Connection Study Requirements

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1. Introduction

The study requirements provided in this document are intended to be used by customers who propose connecting a new facility or modifying an existing facility within the Alberta Interconnected Electric System ("AIES"). The AESO will review the customer's engineering study results to ensure completeness and accuracy of the studies and its alignment with the AESO long term transmission development plans before selecting a preferred connection alternative.

In case of any ambiguities or questions regarding the study requirements please contact the AESO engineer assigned to the project.

2. Process for Engineering Studies

2.1 Study Scope

The study scope is prepared by the AESO and reviewed by the customer (and transmission facility owner ("TFO"), if appropriate) prior to performing the connection studies. Also, the AESO may require additional criteria and standards to be applied depending on the complexity of the project, and constraints of the connection area.

The AESO will specify all criteria, standards, and guidelines as well as the AESO's Authoritative Documents (e.g., ISO rules, Alberta Reliability Standards) and practice (market or otherwise) which must be applied when performing connection studies.

The customer must understand the AESO's Authoritative Documents that can have potential impact on the customer facility connection or upgrades, and apply the considerations when performing connection studies.

2.2 Engineering Study Report

The customer shall use the Engineering Study Report template available on the AESO's website to report all study assumptions, methodology, results and analysis including any modifications made in the study scope. A registered Professional Engineer within the province of Alberta shall sign and stamp the complete engineering study report on behalf of the customer.

The engineering study report must be submitted to the AESO to be reviewed for the following:

- sufficient studies are performed to analyze the connection under known system conditions;
- connection aligned with the AESO's long term transmission development plans; and
- adequate amount of information is enclosed in the engineering study report.

The AESO will review and apply any necessary modifications to the studies to be completed and may additionally identify sensitivity studies based on the complexity of the project, connection area, system requirements and any study results obtained.

Communication between the customer and the AESO throughout the connection studies is advised particularly where the studies identify required mitigation.

3. Study Methodology

3.1 Power Flow Analysis

When performing power flow studies, the software used by the customer must be able to read and write the PSS/E format data. This is indicated in the study scope.

As provided by the applicable AESO documents, the Alberta transmission system must be capable of steady state operation within acceptable voltage ranges during normal and abnormal conditions. “Normal conditions” refer to a Category A condition which indicates that all transmission elements are in service. “Abnormal conditions” refer to either a Category B or Category C contingency. A Category B contingency indicates a single outage event while a Category C contingency indicates multiple outage events.

All contingencies must be modeled based on the actual bus configurations, breaker types and locations. The AESO will review and provide direction on how to properly model contingencies if the customer does not have access to such data.

Starting with all related facilities in-service[1] and following any contingency types described in the AESO Reliability Criteria[2], the system must demonstrate acceptable performance in the following ways:

- all facilities must be operating within their facility seasonal ratings with no thermal overloads;
- Alberta system operating limits must be respected including minimum acceptable voltages, voltage stability margins and angular stability; and
- system instability, cascading outage(s), and uncontrolled load or generation shedding must not occur.

The AESO may require additional planning and operations criteria, standards and guidelines to be applied depending on the study scope and results obtained from the connection studies.

The seasonal continuous thermal rating of any transmission element based on 100% static thermal rating shall not be exceeded under normal operating conditions with all transmission elements in-service. All contingencies that result in violation of seasonal continuous thermal rating of any transmission line should be indicated to and discussed with the AESO.

For information purposes, the customer should also provide a list of any transmission elements where the thermal loading exceeds 95% of the element’s normal rating under Category A and Category B conditions.

Acceptable post-contingency voltage deviations at the Point of Delivery (POD) are provided below:

- following a single contingency voltage deviation shall not exceed +/- 10% of the pre-contingency voltage within the first 30 seconds of simulation;

[1] As identified in the AESO Reliability Criteria, the most critical generator, i.e. the unit that will cause the greatest stress on the component of the AIES being studied, can be assumed out of service due to commercial or maintenance reasons. Under this condition where the system operation is normal with the most critical generator out of service, Category B events (i.e. single element out of service) will be studied. This condition is referred to as N-G-1 criteria.

[2] The Transmission Planning (TPL) Standards, which are included in the Alberta Reliability Standards, and Transmission Planning Criteria – Basis and Assumptions (see Attachment A), (collectively, the AESO Reliability Criteria)

- following a single contingency and post auto control actions (e.g. Under-Load Tap Changer ("ULTC") transformers are tapped) voltage deviation shall not exceed +/- 7% of the pre-contingency voltage; and
- following a single or multiple contingencies, i.e. Category B or C events, voltage deviation shall not exceed +/- 5% of the pre-contingency voltage after operator manual control and when steady state conditions are restored.

Voltage deviation must be calculated based on the pre-contingency voltage level at the POD bus as a reference. ULTC transformers shall be kept locked for the 10% voltage deviation evaluations. Also, automatic switching of capacitor banks and/or reactors shall not be allowed for 10% or 7% voltage deviation evaluations. Manual voltage control actions should be practical to be completed within 30 minutes.

It is recommended that the customer consult with the AESO at an earlier stage if any system issues are identified as part of the power flow studies that can affect system operation (e.g. deteriorate existing constraints or violate the AESO Reliability Criteria) and may require mitigation measures such as remedial action schemes ("RAS").

3.2 Voltage Stability Analysis

Power-Voltage (PV) stability analysis is required as part of the connection studies for system normal and post-contingency. Steady state voltage stability margin is required with the system load or cut-plane transfer (whichever applicable) modeled at a minimum of 105% of the peak operating point for Category A conditions and following Category B contingencies. For Category C contingencies, steady state voltage stability is required with the system load or cut-plane transfer (whichever applicable) modeled at a minimum of 102.5% of the expected peak.

Voltage stability margin must be respected with the ULTC transformers taps locked (short time frame) and stepping (longer time period). Also automatic switching of capacitor banks and/or reactors should not be allowed when performing PV analysis. For all power flow solutions area interchange control must be disabled and VAr limits of generators and static VAr compensators (SVCs) applied automatically.

3.3 Short Circuit Analysis

Worst case scenario should be assumed in preparation for the short circuit analysis as discussed and agreed upon with the AESO. Analysis should be performed using PSS/E or PSAT tools. Other industry recognized software may also be acceptable subject to approval from the AESO.

When performing short circuit analysis and reporting the results the following must be considered:

- system conditions for initial fault calculations with consideration of worst case fault conditions (e.g. area generators online);
- three-phase faults and single line to ground faults; and
- polar coordinates and physical values to report results.

Further sensitivity analysis may be required by the customer in co-operation with the transmission facility owner(s) should the primary analysis indicate a potential to exceed or approach existing rated fault duty of transmission equipment.

3.4 Transient Stability Analysis

Prior to conducting transient stability analysis all study assumptions including the following data must be reviewed and acknowledged by the AESO as part of the study scope:

- list of contingencies to be considered; in addition to the contingencies identified in the study scope other contingencies may be deemed necessary to be investigated based on the power flow study results if such studies were performed earlier.

- fault clearing time for each transmission element; it is necessary to obtain fault clearing times for the contingencies from the area TFO prior to conducting any transient stability analysis.

- load model; assumptions related to load model, motor loads, and natural load relief due to motor protection schemes should be discussed and agreed upon by the AESO. Refer to Section 4.1 for more details.

- reference generator; angular stability of all related generators to be determined with reference to this generator.

Transient stability analysis should be performed using PSS/E or TSAT; versions used should be compatible with the AESO in-house version for ease of cooperation. Other industry recognized software may also be acceptable subject to approval from the AESO.

The report presenting the results of the transient stability studies must provide response plots for several variables, including rotor angle, active and reactive power output for the unit(s) specified in the study scope.

For all Category B or C contingency analysis, the AESO requests that a bolted three- phase to ground fault to be applied first as this is a worse case compared to a single line to ground fault (SLG). However, SLG fault can be tested if simulation results indicate instability following a three phase fault. Type and location of applied fault must be documented in the engineering study report.

All contingencies must be modeled based on the actual bus configurations, breakers types and locations. The AESO will review and provide direction on how to properly model contingencies if the customer does not have access to such data.

Dynamic stability of the AIES must be maintained following a Category B or Category C contingency with all generators remaining stable. Also following single or most[3] multiple contingencies, the AIES must remain connected to the WECC system. Any violations must be documented in the engineering study report.

All simulated contingencies that trigger any of the existing automatic and/or manual protection schemes must be indicated when presenting the transient stability analysis results to the AESO. Under Frequency Load Shedding (UFLS) and Under Voltage Load Shedding (UVLS) schemes are examples of the automatic protection schemes that if triggered must be indicated to the AESO.

It is recommended that the customer consult with the AESO at an earlier stage if any system issues are identified as part of the transient stability analysis that can affect system reliability and may require mitigation measures such as RAS.

3.5 Sensitivity Studies

[3] Related multiple contingencies that may impact Alberta electric system connection to the rest of the WECC system will be outlined in the study scope.

Based on the results obtained from earlier power flow and/or transient stability analysis, sensitivity studies can be requested by the AESO. Since the nature of these studies is highly relevant to the earlier analysis, it is sometimes impractical to identify the need or details of the sensitivity tests in the study scope. Therefore, these studies can be added as necessary to the study scope at a later stage. It is recommended that the customer discuss all aspects of the sensitivity tests in detail with the AESO prior to conducting such studies.

When sensitivity studies are requested, the study scope shall be updated to incorporate details of the studies including but not limited to the following:

- study assumptions including system conditions, generation dispatch, load level, reactive resources, and other relevant data that can affect study results;
- study methodology;
- list of contingencies and system scenarios to be investigated.

The AESO can propose additional sensitivity studies identified by the customer based on the reported study results.

3.6 Motor Starting Studies

When the customer facilities include installation of motors, the customer must perform motor starting studies to evaluate the potential impacts of motor starting operations on the surrounding system. The study results should illustrate the following:

- expected voltage drop in the surrounding system during motor starting;
- flicker impacts of motor starting over time.

The customer must provide details of study assumptions, motor model and software used to perform the studies. Also, the type of motor starting equipment and/or starting methodology that would be implemented must be specified when providing the study results.

All study assumptions, results, and motor starting methodology shall be reviewed and acknowledged by the AESO.

3.7 Mitigation Measures

The customer facility upgrades or connection should not adversely impact system reliability and/or the existing constraints. The facility connection or upgrades must meet the requirements of the AESO Reliability Criteria, Alberta Reliability Standards, and ISO rules as established in the study scope. The AESO must be informed of any adverse impact on system reliability prior to system or customer mitigation plans being implemented. Appropriate mitigation measures must be devised if needed based on the results obtained from power flow, transient stability, or other analysis to negate the impact of the customer connection on system reliability.

Operation of the existing and proposed schemes in studies may require manual steps in the simulations to evaluate system performance. The consequence of RAS failure must also be considered when performing such studies. Miscoordination and complexity of too many schemes may be a real-time concern. Hence all applied mitigations measures must be acceptable practical solutions to facilitate reliable system operation.

The customer must devise any mitigation measures required for facility connection or upgrades in coordination with the AESO to ensure system reliability is maintained and also related Authoritative Documents, and/or other operational procedure and information documents are revised in a timely manner.

4. Study Assumptions and Modeling

For all the customer connection studies, the AESO will provide generic power flow base cases and appropriate dynamic data in the PSS/E format used by the AESO. The customer must generate suitable study cases by applying specific assumptions for the connection studies. All study files, such as single line (slider) diagrams, contingency modeling, and idev response files, should be developed by the customer[4]. All developed study cases and files shall be made available to the AESO when requested.

The AESO converts all the 72kV voltages to 69kV and 144kV to 138kV in the AESO base cases. Associated equipment ratings are converted accordingly.

4.1 Load

Assumptions regarding high and/or low ranges of the AESO load forecast must be applied to the study base cases prepared for the connection studies to simulate worst case system conditions.

For the purpose of power flow analysis, loads shall be modeled as constant MVA load. However, the amount of motor load modeled is significant to the outcome of transient stability analysis. Typically the AESO assumes 70% of the load to be motors (40% large motors and 30% small motors) in north regions of the AIES, i.e. areas 17 to 23, 25, 27 and 28. Basic motor load modeling in dynamic simulations shall be at least 20% induction motors in all other areas. The remaining load is modeled as constant current for active power, and constant impedance for reactive power. Depending on the connection area and system load makeup, the AESO may require additional analysis with different proportions of motor loads.

Assumptions on the amount of static load to be converted to motors for transient stability analysis must be indicated in the study scope and accepted by the AESO prior to conducting such studies. The load response to frequency and voltage changes should also be correctly modeled (e.g. UFLS / UVLS settings).

4.2 Generation

All assumptions made on generation dispatch and market practice must be clarified in the study scope and acknowledged by the AESO. Sensitivity studies may be identified to test the effect of various generation levels and dispatch patterns on the study results.

For more information about required generator data, see the PDUP-IM posted on the AESO's website.

4.3 Dynamic Models

The customer must represent proposed equipment with the most current model available including turbine governors, power system stabilizers (PSS), excitation system and its limiters, static VAR compensators (SVC), wind turbines and all other relevant dynamic representation of the proposed facilities.

[4] The AESO will share any applicable slider diagrams, contingency and idev response files if such files are readily available due to past AESO planning studies. However, the AESO will not develop any of the study files for the connection study purposes.

The customer should notify the AESO if any particular equipment model causes error or improper simulation interruption. Depending on the study scope, the dynamic model(s) may be modified following the AESO approval.

4.4 Protection Fault Clearing Time

It is critical for the customer to obtain fault clearing times from the area TFO when conducting transient stability analysis as part of the connection studies. Protection fault clearing times that do not meet the AESO protection standards and/or can cause potential dynamic stability issues may drive protection upgrades and must be discussed with the AESO once identified. The AESO may request additional studies using a range of protection fault clearing times to ensure system performance results are robust.

5. Application of New or Non-Traditional Technology

When the customer connection encompasses new technologies in the AIES (e.g. nuclear, permanent magnet generators, energy storage), the customer should provide detailed information to the AESO on how these additions are expected to perform and to be integrated into system operations as such information becomes available.

6. Maintenance and Outage Planning

All facilities will need to be out of service at some point due to forced outage or planned maintenance. Consequently, the impact of transmission elements being out of service for maintenance should be known. Similarly, the impact of assumed base loaded generators being out of service should be known.

Furthermore, if significant outages are required to convert, upgrade, or construct new facilities, the work should be staged such that periodic updates are available to the AESO for approval. The updates must include the study results of every project phase during various planning and construction phases.

7. Assessment of Connection Alternatives

The customer shall coordinate with the AESO to ensure that the connection alternatives are not deteriorating existing system constraints and affecting system plans that are in progress in the area. If there is a correlation, the customer and the AESO must work together to devise a mitigation plan or revise the connection alternatives to ensure system reliability is maintained.

When a customer NID application is dependent on a system NID application, the AESO and the customer should consider developing other alternatives or mitigation measures if system projects are delayed in construction and commissioning stages.

Customer facility connection or upgrades shall not adversely impact the existing system reliability or violate the AESO Reliability Criteria.

Appendix A – Transmission Planning Criteria – Basis and Assumptions

1. Introduction

This document presents the reliability standards, criteria, and assumptions to be used as the basis for planning the Alberta Transmission System. The criteria, standards and assumptions identified in this document supersede those previously established.

2. Transmission Reliability Standards and Criteria[1]

The AESO applies the following Alberta Reliability Standards to ensure that the transmission system is planned to meet applicable performance requirements under a defined set of system conditions and contingencies. A brief description of each of these standards is given below:

1. **TPL-001-AB-0: System Performance Under Normal Conditions**

   Category A represents a normal system condition with all elements in service (N-0). All equipment must be within its applicable rating, voltages must be within their applicable ratings and the system must be stable with no cascading outages. Under Category A, electric supply to load cannot be interrupted and generating units cannot be removed from service.

2. **TPL-002-AB1-0: System Performance Following Loss of a Single BES Element**

   Category B events result in the loss of any single element (N-1) under specified fault conditions with normal clearing. The specified elements are a generating unit, a transmission circuit, a transformer or a single pole of a direct current transmission line. The acceptable impact on the system is the same as Category A with the exception that radial customers or some local network customers, including loads or generating units, are allowed to be disconnected from the system if they are connected through the faulted element. The loss of opportunity load or opportunity interchanges is allowed. No cascading can occur.

3. **TPL-003-AB-0: System Performance Following Loss of Two or More BES Elements**

   Category C events result in the loss of two or more bulk electric system elements (sequential, N-1-1 or concurrent, N-2) under specified fault conditions and include both normal and delayed fault clearing. All of the system limits for Category A and B events apply with the exception that planned and controlled loss of firm load, firm transfers and/or generation is acceptable provided there is no cascading.

4. **TPL-004-AB-0: System Performance Following Extreme BES Events**

   Category D represents a wide variety of extreme, rare and unpredictable events, which may result in the loss of load and generation in widespread areas. The system may not be able to reach a new stable steady state, which means a blackout is a possible outcome. The AESO needs to evaluate these events, at its discretion, for risks and consequences prior to creating mitigation plans.

5. **FAC-014-AB1-2: Establishing and Communicating System Operating Limits**

   The AESO is required to establish system operating limits where a contingency is not mitigated through construction of transmission facilities

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[1] A complete description of the *Alberta Reliability Standards* can be found on the AESO's website: https://www.aeso.ca/rules-standards-and-tariff/alberta-reliability-standards/

2.1 Thermal Loading Criteria

The AESO Thermal Loading Criteria require that the continuous thermal rating of any transmission element is not exceeded under normal and post-contingency operating conditions. Thermal limits are assumed to be 100% of the respective normal summer and winter ratings. Emergency limits are not considered in the planning evaluations.

2.2 Voltage Range and Voltage Stability Criteria

The normal minimum and maximum voltage limits as specified in the following table are used to identify Category A system voltage violations, while the extreme minimum and maximum limits are used to identify Category B and C system violations. Table 2-1 presents the acceptable steady state and contingency state voltage ranges for the AIES. Table 2-2 provides voltage stability criteria used to test the system performance.

Table 2-1: Acceptable Range of Steady State Voltage (kV)

Nominal Voltage	Extreme Minimum	Normal Minimum	Normal Maximum	Extreme Maximum
500	475	500	525	550
240	216	234	252	264
260 (Northeast & Northwest)*	234	247	266	275
144	130	137	151	155
138	124	135	145	150
72	65	68.5	75.5	79
69	62	65.5	72.5	76

Table 2-2: Voltage Stability Criteria

Performance Level	Disturbance (1)(2)(3)(4) Initiated by: Fault of No Fault DC Disturbance	MW Margin (P-V method) (5)(6)(7)	MVAr Margin (V-Q method) (6)(7)
A	Any element such as: One Generator One Circuit One Transformer One Reactive Power Source One DC Monopole	≥5%	Worst Case Scenario(8)
B	Bus Section	≥5%	50% of Margin Requirement in Level A
C	Any combination of two elements such as: A Line and a Generator A Line and a Reactive Power Source Two Generators Two Circuits Two Transformers Two Reactive Power Sources DC Bipole	≥2.5%	50% of Margin Requirement in Level A
D	Any combination of three or more elements such as: Three or More Circuits on ROW Entire Substation Entire Plant Including Switchyard	> 0	> 0

2.3 Transient Stability Analysis Assumptions

Standard fault clearing times as shown in Table 2-3 are used for the new facilities or when the actual clearing times are not available for the existing facilities. Double line-to-ground faults are applied for the Category C5 events with normal clearing times. Single line-to-ground faults are applied for Category C6 to C9 events with delayed clearing times as depicted in Table 2-4 and Table 2-5.

Table 2-3: Fault Clearing Times

Nominal (kV)	Near End (Cycles)	Far End (Cycles)
500	4	5
240	5	6
144/138 with telecommunications	6	8
144/138 without telecommunications	6	30

Table 2-4: Stuck Breaker Clearing Times for Lines

Voltage (kV)	Fault Clearing Times (Cycles)		
	Near End	Far End	2nd Ckt (C5 and C7 only)
138/144	15	24	24
240	12	6	14
500	9	5	11

Table 2-5: Stuck Breaker Clearing Times for Transformers

Voltage (kV)	Fault Location	Fault Clearing Times (Cycles)		
		High Side	Low Side	2nd Ckt (breaker fail)
240/138	240 kV side	12	6	14
	138 kV side	5	15	24
500/240	500 kV side	9	5	11
	240 kV side	4	12	14