aeso

Dynamic Reactive Power Capability Assessment Guideline

MAY 2026

aeso

Alberta Electric System Operator
3000, 240 4 Avenue SW
Calgary, AB • T2P 4H4
aeso.ca

Dynamic Reactive Power Capability

Assessment Guideline

PROFESSIONAL ENGINEER ALBERTA
BRAD E. COLEMAN
ID 121768

April 17, 2026

Date of issue: April 17, 2026

	Name	Signature	Date
Author – Lead Engineer	Brad Coleman, P.Eng	[signature]	**2026/04/17**
Checked & Approved – Senior Advisor, Operational Reliability	Changling Luo, P.Eng	[signature]	**2026/04/17**

PERMIT TO PRACTICE
INDEPENDENT SYSTEM OPERATOR
RM SIGNATURE: [signature]
RM APEGA ID #: 98372
DATE: April 17, 2026
PERMIT NUMBER: P008200
The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

Contents

Executive Summary

Purpose and Scope

The Alberta Electric System Operator (AESO) has developed the Dynamic Reactive Power Assessment guideline to support market participants (MPs) in complying with the effective grounding requirement under Section 503.3 of the ISO rules, *Reactive Power*. It can also be used to make an assessment on reactive power capability as it relates to AESO Connection Requirements for Inverter-Based Resources. This guideline:

- Explains the importance of adequate dynamic reactive power capability
- Provides uniform guidance on assessments of generating resources' dynamic reactive power capability
- Defines a standardized scope for detailed study, including methodology, inputs, assumptions, performance criteria, reporting requirements and mitigation options

Rationale

Dynamic Reactive Power capability is essential to the safe and reliable operation of Alberta's transmission system. The ability of a generating facility to provide adequate dynamic reactive power capability supports stable voltage regulation of the gird and effective recovery from system faults or rapid load changes. Renewable resources like wind and solar are susceptible to intermittent swings in active power production, dynamic and fast acting reactive power compensation is essential to stabilize their connections to the grid. This guideline provides a standardized approach to support dynamic reactive power assessment and the compliance.

Performance Criteria

Generating resources shall be capable of operation between 0.9 power factor supplying reactive power and 0.95 power factor absorbing reactive power in all operational scenarios. Depending on the facility configuration or type, different criteria may be applicable.

Application

MPs are expected to use this guideline for all applicable projects or existing facilities to assess compliance with dynamic reactive power requirements before energizing their facility. For high risk connection projects identified by the AESO, reporting requirements will be included in the functional specification (FS).

1. Dynamic Reactive Power Capability Introduction

1.1 Background

Dynamic reactive power (DRP) capability is related to Section 503.3 of ISO rules, *Reactive Power* and as well the reactive power requirements in section 5.0 of AESO Connection Requirements for Inverter-Based Resources [1] as specified in a facility's functional specification. MP projects that have been as high-risk through the applicability will be required to conduct detailed study, providing evidence of compliance with the AESO Authoritative Document, which will be documented in a project's functional specification.

This guideline was developed to educate stakeholders about why DRP capability assessment is required and how a project will be assessed through a standardized approach. It provides transparency and guidance on how to conduct the applicability and detailed study by the responsible entity and how to provide the detailed study report to the AESO if required, demonstrating compliance. It is not authoritative and for information purposes only.

DRP is important to grid reliability in areas of voltage stability, voltage control and voltage ride-through capabilities. DRP resources can be shared within facilities to meet the applicable ISO rules. DRP is particularly important in facilities containing predominantly inverter-based resources (IBRs) with large internal reactive losses or resource technologies with limited capability, such as asynchronous wind turbine generators or full converter solar facilities.

To confirm the expected DRP capability, the facility or resource can be modelled, and both power flow and dynamic simulations can be undertaken, to verify the expected operation and control of a facility. The simulated response can then be checked against the DRP capability provisions in the ISO rules and the facility's ability to meet these requirements.

This document replaces the former Study Guideline Dynamic Reactive Power Capability of a Wind or Solar Aggregated Generating Facility V1 – April 23, 2019.

1.2 Roles and Responsibilities

This section outlines the high-level roles and responsibilities of various tasks in the study. All the parties can reach out AESO's project manager for details.

Table 1: RACI Chart for Dynamic Reactive Power Capability

Note: R – Responsible; **A** – Accountable; **C** – Consult; **I** – Inform

Deliverable	AESO	Transmission Facility Owner (TFO)	Generation Facility Owner/Market Participant (GFO/MP)
Applicability and Pre-Screening			

Deliverable	AESO	Transmission Facility Owner (TFO)	Generation Facility Owner/Market Participant (GFO/MP)
(Earliest Connection Process Stage: Stage 0, Latest Connection Process Stage: 3)			
Confirm applicability of project	A/R	I	R
Screening Assessment (Earliest Connection Process Stage: Stage 0, Latest Connection Process Stage: 3)			
No screening required, see applicability	NA	NA	NA
Detailed Study (Earliest Connection Process Stage: Stage 3, Latest Connection Process Stage 4)			
Provide transmission system inputs (where applicable)		A/R	I
Perform detailed study	I	NA	A/R
Identify mitigation needs	I	NA	A/R
Provide study report to AESO	I	NA	A/R
Result Acceptance and Mitigation Recommendation (Earliest Connection Process Stage: Stage 4, Latest Connection Process Stage: 5)			
Report and mitigation acceptance	A	NA	I
Functional specification update	A	I	I
Project data update package (PDUP) revision – if applicable	I	NA	A/R
Energization Authorization (Latest Connection Process Stage: Stage 5)			
Confirmed study completion and mitigation to issue energization authorization	I	NA	A/R

Note:

Responsible (R) = “the doer”. Those who do work to achieve the task. There can be multiple resources responsible. The act of approving a deliverable can be categorized under the responsible party.

Accountable (A) = “the buck stops here”. The resource ultimately answerable for the correct and thorough completion of the task There can only be one “A” specified for each task.

Consulted (C) = “in the loop”. Those whose opinions are sought. Those who have special knowledge or expertise needed to make decisions or solve problem. Two-way communication.

Informed (I) = “in the picture”. Those who are kept up to date on progress and decisions (once made). May be impacted by decision but are not active in final decision. One-way communication.

1.3 Applicability

This guideline for verifying the dynamic reactive power capability of facilities is intended for those facilities that are transmission connected. Projects that may be applicable to this guideline include transmission connected facilities that contain:

- wind and solar resources
- IBRs
- DRP devices such as static synchronous compensators, static volt-ampere reactive (VAR) compensators, or other dynamically controlled resources
- switchable shunt capacitor banks utilized to correct collector system reactive power losses within aggregated facilities

or as determined by AESO as facilities or projects requiring a DRP Capability Study.

1.4 Pre-Screening and Screening

The projects listed in the applicability section do not require any pre-screening and screening other than an assessment of applicability. If the project falls within the scope of applicability section, these projects may proceed directly to performing the reactive power capability study and providing the necessary deliverables.

1.5 Detailed Study

As outlined in AESO’s risk-based approach, the need for a detailed study on DRP capability is identified if a project meets the applicability. This indicates that the detailed study is required to ensure that the project complies to the related ISO rule requirements and there is no operational or reliability risk to the AIES or that the risk can be adequately mitigated. As such, the project functional specification will be updated to include the detailed study requirement for DRP capability. For selected high-risk projects, the AESO will ask the MP to submit the study report to the AESO and the AESO may comment on the report within the reasonable time.

1.5.1 Study Methodologies

The AESO recommends that DRP capability study be undertaken in power system simulation platforms to confirm an adequate amount of dynamic range is available by design. Several cases are run with varied equipment in service internal to the facility. The intent of the DRP capability study is to determine if:

- the facility meets the applicable DRP capability requirements with the notes to MPs in Section 3.
- that any static shunt reactive power devices are exclusively used for correction of internal facility losses
- that adequate range of voltage control and any necessary compensation is proven in simulation

1.5.2 Study Assumptions and Limitations

There are many approaches to modelling the facility under study. For the purposes of this study, the model should be resolute enough to be able to adequately define or assess DRP capability and expected flow to the AIES from the facility under study. The study should consider the following to help define it:

- A single machine infinite bus (SMIB) model should be used to represent the system at the proposed point of connection.
- Projects in stage 4/5 of the Connection Process should have most equipment data available as per the detailed design, it is assumed that this data is a foundational input to the simulation and study. However, if enough design detail is available in earlier in the project design, the study can be completed at earlier stages.
- Collector system losses (both active and reactive power losses) can be aggregated if needed, these should be compartmentalized with respect to the physical collector feeder and bus topology.
- Static reactive power and DRP devices should be arranged in the topology such that adequately represent the point of connection to the collector system, the collector losses or capability deficiency they correct for and control parameters for switching.
- The size and rating of equipment should be representative of original equipment manufacturer (OEM) specifications.
- Points of control for voltage and reactive power flows should be modelled such that they represent that defined in the facility design or functional specification. This should include compensation modelling where specified.
- Power plant controllers (PPCs) should be modelled to match the topology and control of the facility:
  - For instance, if there is one PPC that controls the entire facility, it can be modelled a single controller.
  - If this is an aggregate controller of separate smaller PPCs, then the model should reflect this configuration.

- Any dynamic models used in the simulation should be those currently approved by Western Electricity Coordinating Council (WECC) and referenced in AESO ID #2017-013R [2].

1.5.3 Required Inputs and Data

A facility topology is illustrated in Section 2 as example. The AESO currently uses Siemens PTI Power System Simulator for Engineering (PSSE) to simulate and verify study results. This software is recommended to be used in the study and the case study examples provided herein are undertaken using this software. Any edits to the PDUP[1] because of this software would also be accomplished more easily if PSSE is used for this reactive power study.

It is expected that the most current version of PSSE in use at the AESO is used for this DRP external study. If alternative types of modelling software are to be used, this should be agreed upon by the AESO in advance, accompanied by valid reasoning as to why PSSE cannot be used.

Facility data and information attesting to the capabilities and attributes of the facility's electrical power and control equipment should be included in the report or as appendices, and take the form of specifications, screenshots of settings, graphics, etc. The AESO prefers little to no external files. Table 2 lists data inputs likely required to complete a DRP capability study; this data could be provided in documentation already submitted as part of the connection process.

Table 2: Suggested Data Inputs to Dynamic Reactive Power Capability Study

Description	Source
Transmission System Connection	
• Transmission line rating, length, sequence impedances, relevant model parameters • Nominal voltage at the point of connection	Transmission Facility Owner (TFO), AESO functional specification
Step-Up Transformer	
• Mega volt-amperes (MVA) and voltage ratings, winding configuration, losses, excitation current, sequence impedances, on-load tap changer, deenergized tap changer tap settings and voltage regulator information as applicable • If available, include nameplate data	OEM, MP, Engineering consultant
Collector System	
• Cable impedances, lengths, sizes, conductance/capacitances	OEM, MP, Engineering consultant

[1] Any capitalized terms not defined herein shall have the meaning given to them in the AESO's Consolidated Authoritative Document Glossary as amended from time to time.

Description	Source
Low Voltage Step-Up Transformers	
• MVA and voltage ratings, winding configuration, losses, excitation current, sequence impedances, on-load tap changer (OLTC), de-energized tap-changers (DETC) tap settings and voltage regulator information as applicable • If available, include nameplate data	OEM, MP, Engineering consultant
Wind Turbine Generators (WTG)	
• For each different type of WTG: Generator and turbine type, power and voltage rating, available operating modes, power capability curves, other relevant model parameters as needed • Number of turbines should be included as well	OEM, MP, Engineering consultant
Power Converter/Inverters or Power Conversion System	
• OEM specifications including power and voltage ratings, power capability, control/operating modes, other parameters as needed	OEM, MP, Engineering consultant
Solar Voltaic Panels	
• Power and voltage rating, type, tracking capability, power capability curves, other relevant model parameters as needed • Number of Photovoltaic (PV) panels in aggregation should be provided along with the number of strings per feeder/power conversion system (PCS)	OEM, MP, Engineering consultant
Static shunt reactive devices	
• MVAr and voltage ratings, control methodology • If available include nameplate data	OEM, MP, Engineering consultant
Dynamic Shunt Reactive Devices	
• MVAr and voltage ratings, control methodology, dynamic response curves • If available include nameplate data	OEM, MP, Engineering consultant
Voltage Regulating System or Automatic Voltage Regulator	
• Points of measurement, available control modes, voltage and reactive power setpoint ranges, any voltage droop or compensation settings or methods employed, control of shunt reactive power devices, ramp rates, and dynamic response characteristics	OEM, MP, Engineering consultant

Description	Source
Functional Specification	
• Expected voltage levels at the point of connection – i.e., Nominal, Emergency Minimum and Emergency Maximum • Preliminary information regarding design in previous versions of the functional specification	AESO

1.5.4 Study Outputs

Included below are the minimum study cases to be included in the DRP Capability Study and subsequent report. Depending on the attributes and technologies used in the facility, more study cases may be required. The need for additional study cases is left to the MP and their study engineer. The AESO may be engaged for consultation where appropriate. The results and data to include in the study cases for active power flow, voltage control, reactive power limit, DRP device and off-nominal voltage cases should be at a minimum the following (for the optional dynamic voltage step simulation, the required results and data are covered under that section below):

- V at Point of connection
- P at Point of connection
- Q at Point of connection
- Power factor at Point of connection
- Status and reactive power flow of any static shunt reactive power devices (i.e., cap banks or inductor banks)
- Status and reactive power flow of any DRP devices (i.e., DVAR, STATCOM, etc.)
- Facility collector system losses (active and reactive)
- Facility PPC(s) voltage setpoint
- V at collector system bus(es)
- P at collector system bus(es)
- Q at collector system bus(es)
- Power factor at collector system bus(es)
- Aggregate active power provided by generation resources (i.e., WTGs, Inverters, PCS, etc.)
- Aggregate reactive power provided by generation resources
- AESO ISO rule requirements for reactive power flow and the difference between the requirement and simulated power flow

1.5.4.1 Active Power Flow

Check study case parameters, active power limits and normal power flow operation for the facility at the point of connection.

Conditions:

Rated voltage for the facility voltage regulating system setpoint.

All dynamic reactive power devices off.

All generation connected and able to produce active power.

Test Cases:

i. 0.1 x maximum authorized real power (MARP), **nominal** voltage at PoC
ii. 1.0 x maximum authorized charging power (MACP), where applicable for energy storage resources), **nominal** voltage at PoC
iii. 1.0 x MARP, **nominal** voltage at PoC
iv. 0.1 x MARP, emergency **minimum** voltage at PoC
v. 1.0 x MARP, emergency **minimum** voltage at PoC
vi. 0.1 x MARP, emergency **maximum** voltage at PoC
vii. 1.0 x MARP, emergency **maximum** voltage at PoC

1.5.4.2 Voltage Control

Check of manual voltage control range of the facility in simulation.

Conditions:

Nominal voltage set at point of connection.

All static and dynamic reactive power devices off.

All generation connected and able to produce active power.

Test Cases:

i. 0.0 x MARP, facility or generator voltage regulation system (VRS)/automatic voltage regulator (AVR) set point set to 0.95
ii. 0.0 x MARP, facility or generator VRS/AVR set point set to 1.05
iii. 1.0 x MARP, facility or generator VRS/AVR set point set to 0.95
iv. 1.0 x MARP, facility or generator VRS/AVR set point set to 1.05

1.5.4.3 Reactive Power Limit

Check the limits of the reactive power capability of the facility. This study case will primarily confirm if the facility can meet the reactive power capability requirements by design in simulation. These test cases should be repeated for both reactive power capability requirements in the ISO rules [3] and the connection requirements for IBRs where applicable.

Conditions:

Dynamic reactive power device (if applicable) off.

All generation connected and able to produce active power.

Test Cases:

i. **1.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **injection** to power system, for example, 1.10 pu. With static shunt devices **off**, adjust voltage at the point of connection to a level where 1.0pu collector bus voltage is achieved. Alternatively, for IBRs, adjust the point of connection voltage to 1.02 pu (as per the requirement) and make AVR/VRS setpoint adjustments to generation to achieve maximum reactive power flow from generation sources.

ii. **1.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **injection** to power system, for example, 1.10 pu. With static shunt devices **on**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

iii. **1.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **absorption** to power system, for example, 0.90 pu. With static shunt devices **off**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

iv. **1.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **absorption** to power system, for example, 0.90 pu. With static shunt devices **on**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

v. **0.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **injection** to power system, for example, 1.10 pu. With static shunt devices **off**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

vi. **0.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **injection** to power system, for example, 1.10 pu. With static shunt devices **on**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

vii. **0.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **absorption** to power system, for example, 0.90 pu. With static shunt devices **off**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

viii. **0.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **absorption** to power system, for example, 0.90 pu. With static shunt devices **on**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

Where the facility contains an energy storage resource(s), an assessment should be made at MACP in addition to the test cases above. Repeat the test cases for v. through viii. at MACP under the same stipulated conditions.

1.5.4.4 Dynamic Reactive Power Device

These study cases are a repeat of Reactive Power Limits section above with the dynamic reactive power device in operation and controlling.

Conditions:

All reactive power devices in service and operable.

All generation connected and able to produce active power.

Test Cases:

i. **1.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **injection** to power system, for example, 1.10 pu. With static shunt devices **off**, adjust voltage at the point of connection to a level where 1.0 pu collector bus voltage is achieved. Alternatively, for IBRs, adjust the point of connection voltage to 1.02 pu (as per the requirement) and make AVR/VRS setpoint adjustments to generation in order to achieve maximum reactive power flow from generation sources.
ii. **1.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **injection** to power system, for example, 1.10 pu. With static shunt devices **on**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.
iii. **1.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **absorption** to power system, for example, 0.90 pu. With static shunt devices **off**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.
iv. **1.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **absorption** to power system, for example, 0.90 pu. With static shunt devices **on**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.
v. **0.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **injection** to power system, for example, 1.10 pu. With static shunt devices **off**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.
vi. **0.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **injection** to power system, for example, 1.10 pu. With static shunt devices **on**, adjust voltages as in i) such that either the collector bus voltage is

1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

vii. **0.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **absorption** to power system, for example, 0.90 pu. With static shunt devices **off**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

viii. **0.0** x MARP Set facility or generator VRS/AVR setpoint (i.e., Sched Voltage) to achieve maximum reactive power **absorption** to power system, for example, 0.90 pu. With static shunt devices **on**, adjust voltages as in i) such that either the collector bus voltage is 1.0 pu or the point of connection voltage is 1.02 pu as applicable to the requirement being assessed.

If multiple feeders with static shunt reactive power devices are designed within the facility, different permutations may be required if the control of the static shunt reactive power devices are independently controlled. Where the facility contains an energy storage resource(s), an assessment should be made at MACP in addition to the test cases above. Repeat the test cases for v. through viii. at MACP under the same stipulated conditions.

1.5.4.5 Off-Nominal Voltage

This section is specifically applicable to facilities containing IBRs that are required to meet the reactive power capability provisions of the Voltage Control section of the *Connection Requirements for IBRs*.

Conditions:

Facility active power output of 1.0 x MARP.

All reactive power devices in service and operable.

All generation connected and able to produce active power.

Test Cases:

Test cases, in general, should be sufficient to determine if the facility is able to meet the off-nominal voltage provisions of the above-noted requirements. As an example, both absorption and injection of reactive power could be assessed at the following points of operation:

0.90 pu voltage at the point of connection

0.95 pu voltage at the point of connection

1.06 pu voltage at the point of connection

1.10 pu voltage at the point of connection

This is not an exhaustive list of test cases and would be left up to the study engineer to determine if more are required depending on IBR and collector system configuration. It should also be noted as this is a simulation, results of the reactive power and voltage limitation of the generation sources need to be considered and assessed against known equipment capabilities, there may be the need for less reliance on software simulations to make this assessment.

1.5.4.6 Dynamic Voltage Step

Check of the dynamic model under simulation; this is an **optional** assessment.

Conditions:

Facility active power output of 1.0 x MARP

Nominal voltage at point of connection

Static shunt reactive power devices on where appropriate (for anticipated reactive power flow)

Test Cases:

i. Perform a positive 1-3% step test of the VRS/AVR setpoint.
ii. Perform a negative 1-3% step test of the VRS/AVR setpoint.

This is only a brief confirmation of the facility's dynamic model. Complete validation of the dynamic model is completed as per sections 503.19 and 503.20 of the ISO rules as part of a new project connection or regularly as per model-revalidation requirements.

Results and Data:

The results should include both pre- and post-step data values of the following quantities (after a period of stabilization):

- V at point of connection
- P at point of connection
- Q at point of connection
- Power factor at Point of connection
- Reactive power flow of any static shunt reactive power devices (i.e., cap banks or inductor banks)
- Reactive power flow of any dynamic reactive power devices (i.e., DVAR, STATCOM, etc.)
- V at collector system bus(es)
- P at collector system bus(es)
- Q at collector system bus(es)
- In addition, graphics of the step response should be recorded and provided with the finished report that represents the quantities identified above

1.5.5 Study Conclusions and Mitigation

The study should conclude that the facility meets the applicable minimum DRP requirements. This should be clearly identified in the report through a case study summary pointing to reactive power devices that may or may not have contributed to meeting the requirement.

If during study it is found that the facility is deficient in DRP capability, then mitigation strategies could include:

- Addition of DRP resources
- Addition of shunt static reactive power resources to offset losses internal to the facility
- Re-evaluation of the facility's MARP and capability at this level of generation
- Other design options or mitigation strategies as presented by the MP and agreed to by the AESO

1.5.6 Study Report

Upon completion of the analysis and prior to the connection of the facility to the AIES, a detailed DRP study report, authenticated as per the Association of Professional Engineers and Geoscientists of Alberta (APEGA) authentication standard, should be provided by the market participant or their engineering consultant demonstrating that the facility is designed to meet the DRP requirements set out by the AESO. The report should be comprehensive and well-structured and could be part of a larger report submission, including other special or required studies.

The report template in Appendix B can be used to present your detailed study. Using the template can help the efficient and productive review of your report.

The report should be delivered in at the latest in stage 4 of the connection process for the AESO to review or make alterations to the functional specification pending any study outcomes that may prescribe additional DRP capability. Study results may have implications for design and equipment change, which in turn may result in project delays due to facility re-design considerations or equipment changes.

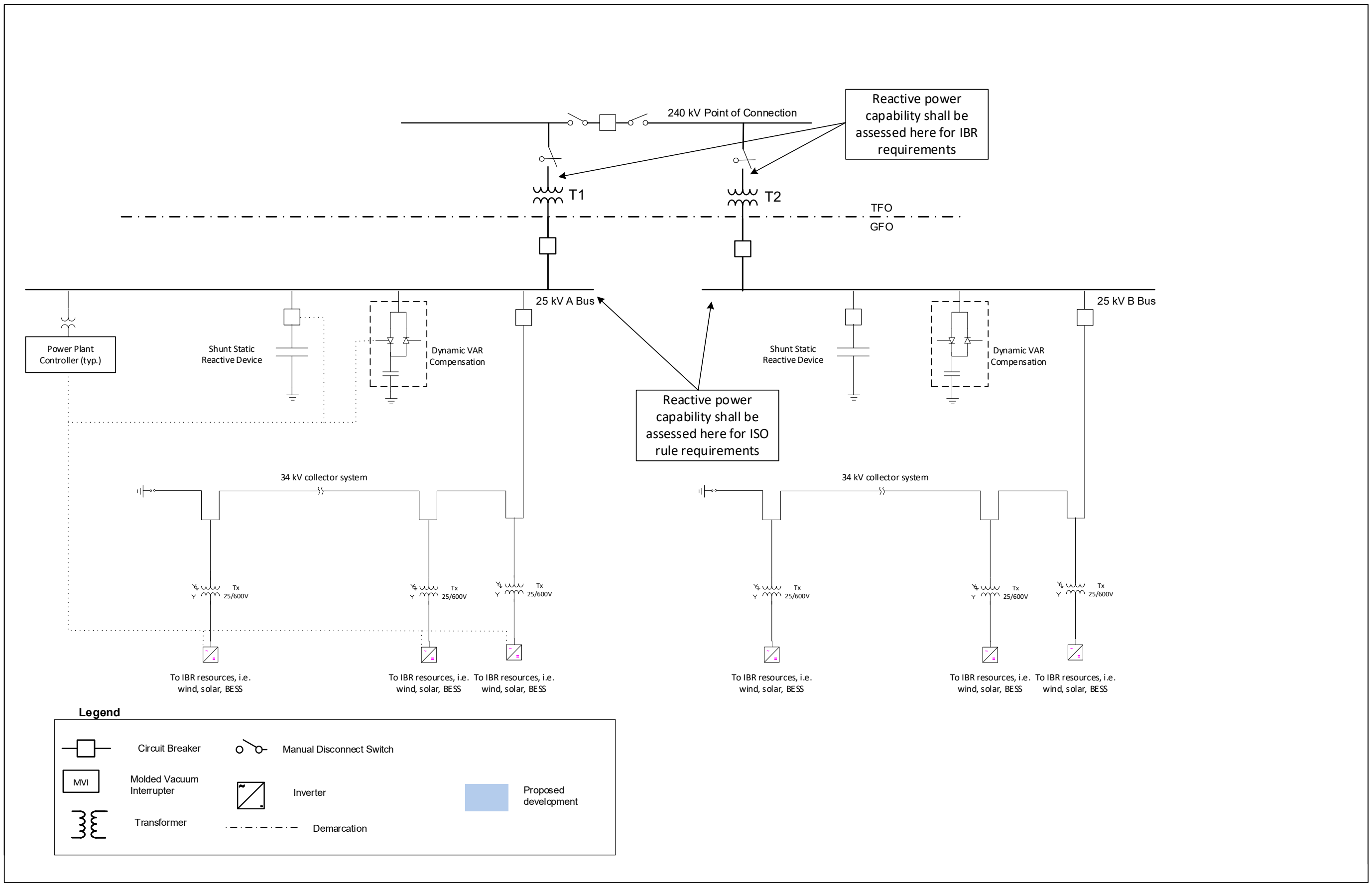
1.6 Result Acceptance and Mitigation Implementation

The MP must submit the study report and the proposed mitigation solution, which must be accepted by the AESO before the in-service date of project. The AESO may review the study report for selected high-risk projects within reasonable time and may provide comments, requesting the MP to respond prior accepting the report. We may revise the functional specification of the project according to the study result or proposed mitigation solution. Any delay on the study report submission may result in a delay of project energization.

1.7 Energization Requirements

The AESO authorizes the project to connect to the AIES and achieve energization when the project meets all the AESO's energization checklist requirements, outlined in the 100-day and 30-day energization packages. The required study report will be included in the energization checklist. The AESO encourages the market participant to check with AESO's project manager to fully understand how to meet the energization requirements.

2. Aggregated Facility Topology Example



3. Notes Regarding Dynamic Reactive Power Requirements

For facilities containing IBRs such as wind and solar, the expectation is that the facility should be able to meet both the DRP requirements of ISO rule Section 503.3*, Reactive Power* (Section 503.3) and those specified in section 5.0 of the Connection Requirements for IBRs. The constraint in most instances for IBRs is the ability to inject reactive power to the AIES.

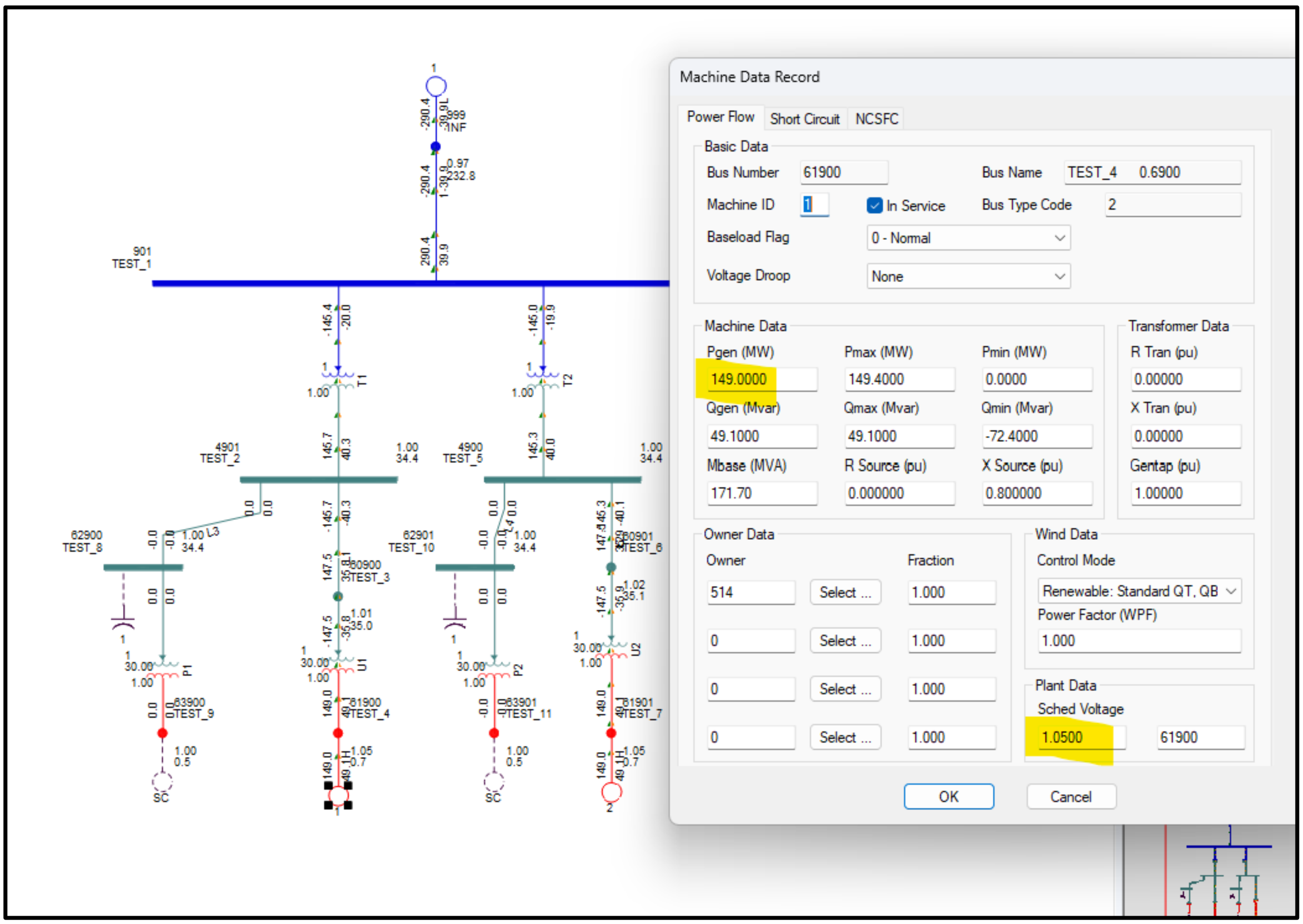
Section 503.3 specifies that the facility must have a full DRP range of 0.9 pf supplying to 0.95 absorbing reactive power, based on MARP and assessed at 1.0 pu voltage at the collector bus. In addition, section 5.0 of the Connection Requirements for IBRs specify that the DRP range of 0.35 * MARP supplying to 0.35 * MARP absorbing reactive power and is assessed at 1.02 pu voltage at the point of connection.

As the minimum reactive power requirement is lower for the IBR assessment at the point of connection than for the Section 503.3 requirement, it is anticipated that this could accommodate any reactive power losses across the step-up transformer such that both sets of requirements are met. If, after completion of the study, it is found that the facility is unable to meet both requirements, then the owner of the facility has several options including the addition of reactive power resources, reconsideration of their stated MARP, or an application for a waiver/variance or in the case of the Connection Requirements for IBRs application for an exemption.

4. PSSE Examples

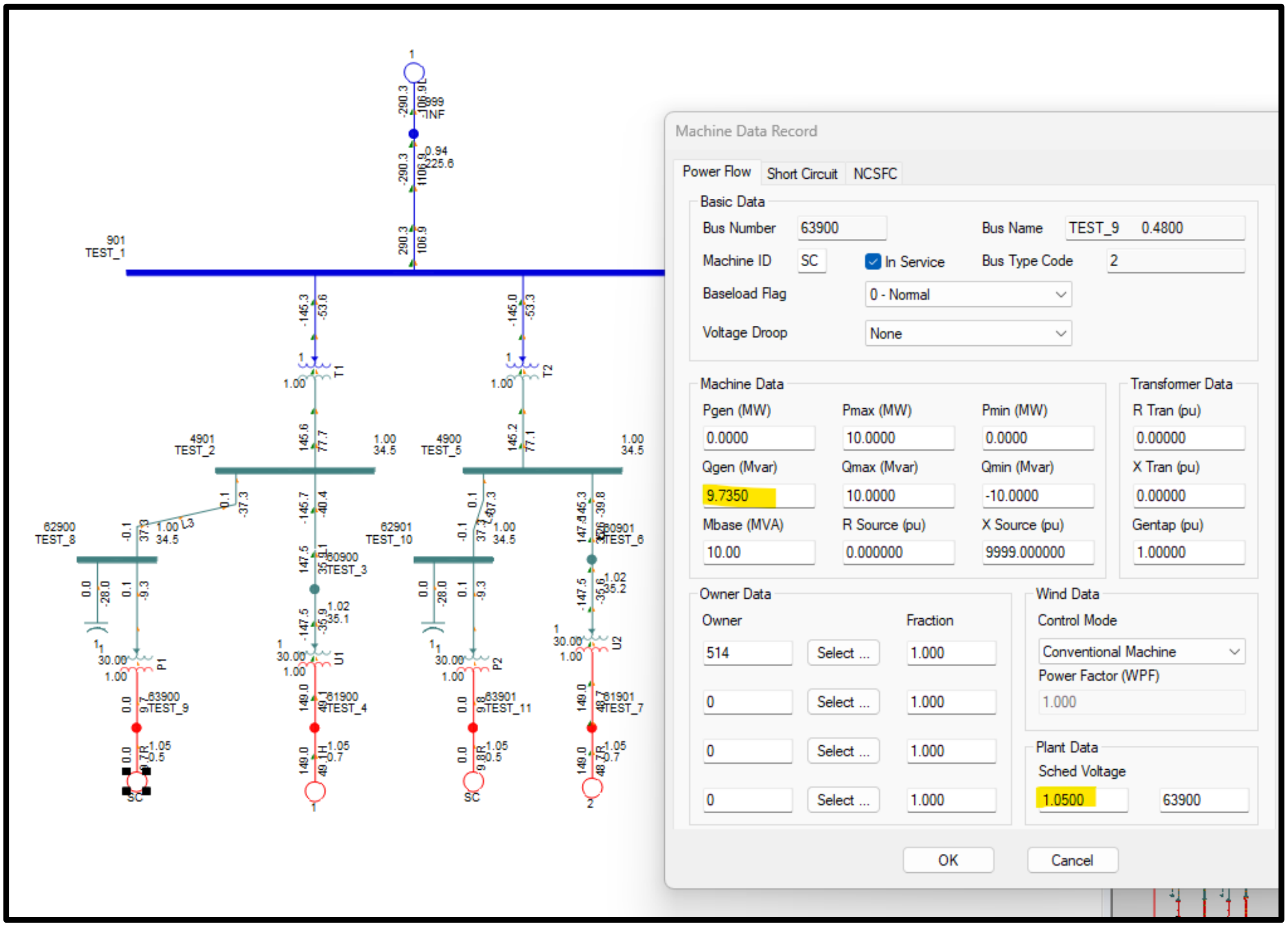
In the example in Figure 1, the facility is injecting up to its reactive power limit of the generators (49.1 MVAr for each of the feeders); however, the requirement is assessed at the collector bus in this case. At the collector bus, 291 MW of active power is produced (100 per cent generation of the facility), and 80.3 MVAr of reactive at full capability. To meet the requirement of 0.9 pf supplying reactive power, the facility would need to produce 141MVAr, which could be supported by the static and dynamic shunt reactive devices. In this example, the Sched Voltage of the aggregated machines are set to 1.05pu and the SMIB machine to 0.97pu; this provides 1.00 pu voltage on the collector system which is the basis of the requirement for ISO rule Section 503.3.

Figure 1: Reactive power flow example, no dynamic or static shunt reactive power devices in service, voltage of 1.0 pu at the collector bus, injecting reactive power



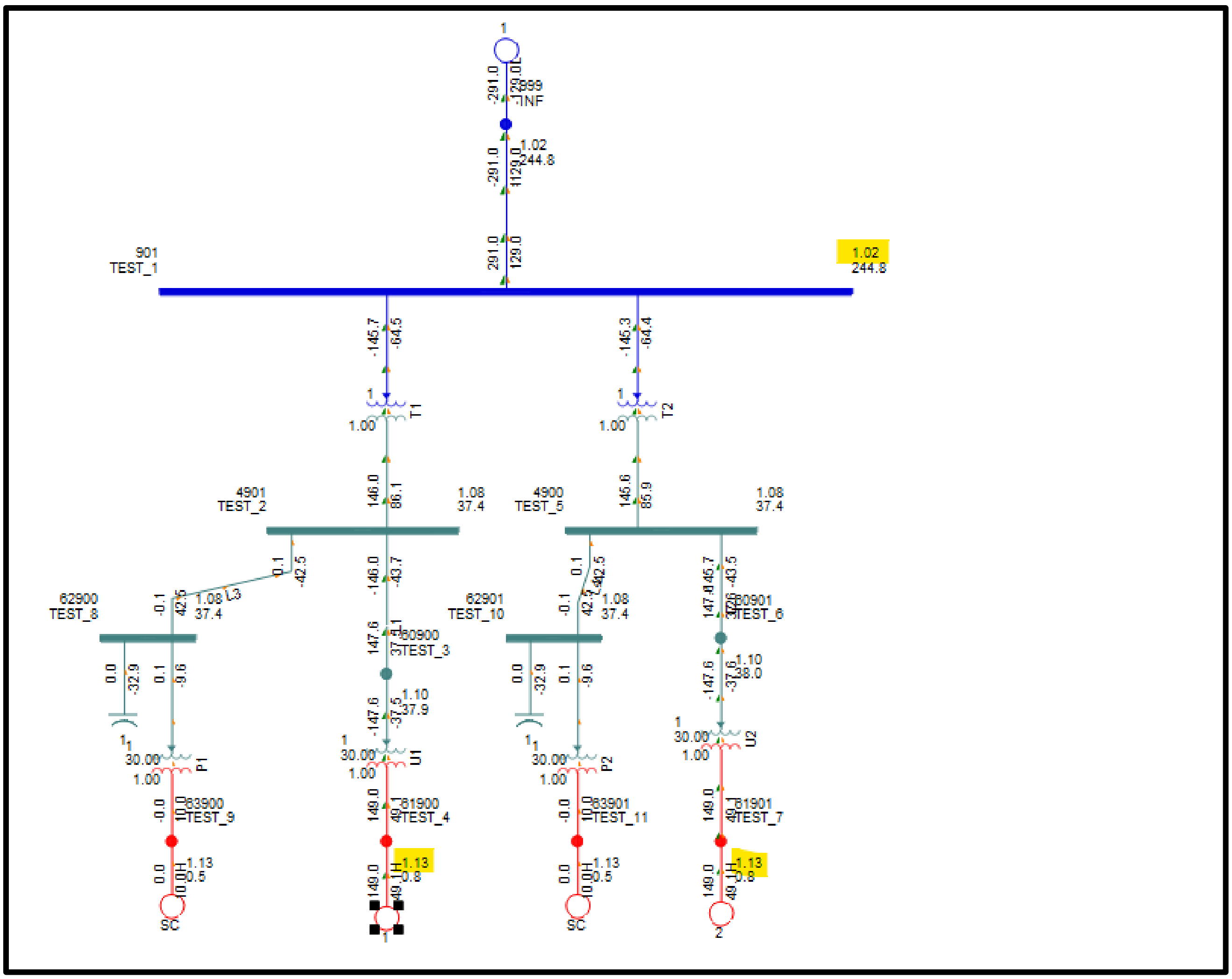
For the same example facility, both the dynamic and static shunt reactive power devices are put in service and the power flow simulation runs again. The reactive power capability can again be assessed at the collector bus, as shown in Figure 2, the facility is now able to meet the reactive power requirements if assessed at the collector bus (0.9 pf supplying reactive power).

Figure 2: Reactive power flow example, with both dynamic and static shunt reactive power devices in service, voltage of 1.0 pu at the collector bus, injecting reactive power



If the connection requirements for IBRs is applicable to this facility, then the reactive power capability needs to be assessed at the point of connection. The requirements stipulate that the DRP capability at the point of connection should be 0.35 * MARP at 1.02 pu of nominal voltage. The limits of the collector system should be checked as part of this assessment to determine any constraints that may need to be mitigated to achieve the required capability. This same example facility is setup to assess whether this requirement is met below in Figure 3.

Figure 3: Reactive power flow example, with both dynamic and static shunt reactive power devices in service, voltage of 1.02 pu at the point of connection to assess DRP capability as per the connection requirements for IBRs



5. References

[1] Wiebe, Daniel; et al, "AESO Reliability Requirements Roadmap," 21 February 2024. [Online]. Available: https://www.aesoengage.aeso.ca/32222/widgets/131431/documents/124307.

[2] AESO, "2017-013R-Model-Validation-and-Reactive-Power-Report-Guidance-2024-04-19," [Online]. Available: https://www.aeso.ca/assets/Information-Documents/2017-013R-Model-Validation-and-Reactive-Power-Report-Guidance-2024-04-19.pdf. [Accessed 05 01 2024].

[3] AESO, "AESO ISO Rules Section 503.3 - Reactive Power," 8 August 2024. [Online]. Available: https://www.aeso.ca/rules-standards-and-tariff/iso-rules/section-503-3-reactive-power/. [Accessed 26 September 2024].

Appendix A: GRIP Overview

Introduction

The Alberta Interconnected Electric System (AIES) is undergoing a period of grid transformation driven by multiple factors, including the increasing integration of inverter-based resources (IBRs) such as wind and solar, changes in system topology, and evolving operating conditions. Collectively, these factors present the following challenges to the Alberta Electric System Operator (AESO):

- High penetration of IBR, which can reduce system capability to manage and maintain frequency stability, system strength and operational flexibility.
- Restrictions on the availability of reliability support through interties due to weak connectivity with the Western Interconnection, where excessive reliance on external resources increases the risk of intertie tripping.
- Increasing operational limitations associated with newly energized facilities.
- An increase in reliability-related phenomena observed during real-time operations.

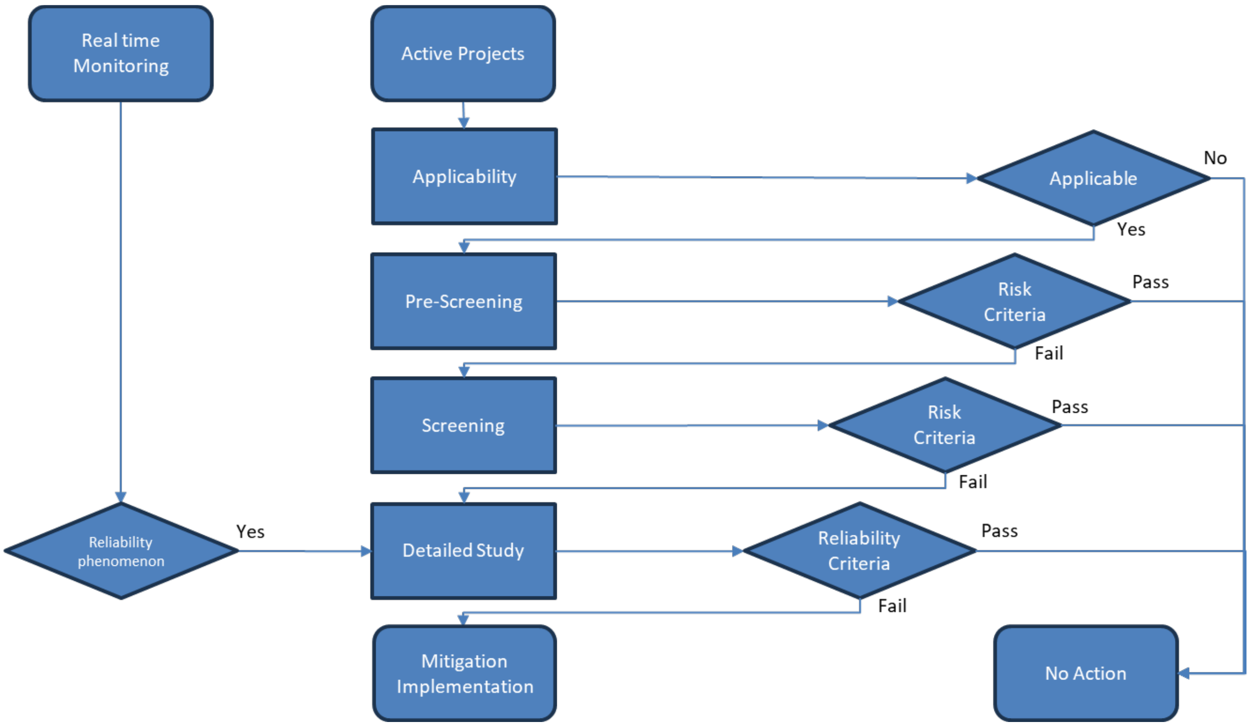
As a result of these emerging AIES reliability challenges, the AESO has identified several areas where performing Grid Readiness, Integration and Performance (GRIP) Requirements would be beneficial. System reliability is also heavily dependent on how market participants (MPs) conduct technical assessment and design the facility accordingly to meet connection requirements prior to energization. Therefore, we have created standard guidelines on how to conduct GRIP. We have adopted a risk-based approach, which considers the risk to the reliability of the AIES using project information, beginning with high-level screening assessments for all active connection projects and, where necessary, proceeding to more detailed studies. These studies may identify potential mitigation measures to be implemented during the connection process. This approach seeks to strike the right balance between moving efficiently through the connection process and exercising the due diligence required to ensure system reliability.

AESO's Risk-Based Assessment Approach

The AESO's process for GRIP uses a risk-based framework, as shown in Figure A1, which consists of:

- Applicability
- Pre-screening
- Screening
- Detailed study, report and submission
- Result acceptance
- Mitigation implementation

Figure A1: Risk-Based Assessment Approach



The phases of this process occur at different points throughout the AESO's Connection Process. For topics related to AESO Authoritative Documents, MPs are responsible for completing applicability, pre-screening and screening steps independently, and are encouraged to use the approach and methodology outlined in this guideline. In all other cases, the AESO will conduct these initial steps. These steps will determine whether a facility requesting system access can be excluded from further analysis or requires further study as a high-risk project. Projects identified as high risk will include a detailed study requirement in the project's functional specification. This guideline provides details on the recommended approach for conducting detailed studies. Upon receiving the detailed study, the AESO will work with MPs to review and comment on the report in accordance with this guideline. We may revise project's functional specification if the report results in changes to a project's scope of work.

Applicability

The objective of applicability phase identifies projects requiring further assessment using applicability criteria based on accessible project information available early in the customer connection process such as, facility size, type and technology. As this topic relates to the AESO Authoritative Documents, the guidelines applicability aligns with that of the relevant AESO's Authoritative Documents.

Once a project meets the applicability criteria it will move to the next relevant step following the guideline. MPs have the option to skip the pre-screening or screening steps and move directly to the detailed study or mitigation steps.

Pre-screening

The objective of pre-screening is to conduct a further assessment once the preferred connection alternative is selected. At this stage, the project details such as point of connection, nearby facilities and project scope are known, which are used to help identify potential high-risk projects. This information helps the MP and the AESO understand the risk of meeting DRP capability requirements. Pre-screening is not applicable to DRP capability assessment.

Screening

The objective of screening is to conduct a further assessment when more detailed technical information on MPs proposed facility becomes known. This guideline introduces a technical evaluation to assess whether a project qualifies as high-risk. Projects are identified as high-risk move to the detailed study stage. Screening is not applicable to DRP capability assessment.

Detailed Study, Report and Submission

The objective of the detailed study is to demonstrate compliance with the AESO's Authoritative Document. If a project does not meet these requirements, it may create reliability risks to the AIES. The study aims to identify potential reliability issues through advanced calculations or simulations outlined in this guideline prior to project energization. To conduct this work, the responsible entity will require detailed project information and models, which usually occurs in the later stages of the customer connection process. The AESO will identify and include the detailed study and report submission requirements in the functional specification for the high-risk projects.

Mitigation

The detailed study report may show that the MP cannot fully demonstrate compliance with the AESO's Authoritative Document. When this happens, the MP must propose a solution to address the potential non-compliance and consult the AESO on the proposed solution. The detailed study will then need to be revised to confirm the effectiveness of the proposed mitigation.

As indicated above, a responsible entity has the option to skip the screening steps and proceed directly to the detailed study. Further, if the responsible entity is aware the detailed study will indicate a reliability issue or potential non-compliance, the responsible entity may proceed with proposing a mitigation solution to the AESO.

Result Acceptance

Upon submission of the detailed study report, the AESO will follow this guideline to review and comment on the report within a timely manner. The responsible entity of the detailed study will be responsible to address all AESO comments and authenticate the study report. The detailed study must be completed 100 days and 30 days prior to the project energization.

It is important to note that this guideline is meant to assist the AESO in understanding and mitigating the risks to reliability of the AIES. This risk-based assessment is not conclusive and if the reliability phenomenon is observed in real-time, we will work with the MP on real-time mitigation measures. Furthermore, project changes, accepted through the AESO's Project Change Proposal process may trigger the need for additional applicability, pre-screening, screening and detailed study.

Appendix B: Detailed Study Report Template

It is encouraged that a study report will be written based on the template below to present your relevant study, analysis, or findings for a specific study topic. Following AESO's study guidelines on the specific study topic can help the AESO to review your study report in an efficient and effective manner. This template can also be used for the report to present screening results if required.

1.0 Title Page

This section shall include report title, project number, author/reviewer/approvers names, date of submission and Association of Professional Engineers and Geoscientists of Alberta (APEGA) authentication.

2.0 Executive Summary

This section will provide a summary of the study report, including main objectives, study methodology, key findings, recommendations, mitigation if required, etc.

3.0 Table of Contents

This table will list sections and subsections with page numbers in the report.

4.0 Introduction/Objective

This section will outline the background information on a specific topic, and study purpose, objective and its scope.

5.0 Methodology and Scenarios

This section will elaborate on the study approach and list the scenarios to study. Other key information such as simulation software and its version, data collection methods, analysis or evaluation techniques should be included. Please check with AESO's corresponding study guideline to use the recommended methodology and scenarios.

6.0 Criteria (if applicable)

This section will define the basis for judgement and decision-making in the report, including applicable standards, justification for selecting these criteria, application of criteria, etc.

7.0 Inputs Data and Assumptions

This section will define the information, variables and underlying assumptions in the report, including raw data and key variables, credible assumptions made in the study. Please check with AESO's corresponding study guideline to use the recommended inputs and assumptions.

8.0 Simulation Results Analysis

This section will demonstrate the key outcomes from the study, including overview of the simulation, data presentation using tables, graphs or charts, and interpretation of expected or unexpected results. Please check AESO's corresponding study guideline to use the recommended way to present simulation results if defined.

9.0 Mitigation/Correction Actions (if applicable)

This section will explore solutions or measures to address risks identified in the study report and proposes the mitigation/corrective actions which shall be implemented prior to the project energization. If the mitigation requires another study to confirm the effectiveness, the separate study report can be submitted to the AESO.

10.0 Conclusion

This section will summarize the main takeaways, interpret the implications of the findings and provide the final thoughts to support the decision-making.

11.0 References

The section will list all sources cited in the study report.

12.0 Appendices

This section will provide some additional information that supports the study report. It can include raw data, diagrams, detailed calculations, etc.

Alberta Electric System Operator

3000, 240 4 Avenue SW
Calgary, AB • T2P 4H4
aeso.ca

06/2026