage stability limits and associated documentation, or any reactive margin requirements per FAC-014-AB1-2.

Thermal Limits

System Operating Limits must not exceed associated Facility Ratings [Ref: FAC-011-AB-2 R1.2].

Pursuant to FAC-008-AB-3, the Legal Owner of the Facility is required to establish Facility Ratings

[4] The AESO may select to use analysis methods such as the P-V or V-Q analysis.

consistent with its Facility Ratings methodology and documentation.

Facility Ratings (including Normal Rating and Emergency Rating), and Temporary Emergency Ratings used in the Operations Horizon are provided to the AESO by the Legal Owner of the Facility in Alberta. When the Legal Owners provide Emergency Ratings and Temporary Emergency Ratings to the AESO, these ratings must be accompanied by corresponding time durations.

SOL versus TTC

SOLs are the Facility Ratings, System Voltage Limits, transient stability limits, and voltage stability limits that are used in the Operations Horizon – any of which can be the most restrictive limit at any point in time, pre- or post-Contingency.

As per CADG, Total Transfer Capability (TTC) means the amount of Real Power the ISO determines can be reliably transferred over the interconnected transmission network under specified system conditions. While it is expected that TTCs respect pre- and post-Contingency reliability limitations associated with Facility Ratings, System Voltage Limits, and stability limits, the determination and communication of TTC is outside the scope of AESO's SOL Methodology.

Exceeding a TTC value does not constitute an SOL exceedance. However, if AESO so chooses, the AESO may utilize TTC (and transfer capability concepts) as part of an operating plan.

G. Determining SOLs that Qualify as IROLs

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

In Alberta, SOLs that qualify as IROLs will be established consistent with the following.

General

The AESO is to identify the subset of SOLs that qualify as IROLs consistent with this SOL methodology. When the AESO identifies an SOL that qualifies as an IROL, the AESO is to communicate the results of its analysis as per FAC-014-AB1-2.

SOL qualify as IROL 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 1,000 MW.

For each identified IROL, the AESO, in conjunction with the impacted RC/Interconnected Transmission Operator, are to develop plans, processes, and procedures that identify actions that are to be taken (up to and including load shedding) to prevent violating the IROL and to mitigate IROL exceedance such that the IROL exceedance is relieved within the IROL T_v.

Impact Containment and IROL Load Impact

When studies in the Operations 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 (a) whether impact containment is demonstrated and (b) the level of load impact. The AESO is to consider impact containment to be adequately demonstrated when all the following are accomplished:

- Impacted area is predefined by studies.
- Cascading is restrained from sequentially spreading beyond the impacted area.
- Coordinated plans, processes, and procedures to ensure adequate containment within the impacted area have been developed and documented.

The AESO is to 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 Remedial Action Scheme (RAS) actions. The 1000 MW threshold is intended to restrict the applicability of IROLs to large-area impacts rather than small-load areas. This requirement is not intended to prevent the AESO from declaring IROLs for unanticipated operating conditions or to preserve the integrity of the Interconnection.

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.

The AESO is to 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.[5] It is recognized that localized issue, such as tripping a generator unit due to out-of-step condition, does not warrant establishment of an IROL.

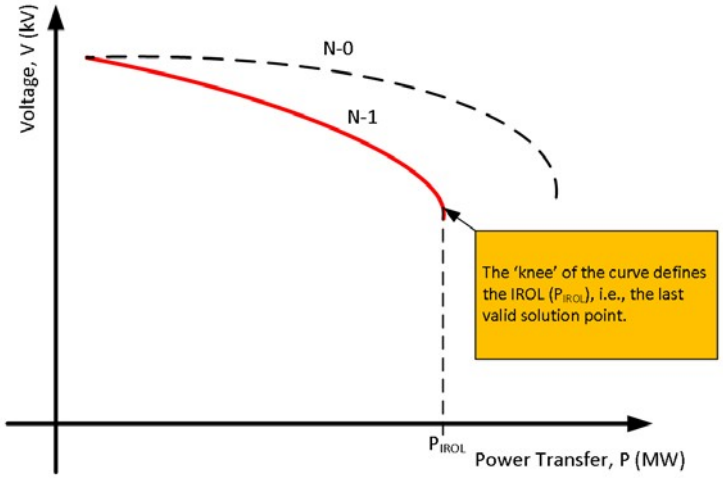
Where transient simulations show loss of synchronism due to disturbances external to Alberta, the AESO is to coordinate with the impacted RC to make a determination as to whether an IROL exists.

Determining 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 are to be addressed in the related IROL plans, processes, and procedures. See the illustration below.

[5] When a group of machines in one area separate from a group of machines in another area, their respective relative rotor angles and frequencies tend to become increasingly out of phase as the simulation progresses. Machines in one area will tend to speed up while machines in the other area tend to slow down. Line flow plots show large magnitude high frequency oscillations. Large magnitude oscillations will also be apparent in the bus voltage magnitude plots. Transmission lines may trip due to protection relays triggering on abnormal values of monitored parameters.

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



Determining Thermally Limited IROLs

Cascading[6] 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).

The AESO is to 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[7]. The process outlined below is to be followed:

a. Run Contingency analysis and identify all Credible Contingencies that result in post- contingency loading in excess of the lower of:
    i. Facility trip settings.
    ii. 125 percent of the highest Facility 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 the simulation.
c. Repeat step (b) for any newly overloaded Facility(ies) in excess of (a) (i) or (ii) above. Continue with this process until the spreading stops within a predefined area or the solution diverges.
d. Evaluate results to identify thermally limited SOLs that qualify as IROLs.

H. IROL T_V in Alberta

The IROL Tv in Alberta is to be less than or equal to 30 minutes [FAC-011-AB-2 R3.7]. The default IROL Tv value is 30 minutes. However, shorter duration IROL Tv values may be established based on relay/protection settings and other considerations.

[6] Refer to CADG for the definition of cascading.
[7] This condition also indicates inadequate impact containment.

I. Current List of IROLs in Alberta

The AESO is to maintain a current list of predefined IROLs in its area. Currently AESO does not have any predefined IROLs in its area.

J. System Study Models

Types of Study Models

The study model used for establishing SOLs must include the entire ISO area and appropriate representation of WECC. [Ref: FAC-011-AB-2 R3.1].

The AESO uses a network model in EMS for real-time operations. AESO operations planning team and operations coordination team use PSS/E or equivalent tool for system studies (offline studies), and for determining the subset of SOLs that qualify as IROLs. The AESO EMS utilizes a network model of the BES, selected facilities (lower than 100 kV) that may adversely impact BES reliability, and an appropriate representation of the external WECC system by a reduced model. Loads served over radial lines are typically lumped at the delivery bus. AESO EMS network model consists of transmission lines, transformers, circuit breakers and switches, reactive devices, generation units, step-up transformers, loads, HVDC links, and other electrical components relevant to the security analysis of the Transmission System in Alberta.

The AESO uses the WECC operating base case for various studies. The Alberta-only study models are more commonly used to determine limits internal to Alberta. The Alberta-only study models rely on the same information that is being used to create the WECC operating base case, however, the Alberta-only models represent the AIES to a greater level of detail than the WECC operating base case, and the rest of the Western Interconnection is represented by an equivalent. For WECC path related studies, a WECC operating base case with a full Alberta model is normally used.

Remedial Action Schemes (RAS)

The AESO makes extensive use of Remedial Action Schemes (RAS) and controlled separation schemes. These RAS and schemes are designed to ensure that grid reliability is maintained following a contingency or system disturbance by administering automatic corrective actions. These corrective actions are intended to preserve system voltages and machine/system stability and to prevent unacceptable Facility loading and prolonged undervoltage conditions, etc.

These RAS and schemes are to be incorporated into the AESO EMS and applicable off-line studies where feasible [FAC-011-AB-2 R3.5].

K. SOL Methodology Document Distribution

The AESO will publish the SOL methodology on its website (www.aeso.ca) and provide printed or electronic copies of this methodology to interested parties upon request. Printed copies are considered to be uncontrolled.

The AESO shall issue this SOL methodology and any changes to this SOL methodology, prior to the changes taking effect, to the entities required by FAC-011-AB-2 R4.

L. Reviewing, Responding to and Archiving Technical Comments

Technical comments on this SOL methodology may be submitted via email to AESORequestedDocuments@aeso.ca.

M. AESO Communication of SOLs and IROLs

The AESO is to provide its SOLs and IROLs in the operating horizon to those entities listed below: [Ref: FAC-014-AB1-2 R5].

- each adjacent Reliability Coordinator;
- each Operator of a Transmission Facility within its area that has a Reliability-related need for those limits;
- each entity that has a Reliability-related need for those limits and provides a written request for delivery of those limits.

The AESO is to provide the following supporting information for each IROL: [Ref: FAC-014-AB1-2 R5.1]

- identification and status information of the associated System Element (or group of System Elements) that is (are) critical to the derivation of the IROL;
- the value of the IROL and its associated Tv ;
- the associated Contingency(ies); and
- the type of limitation represented by the IROL (e.g., voltage collapse, angular stability)

Appendix I: Descriptions

The capitalized terms used in this SOL methodology generally have meanings either defined below for the purpose of this document, or defined in the Consolidated Authoritative Document Glossary (January 1, 2019)[8].

Adjacent Transmission Circuits: Two transmission circuits with separation between their center lines less than 250 feet at the point of separation with no Bulk Electric System circuit between them. Transmission circuits that cross, but are otherwise separated by 250 feet or more between their centerlines, are not Adjacent Transmission Circuits.

Credible: Plausible (i.e., believable) with a sufficiently high degree of likelihood of occurrence.

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.).

IROL Tv: The maximum time that an Interconnection Reliability Operating Limit can be violated before the risk to the Interconnection becomes greater than acceptable. The Interconnection Reliability Operating Limit's Tv must be less than or equal to 30 minutes.

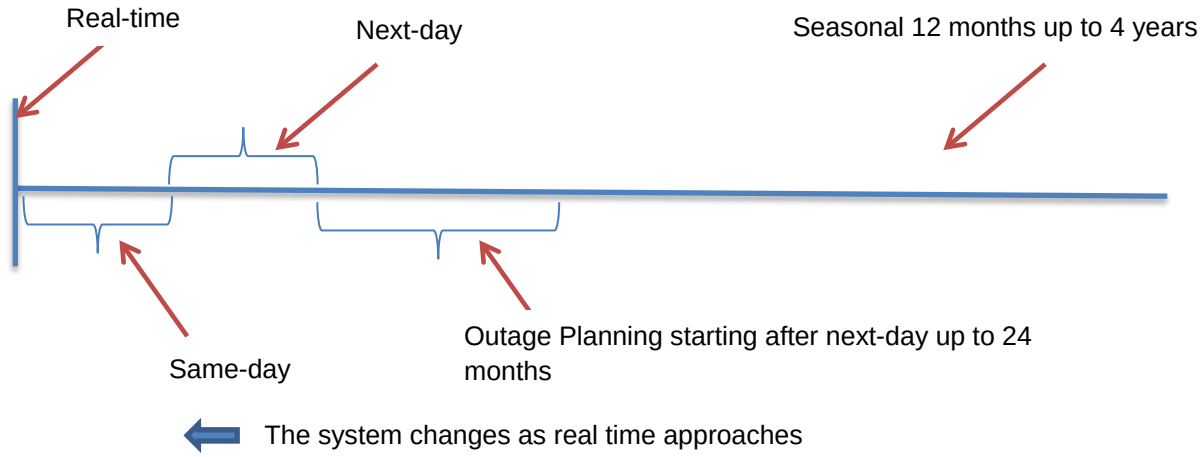
Multiple Contingency: The simultaneous failure of multiple system Facilities that are either physically or electrically linked in response to a single initiating event or common mode failure, e.g., common transmission tower failure, common right-of way or breaker failure.

Planning Horizon: The planning horizon covers the period starting 5 years in future from the current year to at least 20 years from the current year.

Operations Horizon: The operations horizon covers the next 4 year period, starting at Real-time (now) up to the end of year 4, including the following sub-horizons: **Seasonal, Outage Planning, Next-day, Same-day, and Real-time** sub-horizons. The typical Operations Horizon and sub-horizons can be illustrated as shown in Figure 2 below.

[8] https://www.aeso.ca/assets/Uploads/Consolidated-Authoritative-Document-Glossary-January-1-2019-.pdf

Figure 2: Operations Horizon Continuum



Real-time Assessment: An examination of existing and expected system conditions, conducted by collecting and reviewing immediately available data.

Single Contingency: the failure of any single element or Facility that impacts one or more Facilities as determined by prevailing zones of protection.

System Voltage Limit: the maximum and minimum steady-state voltage limits (both normal and emergency) that provide for acceptable system performance.

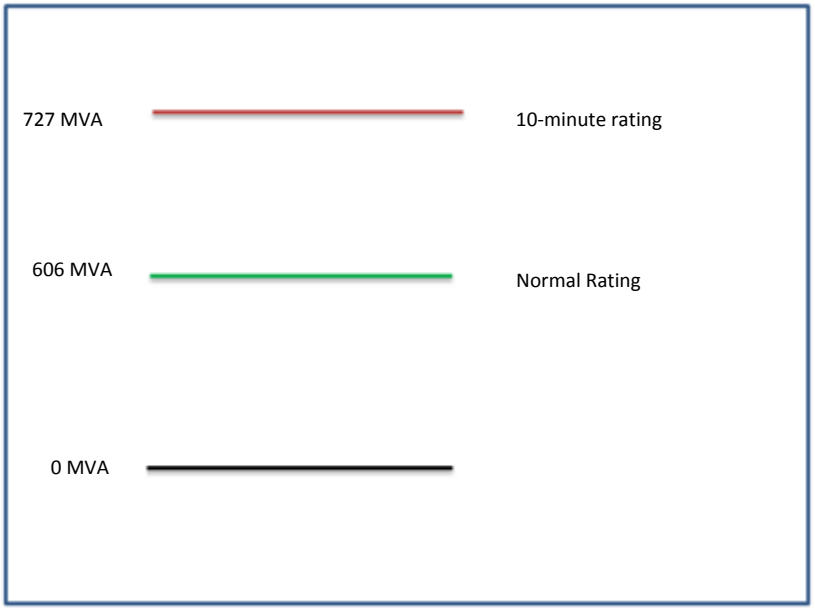
Temporary Emergency Rating: An Emergency Rating that is to be applied on a temporary basis as defined by the transmission facility owner.

Transmission Path/Interface: Any defined grouping of BES Facilities that are treated as a monitored power system element. Transmission paths may include for example, paths internal to Alberta and paths defined by the list of "major WECC transfer paths in the Bulk Electric System" listed on WECC website.

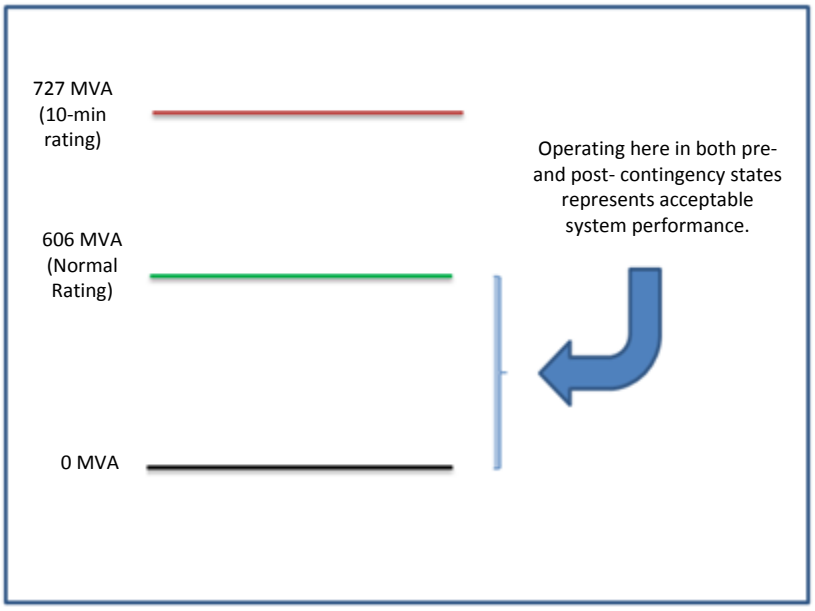
Appendix II: Acceptable Thermal Performance Examples

Transmission Line Facility Rating/Thermal Example

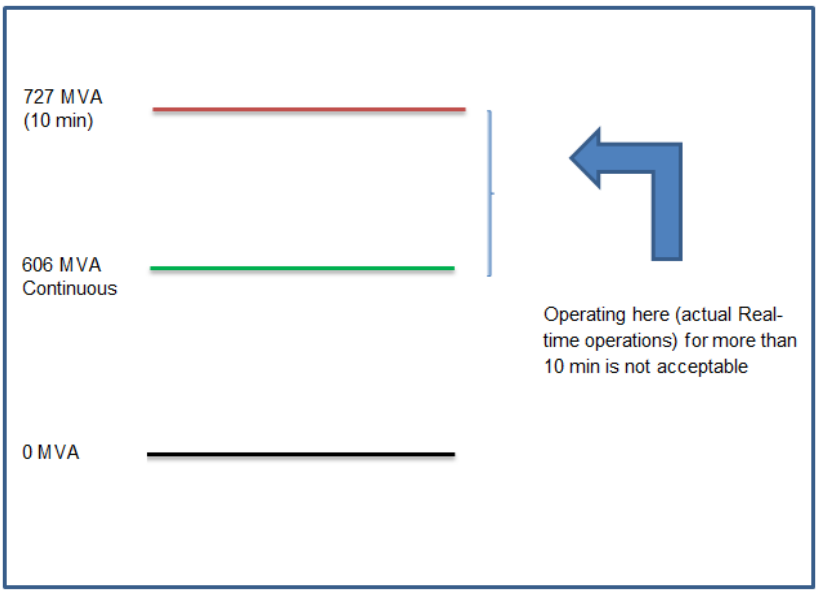
A sample Facility has the following set of Facility Ratings or thermal limits and corresponding time durations as provided by the Legal Owner of the Transmission Facility consistent with its Facility Rating methodology.



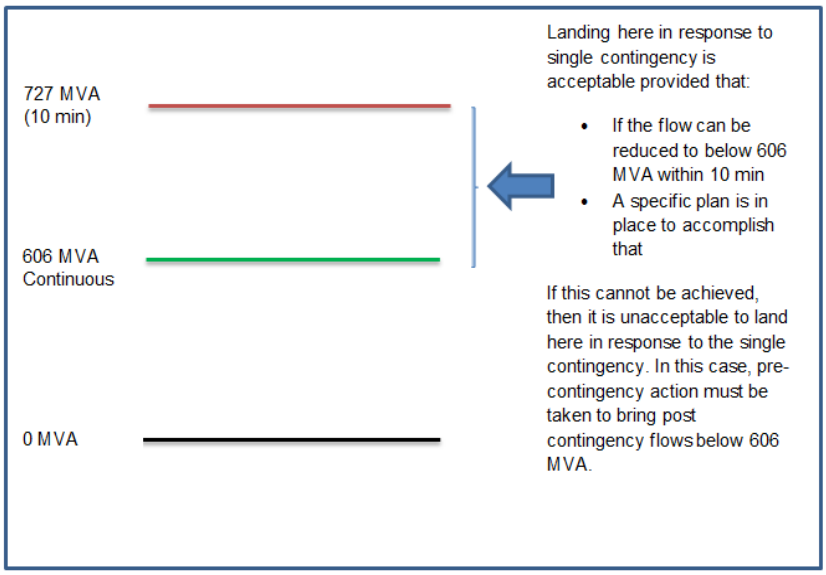
1. Pre- and Post- Contingency State



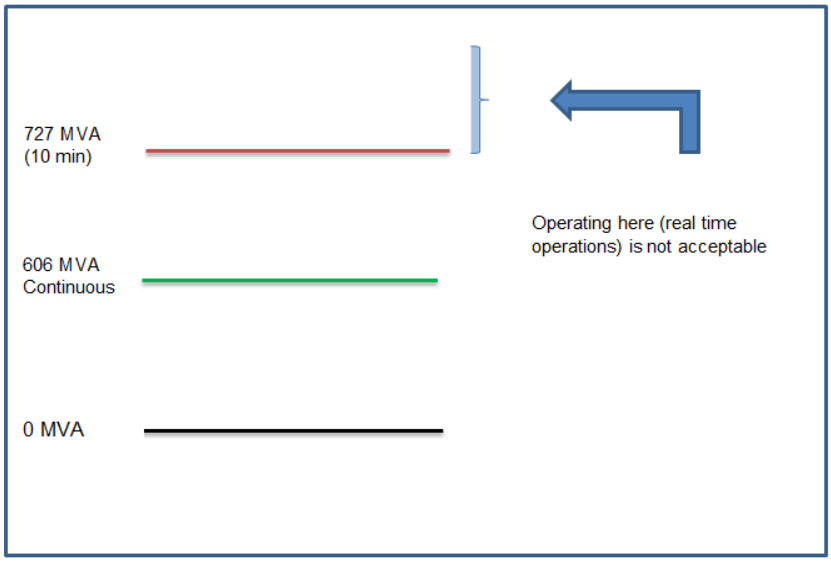
2. **Pre-Contingency State (i.e. actual Real-time operations)**



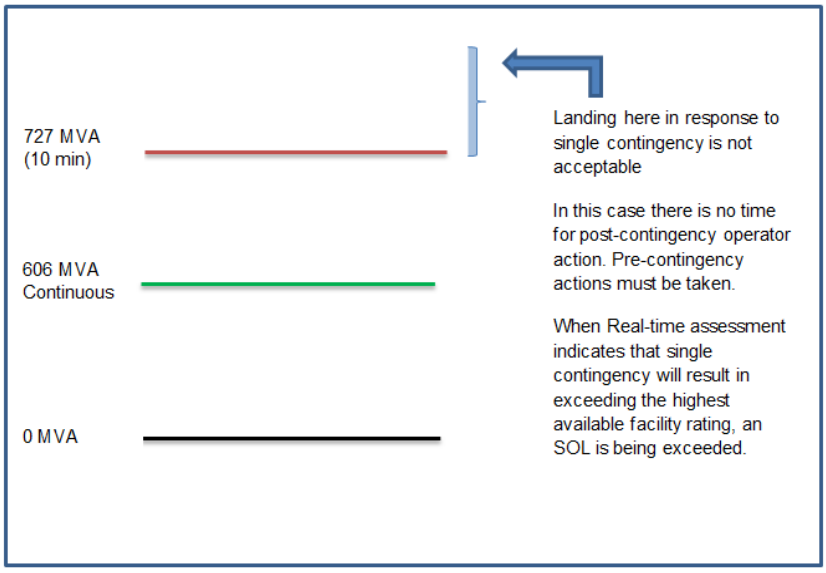
3. **Post-Contingency State (i.e. where the system is expected to land in response to a Single Contingency)**



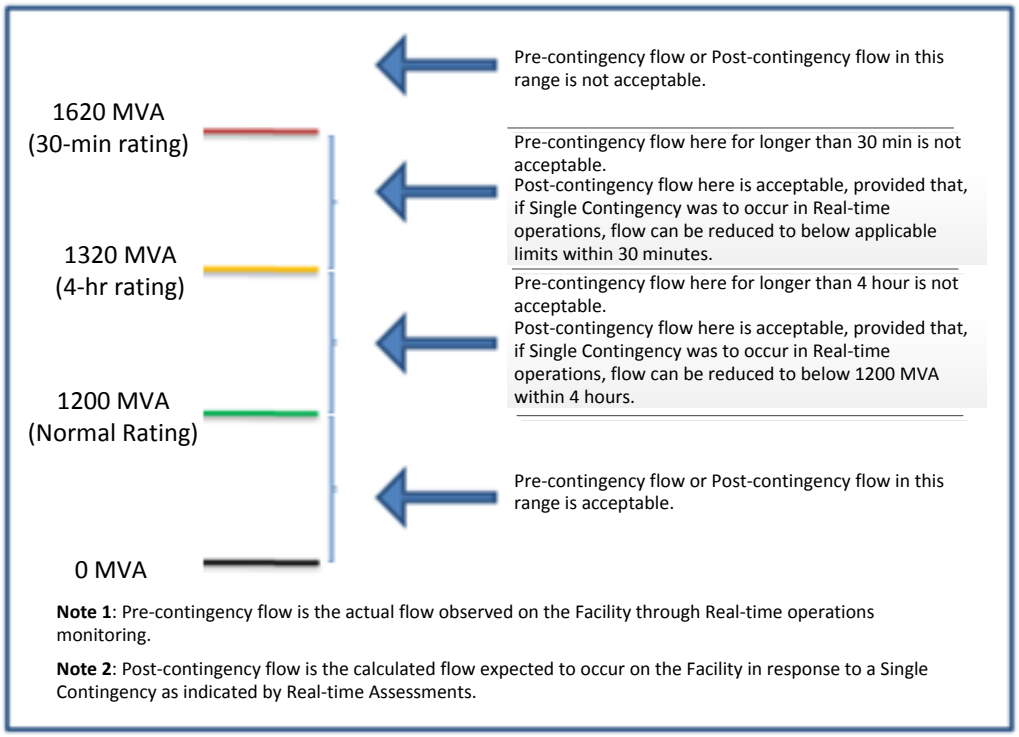
4. **Pre-Contingency State (i.e. actual Real-time operations)**



5. **Post-Contingency State (i.e. where the system is expected to land in response to a Single Contingency)**



SOL Performance Example for a Facility with Multiple Facility Ratings (e.g. Transformer):



Note 1: Pre-contingency flow is the actual flow observed on the Facility through Real-time operations monitoring.

Note 2: Post-contingency flow is the calculated flow expected to occur on the Facility in response to a Single Contingency as indicated by Real-time Assessments.

Revision History

Version	Effective Date	Drafted by	Change Tracking
1	October 1, 2012		AESO SOL Methodology for the Operations Horizon to be consistent with Peak RC Methodology "System Operating Limits Methodology for the Operations Horizon Version 6.1"
1.1	January 1, 2014		Updated to include IROLs
2	March 3, 2014	Noor Leghari	Effective March 3, 2014. AESO SOL Methodology for the Operations Horizon updated to be consistent with Peak RC Methodology "System Operating Limits Methodology for the Operations Horizon Revision 7.0"
2.1	January 5, 2015	Noor Leghari	Updated to be consistent with multiple contingency definitions
3.0	September 1, 2015	Noor Leghari	Revised to be consistent with ARS FAC-011 and FAC- 014
4.0	May 15, 2017	Noor Leghari	Added time to mitigate SOLs, and the TTC Vs SOL table
5.0	October 15, 2019	Ralph Liu	• Updated to reflect the latest ARS and RC transition • Aligned voltage limits terms with SOL methodology of other RCs • Added a section for SOL v.s. TTC. • Removed the list of SOL details that must be communicated • Updated glossary terms and Ops Horizon definitions • Updated the thermal example for transformer • Administrative changes