Conductor and Line Optimization

Assessment Guideline

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

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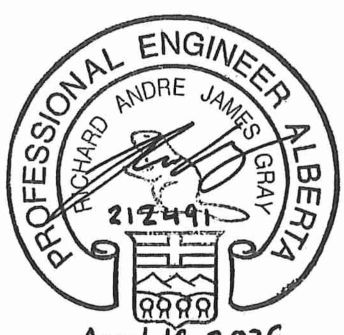
	Name	Signature	Date
Author – Principal Engineer	**Richard Gray, P.Eng**		**April 16, 2026**
Checked & Approved – Senior Advisor, Operational Reliability	**Changling Luo, P.Eng**		**April 16, 2026**



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The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

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Executive Summary

Purpose and Scope

The Alberta Electric System Operator (AESO) has developed the Conductor and Line Optimization Assessment guideline to support market participants (MPs) in complying with the Conductor Selection requirement under Section 503.22(9) of the ISO rules, *Bulk Transmission Line Technical Requirements*. This guideline:

- Informs stakeholders about how a project will assess conductor or line optimization through a standardized approach
- Provides transparency and guidance on how to conduct the applicability, pre-screening, screening and detailed study by the responsible entity and how to provide the detailed study report to the AESO, demonstrating compliance
- Outlines key parameters such as typical tower types, conductor types, conductor sizes and other factors may apply to conduction selection and bundle configuration
- Explains how the Conductor and Line Optimizations Assessments fit into the AESO Connection Process

Rationale

A conductor or line optimization study is about finding the optimal alternative of the type/size of the tower and conductor combination of the subject bulk transmission line. In most cases, the optimal alternative yields the lowest net present value of the combined capital cost, operating and maintenance (O&M) cost, and line thermal loss cost during the entire life of the line. This guideline provides a standardized, risk-based approach to support the conductor or line optimization assessment and the compliance.

Performance Criteria

Final selection of the optimal tower/conductor combination is based on the lowest net present value of the viable options.

Application

MPs are expected to use this guideline for all applicable projects to assess compliance with conductor and line optimization requirements before energizing their facility.

1. Conductor and Line Optimization Introduction

1.1 Background

Legal owners of a bulk transmission line, who meet certain criteria, are required to conduct either a conduction optimization study or a bulk transmission link optimization study pursuant to subsection 9(1) of Section 503.22, *Bulk Transmission Line Technical Requirements* of the ISO rules (Section 503.22), providing evidence of compliance with the AESO Authoritative Document, which will be documented in a project's functional specification.

Market Participant Choice (MPC) project in Alberta allows market participants to build radial transmission line in the project and transfer the line ownership to the transmission facility owner (TFO) in post energization. In several cases, the AESO has observed that market participants did not use the same approach to determine the conductor and line structure to install with the TFO. The TFO may refuse the ownership transfer until the discrepancy is addressed after the line is energized. This issue has added lots of technical uncertainties in operations and took AESO's resource to mediate the argument between the market participant and the TFO.

This guideline was developed to educate stakeholders about how a project will assess conductor or line optimization through a standardized approach. It provides transparency and guidance on how to conduct the applicability, pre-screening, screening and detailed study by the responsible entity and how to provide the detailed study report to the AESO, demonstrating compliance.

This guideline is not authoritative and for information purposes only.

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 Conductor Selection

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

Deliverable	AESO	Transmission Facility Owner (TFO)	Generation Facility Owner (GFO)	Market Participant (MP)
Applicability and Pre-Screening (Earliest Connection Process Stage: Stage 3)				
Determine if the proposed bulk transmission line is applicable to a conductor or line optimization study	A, R	I	I	I
Detailed Study				

Deliverable	AESO	Transmission Facility Owner (TFO)	Generation Facility Owner (GFO)	Market Participant (MP)
(Earliest Connection Process Stage: Stage 3)				
Functional specification will include detailed study with the following key parameters: • Minimum line thermal capacity megavolt-ampere (MVA) for summer and winter • Line impedance range (for looped or system lines only) • Average annual line power flow MW (20 years) • Average annual pool price $/MWh (20 years) • Discount rate, return on equity and depreciation rate	A, R	I	I	I
Detailed conductor optimization study: Carry out the study	C	C	I	A, R
Result Acceptance and Mitigation Recommendation (Earliest Connection Process Stage: Stage 3)				
Provide study report to the AESO. The report must include all information as outlined in the “Study Report” section	I	I	I	A, R
Review study results and as needed, recommend changes to study parameters and methods	A, R	C	I	C
As necessary, redo a conductor optimization study with new parameters and/or methods	C	C	I	A, R
Approve the study results and, as necessary, issue an updated functional specification	A, R	I	I	I
Energization Authorization (Earliest Connection Process Stage: Stage 3)				

Deliverable	AESO	Transmission Facility Owner (TFO)	Generation Facility Owner (GFO)	Market Participant (MP)
Complete line design based on the approved study results	C	C	I	A, R
Complete Conductor or Line Optimization 100-day Energization Checklist to the AESO	I	I	I	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

Projects that may be applicable to this guideline include:

- Conductor optimization study: A bulk transmission line having a length of ≥10 km
- Line optimization study: 240/260/500 kV bulk transmission line having a length of ≥50 km

1.4 Pre-Screening and Screening

The projects listed in the applicability section do not require additional pre-screening and screening. These projects may proceed directly to performing the conductor or line optimization study and providing the necessary deliverables.

1.5 Detailed Study

As outlined in AESO's Risk-Based Assessment Approach section, the need for a detailed conductor or line optimization study is identified if a project meets the applicability. The project's functional specification will then be updated to include the conductor or line optimization study requirement with the information supporting the required study. Based on the study result, the TFO will coordinate with the MP to assess the risk of conductor selection by complying with the conductor selection assessment outlined in this document.

1.5.1 Study Methodologies – Conductor Optimization

A conductor optimization study is about finding the optimal alternative of the type/size of the conductor of the subject bulk transmission line. The word “optimal” generally means the most practical and cost-effective. In most cases, the optimal alternative yields the lowest net present value of the combined **Capital** cost and the line thermal **Loss** cost during the entire life of the line.

Total estimated cost = **Capital** + NPV(**Loss**) in which NPV means “net present value.”

NPV(**Loss**) = $\sum \frac{\text{cost of thermal loss (resistive loss) in year } i}{(1+\text{discount rate})^{i}}$

The study period is usually 20 years for the present value calculations unless otherwise specified in the AESO’s functional specification.

Each of the three cost components mentioned above can be further expressed as:

- **Capital** cost generally includes the following cost components
  - conductor
  - insulators
  - spare

The above cost components are usually based on the owner’s past experience with reasonable consideration of all unique characteristics of the subject line.

- **Loss** cost in a year

= $\left(\frac{\text{Average Line Power Flow (MVA)}}{\sqrt{3} \times \text{Nominal Voltage (kV)}}\right)^{2}$ × 8760 × (line resistance Ω) × (pool price $/MWh)

1.5.2 Study Methodologies – Line Optimization

A line optimization study is about finding the optimal alternative of the type/size of the tower and conductor combination of the subject bulk transmission line. The word “optimal” generally means the most practical and cost-effective. In most cases, the optimal alternative yields the lowest net present value of the combined **Capital** cost, operating and maintenance (**O&M**) cost and line thermal **Loss** cost during the entire life of the line.

Total estimated[1] cost = **Capital** + NPV(**O&M**) + NPV(**Loss**) in which NPV means “net present value.”

NPV(**O&M**) = $\sum \frac{\text{cost of operation and maintetnance in year } i}{(1+\text{discount rate})^{i}}$

[1] The word “estimated” means “practical and reasonable”. The legal owner of a bulk transmission line may use multiple sources including, but not limited to, recent projects, manufacturers’ reports and/or peer utilities’ cost figures if reasonable effort is made to ensure accuracy.

$$\text{NPV}(\textbf{Loss}) = \sum \frac{\text{cost of thermal loss (resistive loss) in year } i}{(1+\text{discount rate})^{i}}$$

The study period is usually 20 years for the net present value calculations. However, the AESO may specify, in the functional specification, a longer or shorter study period. The AESO notes that, historically, some TFOs have voluntarily used a 40-year study period for certain projects and the AESO accepted this study period.

Each of the three cost components mentioned above can be further expressed as:

- **Capital** cost generally includes the following cost components
  - design and engineering
  - foundation
  - tower
  - insulators
  - conductor
  - right-of-way
  - construction
  - spare
  - other costs, e.g., costs of failure and restoration which are further elaborated below

The above cost components are usually based on the owner's past experience with reasonable consideration of all unique characteristics of the subject line.

- **O&M** cost in a year

  = Estimated labor and material cost to carry out O&M activities during the year. This cost can be based on the owner's historical experience on similar lines. If the initial legal owner is an MPC developer, it is suggested that the MPC developer discuss with the incumbent TFO.

  If, in the owner's judgment and/or analysis, the O&M costs of all design options do not vary significantly, this O&M cost element may not be included, as the inclusion does not change the result of cost comparison.

- **Loss** cost in a year

$$= \left(\frac{\text{Average Line Power Flow (MVA)}}{\sqrt{3} \times \text{Nominal Voltage (kV)}}\right)^2 \times 8760 \times (\text{line resistance } \Omega) \times (\text{pool price \$/MWh})$$

1.5.3 Study Assumptions and Limitations

Traditionally, conductor or line optimization studies did not account for other cost components, such as failure and restoration costs. It was generally assumed that, for a given line designed to withstand the same environmental loadings, the cost of failure across different designs would be nearly identical, if not the same.

However, the AESO has since recognized that, in certain climate zone, different structure designs for the same line rating and weather loading may lead to significant variations in the failure modes and, consequently, in expected interruption costs. For example, while wooden poles are less expensive than steel towers, they are more susceptibly to wildfire damage, increasing the risk of catastrophic failure. In an area with high wildfire risk, wooden structures can ultimately prove more costly compared to steel towers once failure and restoration costs are considered. Another example is when a substantial portion of a transmission line lies within a floodplain, where certain foundation options may not remain the lowest-cost choice once failure and restoration costs are included in the total cost.

The AESO now permits a legal owner of the transmission line to include extraordinary factors, such as wildfire risk and flooding concern, in a line optimization study as long as historical climate events their inclusion.

1.5.4 Required Inputs and Data

Tower Type (applicable to line optimization studies)

A viable tower option must support the selected conductor size and meet or reasonably exceed the environmental loadings specified in the AESO's functional specification.

Over the years, each TFO in Alberta has standardized the common tower types in its service territory based on its design templates, experience on historical projects and the supplier list. It is highly suggested that an MPC participant coordinate with the incumbent TFO for the selection of the viable tower types.

A line optimization study for a bulk transmission line with a lattice steel tower often involves estimating the tower weights as part of the optimization process.

The legal owner should consider whether it is best to use standard towers, for which detailed design information is available from the incumbent TFO and/or the AESO, or to develop new structures. The legal owner should discuss the rationale for the use of new tower types with the incumbent TFO and must provide a sufficient explanation in the line optimization study report before entering the design stage.

In selecting the tower type, the AESO permits all 500 kV lines and certain 240/260 kV lines to be designed with a maximum conductor temperature of less than 100°C based on the estimated line power flow, particularly for radially connected lines or tapped lines where there is low probability of other taps in the future. The AESO will specify, in a functional specification, any 240/260 kV lines which can be designed with a maximum conductor temperature of less than 100°C.

Conductor Type (applicable to conductor and line optimization studies)

The AESO allows the following conductor types in a conductor optimization study:

- Aluminum conductor steel reinforced (ACSR) or aluminum conductor steel reinforced/trapezoidal (ACSR/TW)
- Aluminum conductor steel supported (ACSS) or aluminum conductor steel supported/trapezoidal (ACSS/TW)

Any other conductor types must be approved by the AESO on a project-by-project basis. If approved, the AESO will include the approved conductor type in a revised functional specification document.

Conductor Size (applicable to conductor and line optimization studies)

A viable conductor option must meet or reasonably exceed the line thermal capacity requirement specified in the AESO's functional specification. The conductor sizes listed below are standard and preferred sizes for ACSR or ACSR/TW conductors. These standard or preferred sizes contribute to the proper spare strategies for fast emergency restoration within or between TFOs. It is strongly recommended that the legal owner consider these standard sizes in developing the conductor option list. If a different conductor size must be selected, coordination must be made with the incumbent TFO to ensure a satisfactory spare plan.

- 266 kcmil Partridge
- 397 kcmil Ibis
- 477 kcmil Hawk
- 795 kcmil Drake
- 1033 kcmil Curlew
- 1234 kcmil Yukon (note: this conductor size is less common than other sizes in Alberta)
- 1590 kcmil Falcon

Other Factors

For critical 240/260 kV and 500 kV bulk transmission lines, additional factors may apply to conductor selection and bundle configuration, such as corona effect, noise level, system compatibility, line impedance, electrical load sharing and other system-related issues. These factors will be identified in the AESO's functional specification.

The AESO's functional specification may also include special requirements, such as staged developments, line crossing and/or underground options. The AESO encourages the legal owners, especially MPC participants, to engage in discussions with the incumbent TFO as early as possible and if necessary, to communicate with the AESO.

1.5.5 Study Outputs

Upon completion of the conductor or line optimization study, the MP should provide the following:

- Detailed study report, which at a minimum includes:
  - A list of all viable options (for tower and conductor combination) to meet the capacity and functionality requirements in the AESO's functional specification
  - List of risks, assumptions and parameters used in the study
  - A summary table which shows the comparison of the total costs of the viable options
  - Explanation or conclusion on the final selection of the optimal tower/conductor combination

  - For a new design of tower structures (particularly lattice steel tower structures or steel pole structures), design drawings must be attached to the report
  - The finalized report shall be certified by a professional engineer registered, and in good standing, with the Association of Professional Engineers and Geoscientists of Alberta (APEGA)

- As a minimum, a conductor optimization study report should present a comparison of the total cost of different line and conductor options in a summary table format. The following is a sample table:

Conductor Type	Capital Cost ($)	PV (Loss Cost) ($)	Total Cost ($)
Conductor Option 1			
Conductor Option 2			
Conductor Option 3			
……			

- As a minimum, a line optimization study report should present a comparison of the total cost of different line and conductor options in a summary table format. The following is a sample table:

Conductor Type	Tower Type	Capital Cost	PV (O&M Cost)	PV (Loss Cost)	Total Cost
Conductor Option 1	Tower Option 1				
	Tower Option 2				
	…				
Conductor Option 2	Tower Option 1				
	Tower Option 2				
	…				

Conductor Type	Tower Type	Capital Cost	PV (O&M Cost)	PV (Loss Cost)	Total Cost
…More conductor options…	Tower options				

- Study results may have implications for design or equipment change, which in turn may result in:
  - Additional time for the market participant to consider the tower type and conductor size based on the study results; or
  - The market participant required to redo the study with new parameters.

1.5.6 Study Report

The conductor optimization study report in Appendix A and a conductor optimization study report in Appendix B, can be used to present your detailed study. Using the template can help the AESO review your report in an efficient and productive way.

1.5.7 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 shall review the study report within reasonable time and may provide comments, requesting the MP to respond prior accepting the report. The AESO 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.

1.6 Energization Requirements

The AESO authorizes the project to connect to the AIES and achieve energization when the project meets all our 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 MP to check with AESO's project manager to fully understand how to meet the energization requirements.

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

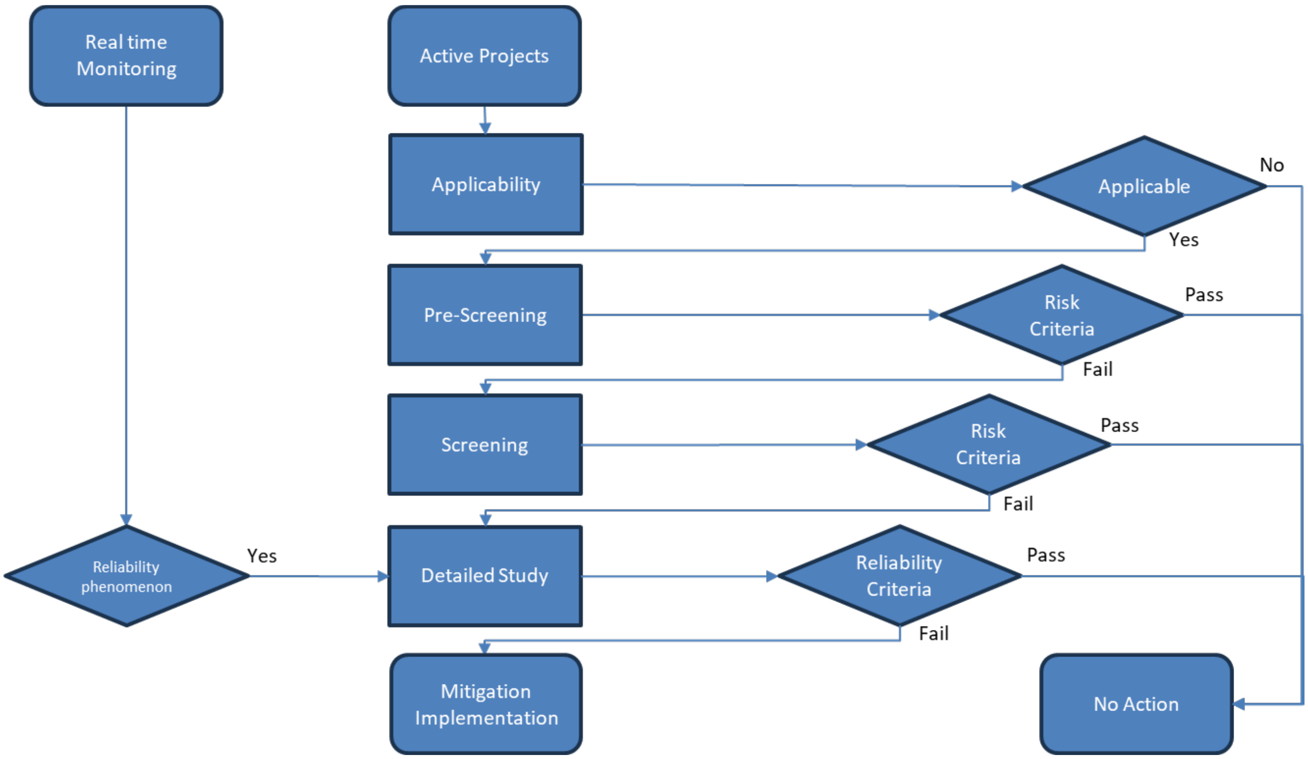
As a result of these emerging AIES reliability challenges, the AESO has identified several areas where performing Grid Readiness, Integration and Performance (GRIP) Requirements would be beneficial. System reliability is also heavily dependent on how market participants (MPs) conduct technical assessment 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



These phases occur at different points throughout the AESO's Connection Process. The objective of each phase is for the AESO to identify whether a facility requesting system access can be excluded from further analysis, through assessing defined parameters, criteria or results. For a topic already included in the AESO's Authoritative Documents, MP 's are responsible for completing each phase by using the AESO's recommended approach and methodology in the guideline.

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. If the project meets the applicability, it will move directly to the detailed study phase.

Pre-screening and Screening

Pre-screening and screening are used to conduct a further assessment when more detailed technical information on MP's proposed facility becomes known. But they are not required to conductor and line optimization assessment.

Detailed Study

The objective of the detailed study is to demonstrate compliance with the AESO's operational requirements through advanced calculations or simulation outlined in this guideline prior to project energization. To conduct this work, the responsible entity will require detailed project information and models, usually 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.

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. The AESO will review the detailed study results and proposed mitigations provided by the legal owner of a bulk transmission line, and the project functional specification will be revised to reflect the required mitigations, as applicable. In 100 days and 30 days before project energization, deliverables related to conductor selection assessment and mitigations shall be submitted, per the AESO's Energization Package Requirements and must be accepted by the AESO to achieve project energization. Details of the AESO's approach are presented in the following sections.

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: Conductor Optimization and Line Optimization 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.

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aeso.ca

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