Transmission System Utilization
Concepts and 2022 Assessment

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Executive Summary

Transmission system utilization is the retrospective result of forward-looking transmission planning practices that balance the objectives of achieving good system utilization while maintaining unutilized capacity to meet future needs. The AESO has developed utilization metrics and related concepts to: 1) facilitate a common understanding of this multifaceted subject; and to, 2) provide transparent communication about utilization in the context of both a retrospective assessment and the prospective assessment of enabling future needs.

This report discusses, and illustrates with examples, four key concepts of transmission utilization:

- Capacity margin
- Reliability margin
- Capacity used for power flow
- System constraints

> *A key conclusion from this analysis is that transmission utilization and transmission capability are the same concept but viewed from different perspectives.*

Utilization is the portion of capacity already in use, while capability is the remaining portion of capacity used to accommodate future transmission needs. As such, a transmission system must be designed with an appropriate balance between utilization and capability. This balance ensures that the transmission system can provide the necessary capacity to meet current and future power demand while maintaining operational reliability and flexibility, and that it can adapt to changing generation, load, economic and market conditions.

Based on the established concepts, the AESO developed a methodology and process to perform the transmission utilization assessment in a consistent, efficient and transparent manner. The AESO's methodology for transmission system utilization includes:

- A model and process to estimate common transmission line-by-line utilization metrics based on their thermal rating
- An interactive transmission utilization map for effective communication
- A process for assessing utilization within specific system contexts

This estimation includes simplifications and does not capture all aspects of utilization. For example, when assessing the utilization of a specific line, the results must be assessed on that particular line and within that line’s unique context. Using this methodology, the AESO conducted the 2022 utilization assessment for 240 kV and 500 kV transmission lines.

Key Findings

> *At a high level, the assessment found that the basic transmission utilization metrics reflect a balanced overall Alberta electric system utilization pattern between retrospective transmission utilization and forward-looking transmission capability.*

Further in-context assessment at the facility (line) level reveals that transmission utilization of a specific facility should be assessed with considerations for the timing and related uncertainty of the growth associated with that facility.

For instance, a new transmission line should not be highly utilized in its first in-service years, otherwise, there is no remaining capacity for future growth. In some situations, there might be more limited constraints than the estimated thermal rating utilization, such as voltage stability or dynamic constraints. In these situations, the line's utilization should be further assessed based on the most limited constraints.

In summary, the AESO's utilization assessment is intending to assist stakeholders' understanding of how to manage capacity, reliability and future needs to ensure the system's continued success. To the extent stakeholders find this assessment informative, the AESO will update the assessment annually.

Table of Contents

Figures

1 Introduction

The Alberta Electric System Operator (AESO) has developed utilization metrics to facilitate a common understanding of this complex subject, and to provide transparent communication about utilization. This report documents notable utilization concepts, the methodology used to estimate utilization, and the utilization results for the year 2022.[1] Utilization results were calculated for 240 kilovolt (kV) and 500 kV lines in the Alberta Interconnected Electric System (AIES).

This report provides a retrospective assessment of the utilization of the transmission system in the context of forward-looking transmission planning and development and offers insights into the factors that affect utilization performance. It also discusses the factors that influence utilization, including:

- Capacity margin
- Reliability margin
- Capacity used for power flow
- System constraints

It is important to note that transmission planning is a balancing act between achieving good utilization and maintaining unutilized capacity to meet future needs.

1.1 Disclaimer

The report provides the estimated historical utilization of the transmission system in 2022. Although utilization is a consideration in transmission planning and development, it alone is not a sufficient factor to evaluate the need, feasibility and impact of a specific transmission project. The need for transmission capacity expansion is approved in a formal regulatory application and approval process (see the AESO's Long-term Transmission Plan and Transmission Projects for more information on each transmission project). It is also important to note that the utilization of each transmission line does provide an indicator of the remaining capacity on a given line. However, because utilization does not consider system-related constraints it does not provide an accurate assessment of the estimated additional capacity (capability) that could be connected to the transmission line or the substation(s) linked with that line. The AESO’s Transmission Capability Map provides information related to transmission capability.

The AESO makes no representations, warranties or guarantees, whether express or implied, as to the accuracy, reliability, completeness, currency or non-infringement of the map and associated information, or its fitness for any particular purpose. While the AESO has made every attempt to ensure that the information is timely and accurate, the AESO is not responsible for any:

- Errors or omissions in the report and associated information; or,
- Losses or costs incurred as a result of the use, conversion, publication, transmission, installation or improvements to the map and associated information, even if such losses or costs are foreseeable.

[1] The AESO first discussed utilization in the ‘Transmission Capability and Utilization – Information Session 1’ on November 23, 2021. During this session, the AESO committed to establish a methodology and solution process in 2022, conduct transmission utilization studies in 2022-2023, and communicate the results in 2023.

2 Utilization Concepts

This section discusses utilization concepts, specifically within the Alberta legislative and policy framework.

The facility rating (capacity) of a transmission facility is the maximum limit at which power can flow through the facility. This capacity is used in four ways:

1. Capacity margin to accommodate future transmission system needs
2. Reliability margin to facilitate reliable operation of the transmission system
3. Capacity used for power flow which facilitates fluctuating power flows through the facility over time
4. Capacity that cannot be utilized at the facility level due to system constraints, such as system operating limits

It is a common misconception to equate utilization to only the flow aspect of how capacity is used[2]—it is essential to also consider the other three aspects in understanding how the transmission system operates. Each of these factors is discussed in more detail in the following sections.

In its simplified form, utilization of a transmission facility is the ratio of the sum of capacity used for power flow (2.3) and reliability margin (2.2) to its facility rating, expressed as a percentage, as shown in the following equation.

$$utilization = max\left(\frac{|\,flow\,| + reliability\ margin}{\text{thermal rating (capacity)}}\right)$$

This simplified utilization equation does not include the capacity margin for future needs (2.1) or the capacity that cannot be utilized due to system constraints (2.4), whereas transmission system expansion planning includes all four factors as key considerations. This difference can cause utilization results and the need for transmission system development to deviate.

2.1 Capacity Margin to Accommodate Future Transmission Needs

Utilization does not consider the "capacity margin to accommodate future transmission needs." However, capacity margin is a key planning[3] consideration that drives transmission system development which, in turn, impacts utilization and therefore should be considered when reviewing the results.

Transmission system infrastructure has an economic and expected lifespan lasting decades. It typically takes around seven years to conceptualize, permit and construct a new transmission line. Given this timeline, it is not feasible to build new transmission infrastructure on demand or in marginal increments to accommodate gradual growth.

It is often an appropriate economic choice to plan and build the transmission system at an appropriate scale and in advance of the forecasted growth when certain milestones have been met.

[2] Utilization metrics are well defined in other industries and usually focus on "average divided by total." For instance, businesses measure resource utilization as "productive hours / available work hours." Extending this standard definition to the transmission system results in "average flow / capacity." However, this results in a misconception as it does not appropriately measure how the transmission system is planned or operated.

[3] *Transmission Regulation*, Part 2 Transmission System Planning and Part 3 Transmission System Criteria and Reliability Standards.

Transmission lines built to accommodate forecasted gradual growth will likely (as intended) have relatively low utilization at the beginning of their service life, and their utilization will gradually increase as the forecasted growth materializes.

For this situation, a relatively low annual utilization in a transmission line's early life should be assessed within the context of gradual growth of installed generation and load. This 2022 utilization assessment is based on a single year and therefore is neither able to adequately reflect the concept of historical gradual growth in utilization, nor does it capture the planned future utilization of Alberta's transmission system.

Due to the nature of Alberta's uncongested transmission policy and energy-only market structure, infrastructure planning needs to be based on a forecast of market-driven generation project development and load growth (system need growth). Since the need for planned infrastructure is based on forecasts, the timing to construct new developments can be uncertain—too early and there is potential for a prolonged period of low utilization; too late and there is potential for congestion, or inability to serve load.

In order to minimize the impact of future growth and construction timing uncertainty, the AESO uses a milestone-based planning approach, which links transmission development planning decisions to milestones of related generation projects or load development(s). This seeks to ensure the right transmission facilities are available at the right time, in a way that optimizes the use of the transmission system.

In addition, having additional capacity margin provides flexibility in how transmission infrastructure is used. Flexibility in the transmission system is beneficial when contemplating, planning and facilitating different potential future scenarios—for example, accommodating significant energy system transitions, including growth in new technologies such as grid-scale solar and electric vehicles.

Figure 1[4] illustrates this forecasted gradual growth in utilization concept. The figure shows the estimated utilization of transmission line 955L between Goose Lake 103S and Peigan 59S. As seen in the figure, transmission line 955L's annual utilization was about 35 per cent in 2011, its first full year of service, and gradually increased to about 70 per cent in 2021. This gradual increase in utilization is caused by the gradual growth of installed generation in the local area.

This example demonstrates that the 955L transmission development provided capacity margin to accommodate future transmission needs, namely generation in the local area, and this capacity margin decreased as the utilization increased. By extension, a transmission development could be required to further accommodate future transmission needs should the forecasted growth exceed the capacity margin; consequently, this development would result in a decrease in the local line's utilization until that growth materializes.

Finally, this example illustrates that a transmission line's utilization should be assessed over a longer time horizon, as the line is intended to accommodate load or generation growth over its projected lifespan. This assessment did not calculate line utilization over a longer time horizon due to prohibitive transmission system complexities and resource requirements.

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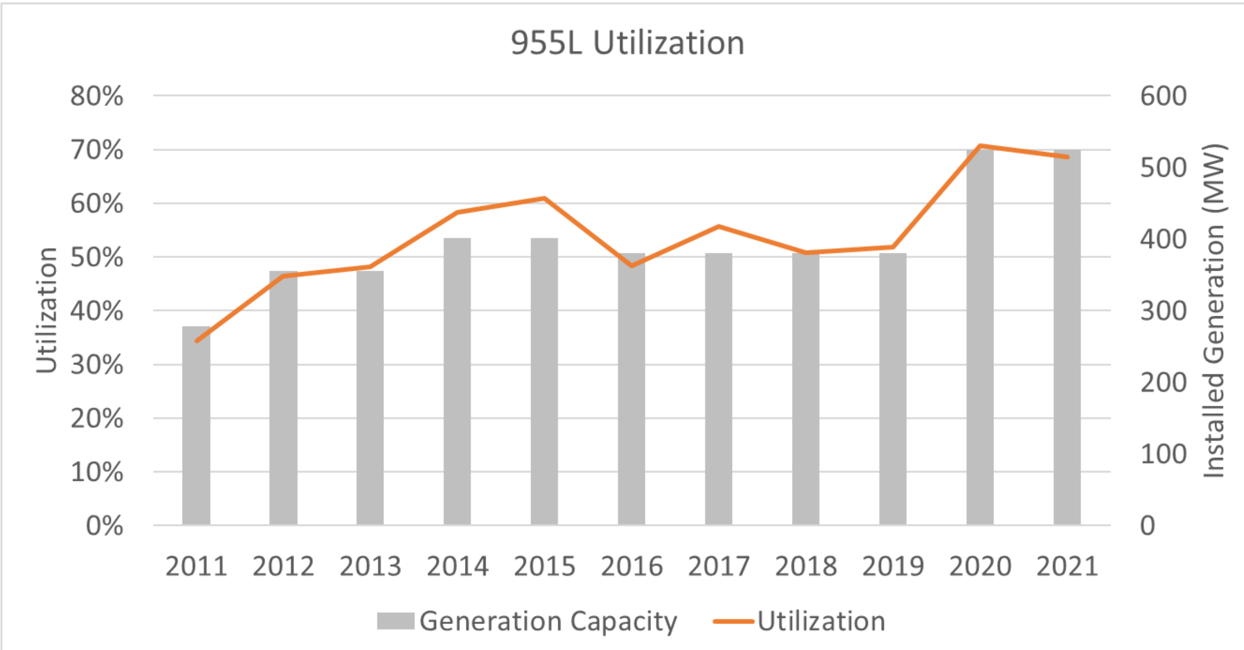
[4] The ten-year historical utilization was estimated for only 955L using a different methodology than the methodology employed in this assessment. This assessment focused on the year 2022 – the AESO did not apply the methodology employed in this assessment to other historical years.

Figure 1: Transmission Line 955L Annual Utilization from 2011 to 2021



2.2 Reliability Margin

As mentioned in the opening of this section, utilization considers the "reliability margin to facilitate reliable operation of the transmission system."

> *It is by design that the electric power system is planned and operated with "reliability margin" to accommodate credible uncertainty, as there could be planned and/or unplanned outages (forced outage or contingency) at any time.*[5]

In a transmission network, when there is a contingency, the flow carried on the transmission facility before the contingency instantaneously (after the contingency) reroutes to other transmission facilities based on the network topology, impedances and physics. This can significantly increase the flow on other facilities, especially for those nearby (measured electrically by impedances). For any transmission facility, reliability margin is reserved to instantaneously accommodate additional flow due to associated contingencies and facilitate reliable operation of the transmission system.

The following Figure 2 illustrates the "reliability margin" concept using two similar lines in parallel. In the left picture, both lines are in service, and each carries a similar level of power flow at ~40 per cent of its facility rating. In the right picture, there is a contingency on the top line (967L), and the flow that was on 967L instantaneously and automatically reroutes to the other line (968L), doubling its flow. Reliability margin is required to ensure the post-contingency flows do not exceed the facility rating.

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[5] *Alberta Reliability Standard*, TPL-002, FAC-010, and FAC-011

Figure 2: Transmission Line Flow Increase due to a Contingency

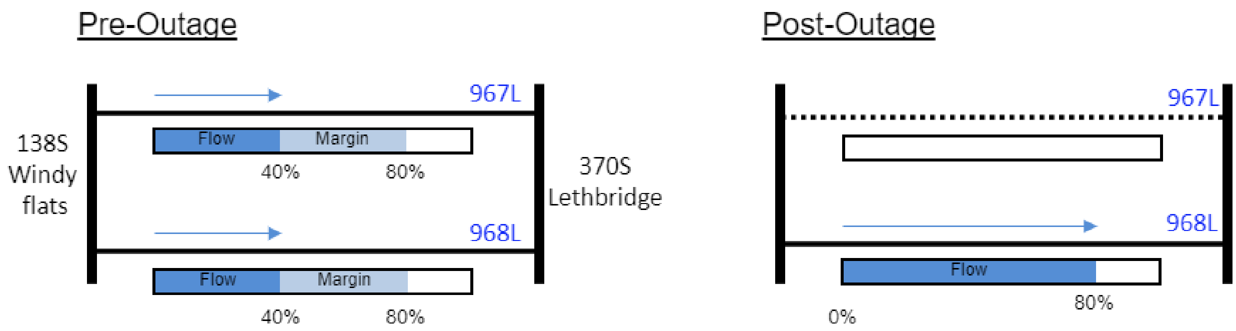
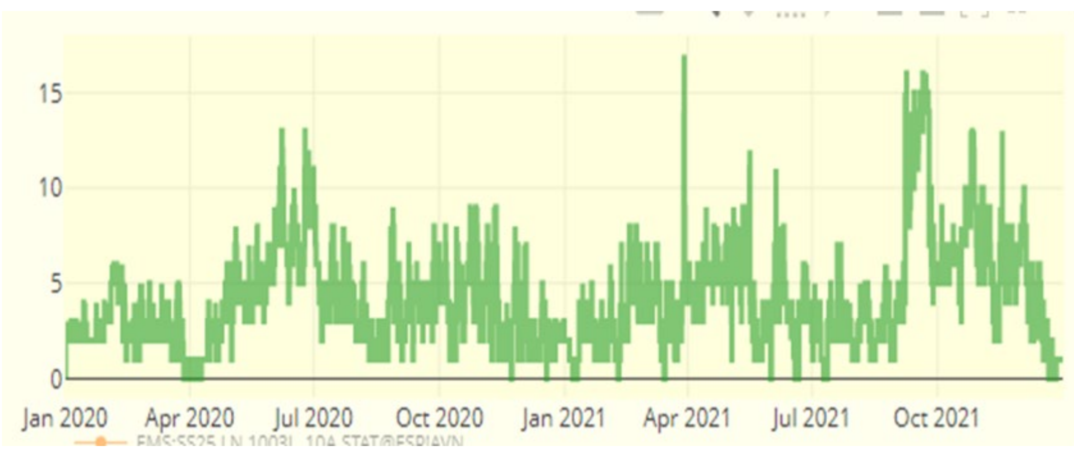


Figure 3 shows the historical number of simultaneous transmission line outages of 240–500 kV transmission lines in 2020 and 2021. The number of simultaneous outages ranges from zero to 17. Outages on the system are a normal occurrence. In fact, 85 per cent of the time, two or more 240 kV and above transmission lines were out of service in 2020 and 2021. Moreover, in April 2021, there were 17 different 240–500 kV transmission lines simultaneously out of service due to a winter storm. This further illustrates why the transmission system needs to be planned and operated with a sufficient reliability margin to accommodate credible contingencies and outages.

Figure 3: Number of Simultaneous Line Outages on Alberta's 240–500 kV Transmission System



There is an additional special consideration within the reliability margin concept. When adding capacity to the transmission system, as discussed in Section 2.1, the system can be enhanced by either (i) increasing the capacity of existing facilities, or (ii) constructing new facilities. The second option has the benefit of providing additional redundancy for transmission outages, which increases the reliability of the load and/or generation connection. In other words, more outages are required before the load and/or generation is disconnected from the system.

This is a significant consideration in the situation of a single radial line.

If having a reliable and uninterrupted connection is of utmost importance, then a double-circuit line is required to ensure redundancy for the outage of one the transmission lines. This can impact the utilization since the design is focused on ensuring reliability instead of the required capacity.

2.3 Capacity used for Variable Power Flow

Utilization considers the "capacity used for power flow." This capacity facilitates fluctuating power flows through the transmission facility over time.

Load demand is continuously fluctuating, based on the time of day and time of year. For example, demand fluctuates with:

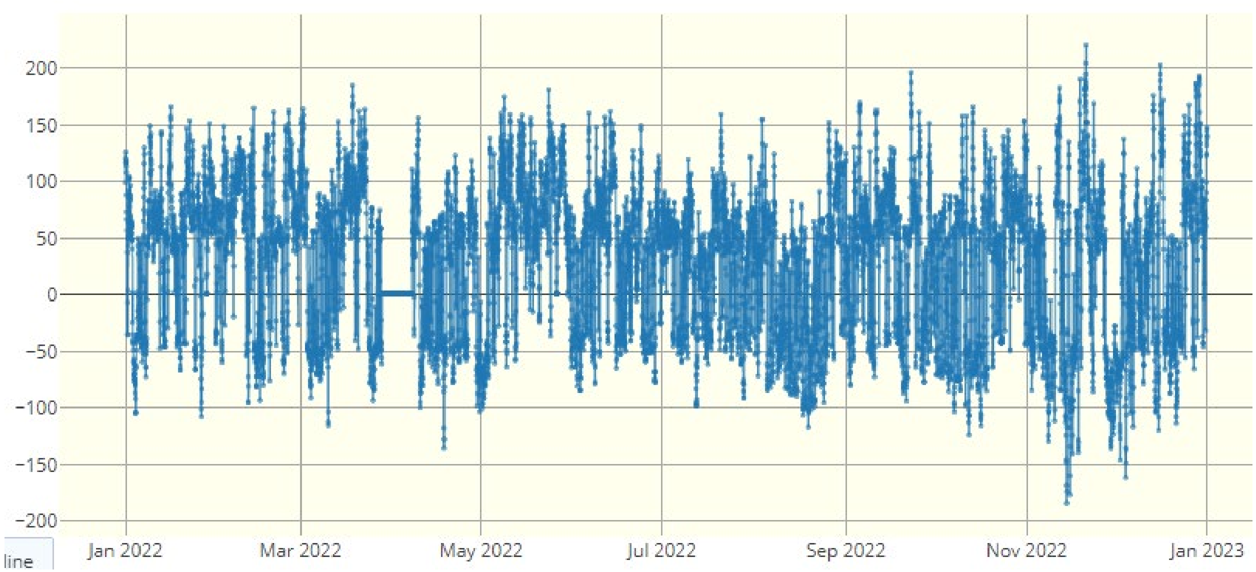
- Ambient temperature as air conditioning or heating demand changes
- Typical daily routines—for instance, electric appliances such as stoves and ovens are used around mealtime

Likewise, generation is also continuously fluctuating. For example:

- Generation fluctuates with load demand
- Individual generating units fluctuate to best compete in the electricity market
- Renewable generation fluctuates with weather conditions

These fluctuations in generation and demand result in swings in transmission facility flows. To accommodate the fluctuations in flow for all hours during the period, the line's flow capacity (rating) needs to be big enough to accommodate the maximum absolute flow (plus reliability margin).[6] Figure 4 illustrates the variable nature of transmission facility flows. For this transmission line, the flows varied between approximately -200 to 200 megavolt-ampere (MVA) (negative means flow is in the opposite direction).

Figure 4: Hourly Flow (MVA) of a Transmission Line over 2022



[6] *Alberta Reliability Standards*, TPL-001, TPL-002, FAC-010, FAC-011

Since line capacity must be designed to accommodate the maximum flow, utilization should be a function of the maximum absolute flow during the period. This max flow-based calculation rebuts the popular, though incorrect, belief that utilization is a function of average flow. The difference between max and average flow is the variance (fluctuation) in a general sense. The next two paragraphs further discuss why the max flow-based definition is more appropriate for calculating utilization. The key takeaway is that the average-based definition does not recognize the flow variance components that must be accommodated in transmission system operation and planning practices.

In Figure 4, the average absolute flow is 62 MVA. Therefore, if using an averaged-based definition, the line would be 100 per cent utilized if the line rating was 62 MVA; however, this would result in congestion for 44 per cent of hours during the year in this example. So, a 100 per cent average-based utilization would mean the transmission system was significantly under-planned or under-built for its intended purpose.[7]

Assessing the utilization of a transmission system based solely on its average use can be misleading and will not provide an accurate picture of its capacity utilization. This is because average use does not take into account the system's peak usage, which can have a significant impact on the system's ability to meet demand. For example, a transmission line with an average use of 40 per cent may appear to have ample unutilized capacity; however, if the peak usage is consistently above 90 per cent, it is operating at or near capacity and may require additional resources to meet demand. Therefore, it is important to consider peak usage when assessing capacity utilization.

2.4 Capacity that Cannot be Utilized Due to System Constraints

Utilization does not consider the “capacity that cannot be utilized due to system constraints.” However, having capacity that cannot be utilized due to system constraints inhibits utilization and should be taken into consideration appropriately.

Transmission facilities are a part of the interconnected system and, in many cases, are constrained due to system behaviours and interactions on the wider network. In other words, achieving a high utilization on a particular facility would result in reliability concerns on the wider transmission system. These reliability concerns could be related to voltage, transient or other thermal constraints in a region, area or sub-system. Facility capability is the power transfer limit respecting these system constraints (capacity minus the capacity that cannot be utilized due to system constraints). In many cases, a transmission facility’s capability is lower than its capacity (thermal limit). This concept is best explained using the following examples.

EXAMPLE 1 | SYSTEM LIMIT FROM A COMMON CONSTRAINT

In the following Figure 5, three transmission lines are in parallel and the power flowing through the group divides across all three lines (division is inversely proportional to line impedance). In other words, increasing the power transfer increases the flow across all three lines.

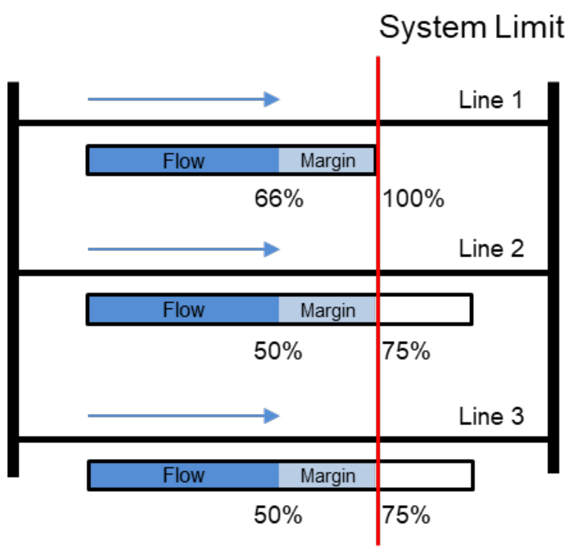
Because Line 1’s capacity is smaller than Line 2 and Line 3, Line 2 and Line 3 are only 75 per cent utilized once Line 1 is 100 per cent utilized. Further increasing the power transfer so that Line 2 and Line 3 would have a utilization higher than 75 per cent would result in reliability concerns on Line 1.

[7] *Transmission Regulation*, Section 15(1)

Therefore, the maximum achievable utilization on Line 2 and Line 3 is 75 per cent, and 25 per cent of the line capacity cannot be utilized due to the system constraint (Line 2 and Line 3 capability is 75 per cent of their capacity).

> *Line 2 and Line 3 are reported as 75 per cent utilized even though their practical utilization is 100 per cent.*

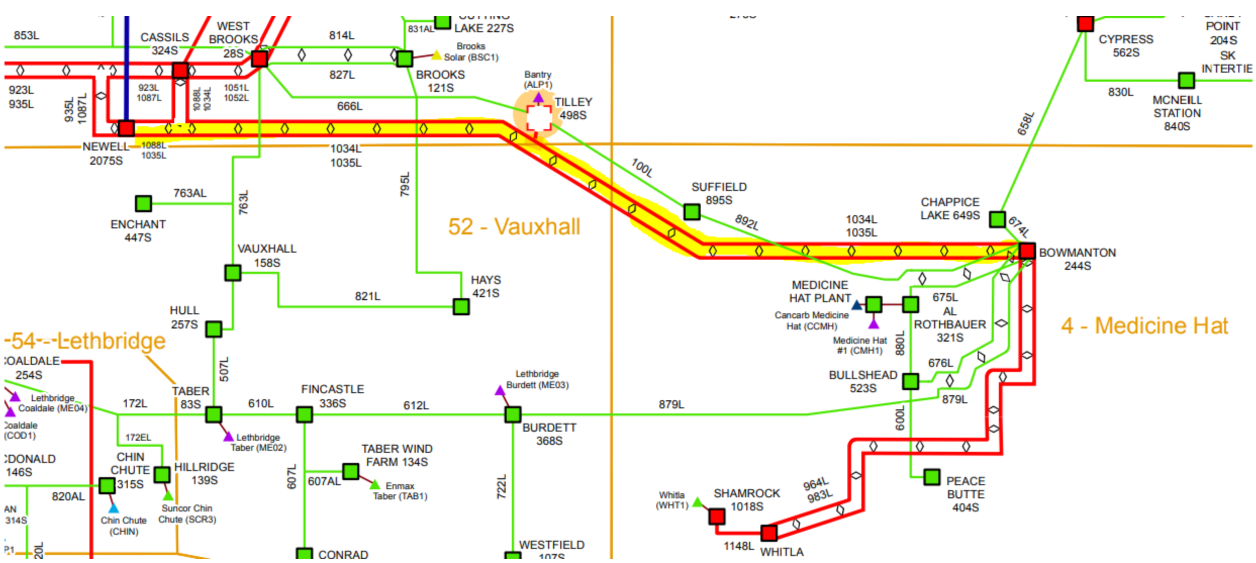
Figure 5: Common constraint System Constraint



EXAMPLE 2 | SYSTEM CONSTRAINT FROM VOLTAGE LIMIT AND MSSC

Figure 6 shows the Southeast Region of the AIES. Two 240 kV double circuit lines, 1034L and 1035L, from Cassils (342S) / Newell (2075S) to Bowmanton (244S) are highlighted.

Figure 6: 1034L and 1035L



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The 2022 utilization results are 61 per cent for 1034L and 59 per cent for 1035L. However, the power transfer capability of these two lines is limited by a voltage limit and most severe single contingency (MSSC) constraints.[8] The combined capability of these two lines is between 600 MW and 860 MW, which is 32 per cent to 45 per cent of the combined capacity (thermal rating). Therefore, after considering the reliability margin, the maximum achievable utilization on 1034L and 1035L is 64 per cent to 90 per cent, and 10 per cent to 36 per cent of the line capacity cannot be utilized due to the system constraints.

The practical utilization of these two lines should be assessed based on the more limiting system constraints; therefore, the practical utilization is between 68 per cent and 95 per cent.

These two examples reinforce the need, in certain situations, to further assess utilization within the context of system constraints.

2.5 Utilization Metric

As discussed in Sections 2.1 to 2.4, capacity is used four ways: i) capacity margin for the future, ii) reliability margin for reliable operation, iii) capacity used for maximum power flows, and iv) capacity that cannot be utilized due to system constraints.

In its simplified form, the utilization of a transmission facility is the maximum ratio of the sum of capacity used for power flow and reliability margin to its facility rating, expressed as a percentage. This is shown in the following equation:

$$utilization = max\left(\frac{|flow| + reliability\ margin}{\text{thermal rating (capacity)}}\right)$$

The equation is the cumulation of the utilization concepts.

1. The utilization is a function of maximum absolute flow (Section 2.3)
2. The utilization includes the reliability margin to accommodate contingencies (Section 2.2)

This equation is used in the methodology to calculate the historical utilization for 240 kV and 500 kV transmission lines. However, the equation does not include the capacity margin for future needs or the capacity that cannot be utilized due to system constraints. These concepts impact the overall utilization and should be considered when interpreting the results:

1. Utilization, a historical-facing metric, does not include the capacity margin built to accommodate future transmission needs (Section 2.1). However, capacity margin is a key planning consideration that drives transmission system development, which, as a result, impacts utilization and should be considered appropriately when interpreting the results.
2. Importantly, utilization does not include capacity that cannot be utilized due to system constraints (Section 2.4). System constraints reduce the capability of transmission facilities and should be considered; however, capturing the capability for each facility is very complex and is not feasible to implement within the methodology; these constraints are only applicable

[8] Refer to the *Bowmanton 244S Substation Voltage Support Project (7083)* on the AESO website

to specific situations and cannot be universally applied to every line. As discussed in Section 2, the analysis studies hundreds of transmission lines and thousands of different contingencies, which results in tens of millions of data points. In this case, trying to incorporate unique situations into a universal utilization calculation for every line is not a feasible approach.[9] Instead, the calculations use capacity—and system context needs to be considered when interpreting the results in areas with system constraints.

[9] The AESO first discussed utilization in the "Transmission Capability and Utilization – Information Session 1" on November 23, 2021. During this session, the AESO communicated that calculating utilization using only the thermal line rating (capacity) "is complicated enough to start with."

3 Implementation and Methodology

The objective of this assessment was to estimate and communicate historical transmission system utilization. This section discusses how the assessment was implemented and the methodology used to estimate utilization.

3.1 Implementation Overview

The transmission system utilization assessment covers a diverse array of situations, with some having specific complex considerations. The analysis studied hundreds of transmission lines, 8,760 hours and thousands of different contingencies, which resulted in tens of millions of data points. The assessment followed a multi-step approach to assess transmission utilization in an efficient and comprehensive manner.

There are three key steps in a transmission system utilization assessment:

1. **Calculate basic utilization metrics** for each transmission line in the system, as defined in Section 2.5. The methodology for this calculation is discussed in Section 3.2.
   - Addresses the generic and basic calculations that are common to all lines in a consistent and efficient manner. Appropriate modelling simplifications and automation are required to ensure an efficient, consistent and repeatable process.
2. **Implement an interactive transmission utilization map** to present, communicate and further analyze the basic utilization metrics for each line. The map is used to investigate and understand utilization patterns across the transmission system and to identify potential utilization outliers within the system context. This step is discussed in Section 3.3.
   - Communicates the result transparently and supports further case-by-case analysis, as needed.
3. **Analyze the utilization results** with the considerations discussed in Sections 2.1, 2.4, and 2.5. This step is discussed in Section 3.4.
   - Covers the specific considerations (discussed in Sections 2.1, 2.4, and 2.5) that are not reflected in the first-step calculation.

3.2 Calculate Basic Utilization Metrics

As discussed in Sections 2.2, 2.3, and 2.5, the utilization calculation requires hourly pre- and post-outage power flow data for every line in the transmission system being assessed. As there are hundreds of lines, thousands of hours and thousands of contingencies to be considered in the utilization calculation, it is necessary to have an automatic process that includes a system-level power flow model to calculate all the required data.

To address the millions of simulations and calculations required, as discussed above, the AESO developed a utilization simulation and calculation solution that leverages DC power flow (DCPF) and optimization techniques. The DCPF solution simplifies the calculation so that it is efficient and repeatable while maintaining acceptable accuracy. The complexity of system constraints cannot be assessed with DCPF; however, this is acceptable as the complexity is addressed in Section 3.4.

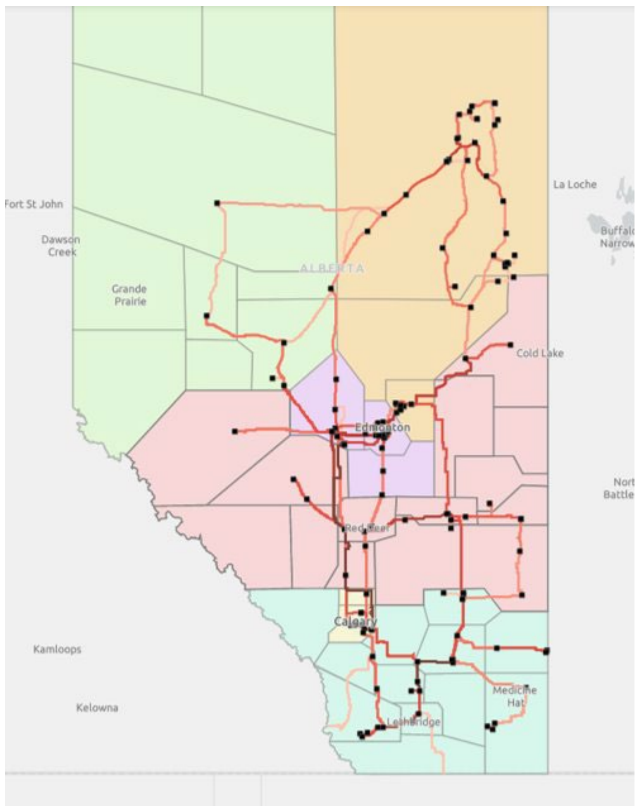
The AESO also implemented a result validation process by comparing the simulation results with historical line-by-line and hour-by-hour flow data. This included comparing pre-contingency and post-contingency flows for contingencies that happened in 2022. This validation process identified the accuracy range of the proposed solution and confirmed the accuracy of the methodology.

3.3 Interactive Transmission Utilization Map

The interactive utilization map is used to present, communicate, investigate and understand the utilization patterns across the transmission system. The map shows the utilization metrics calculated in Section 3.2 as well as basic line information.

Figure 7 shows the interactive transmission utilization map. On the map, the utilization of a line is represented in the scaled reddish colour; the darker the colour the higher the utilization; clicking on each line will open a pop-up window with more detailed information.

Figure 7: Interactive Transmission Utilization Map



The interactive transmission utilization map illustrates the utilization results so that the context of each line and its surrounding factors can be visualized. This helps to identify patterns and trends to better understand transmission system utilization and helps to support a deeper and more in-context utilization assessment and related discussion.

3.3.1 Comparing to the AESO Capability Map

In March 2022, the AESO published a Transmission Capability Map, which illustrates the estimated additional generation capacity that could be connected at different locations on the existing transmission system. Transmission capability and utilization are essentially the same thing but viewed from different perspectives.

- **Transmission capability** | Assesses the "unutilized" capability on the system to enable future generation connection opportunities—it takes a **forward-looking perspective** to assist in optimizing the use of the existing transmission system.
- **Transmission utilization** | Assesses the "already-utilized" capability/capacity on the system—it takes a **backward-looking perspective** to understand the current state of the transmission system, which can provide opportunities to inform forward-looking-based transmission planning and development practices.

3.4 Analyze Results with Additional Context Considerations

As discussed in the Section 2.1, the forecasted gradual growth of installed generation or load is not reflected in the annual basic utilization calculation. It needs to be further assessed on a case-by-case basis, especially for those transmission lines with low utilization during their early in-service years.

Also as discussed in Section 2.4, there are other system constraints due to complex interactions through the transmission network that only apply to specific lines. These also need to be further assessed on a case-by-case basis.

This case-by-case analysis was completed for lines with a utilization above 70 per cent or below 40 per cent and the results are shown in Appendix A.

4 Utilization Results

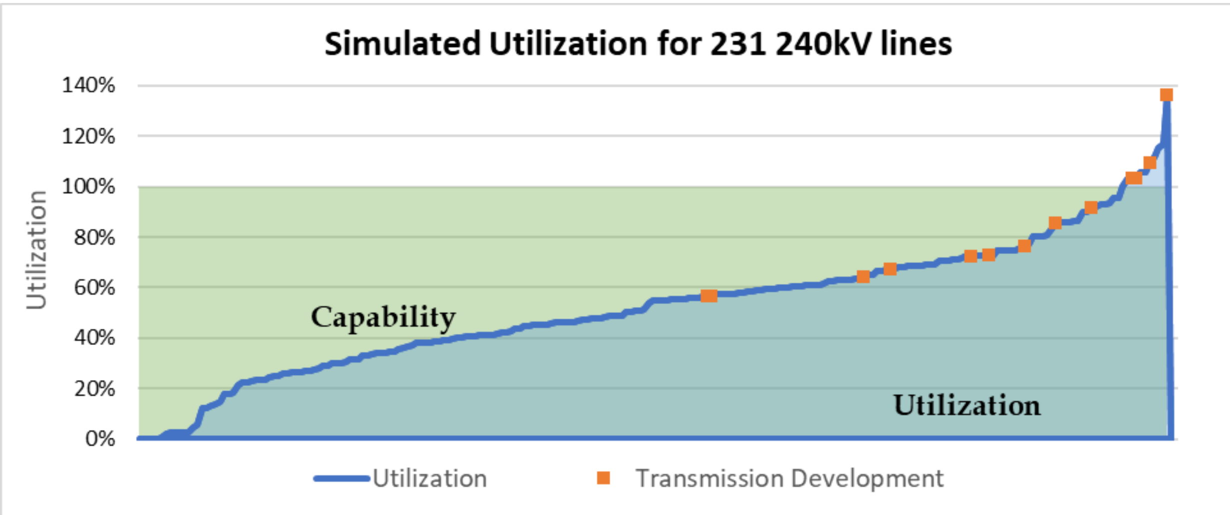
This section discusses the results of the transmission system utilization assessment.

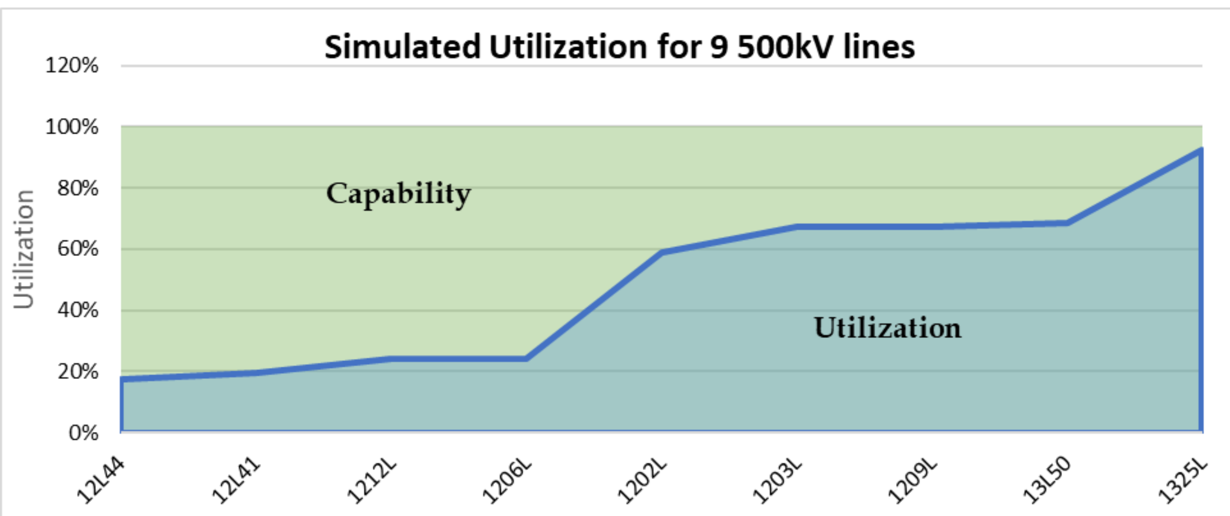
4.1 Transmission System Basic Utilization Metrics

The Transmission Utilization results were calculated according to Section 3.2.

Figure 8 shows the 2022 basic utilization metrics for 240 kV transmission lines in the top chart, and for 500 kV transmission lines in the bottom chart. In both charts, the utilization results are sorted from lowest to highest utilized. The orange marks show some of the lines associated with recent transmission system projects.

Figure 8: Sorted Utilization Results for 240 kV and 500 kV Transmission Lines





4.1.1 A Balanced Approach

In general, the blue-shaded area below the sorted metrics line indicates the estimated degree of thermal-based utilization in 2022, and the green-shaded area above indicates the estimated degree of thermal-based system capability or facility capacity margins that is available to accommodate additional flow and flow variance driven by forecasted system growth and energy system transition for future years.

> *Overall, for both the 240 kV and 500 kV transmission system, the transmission utilization assessment shows a balanced result, ranging from low utilization (high capacity margin) to high utilization.*

A **balanced approach** is desirable because having a significant number of lines with:

- **Low utilization (unbalanced–low)** would potentially indicate:
  - The system constraints are much more limiting than the thermal-base utilization results
  - The system is being built out in advance of a large transition
  - The system is "overbuilt" beyond the capacity needed
- **High utilization (unbalanced-high)** would potentially indicate the system is:
  - "Under built" and does not have any capacity margin to accommodate future growth
  - Not expecting material growth in the future and the current capacity is anticipated to be sufficient

> *An unbalanced-high result should not be the desired result if the transmission system is to continue to support Alberta's continued robust economic growth.*

4.1.2 Additional Context Considerations

When looking at the results for any specific line, the system context for that line should be considered in order to understand and interpret the result. This line-by-line analysis was completed for lines with a utilization below 40 per cent and select lines above 70 per cent, and the results are shown in Appendix A. Three high-level contextual observations can be drawn from these results:

1. Some 240 kV transmission lines have very low utilization. These are either:
   - A newly in-service line with load or generation coming online very soon.
   - A radial line for a single customer connection built at an appropriate scale for the voltage and technology selected. For example, when comparing two connection alternatives, the lower voltage option would have a lower capacity and thus a higher utilization. It may be cheaper to construct the lower voltage line itself, but a more expensive solution overall depending on the line length, substation configuration and need for transformers—thus the lower utilization option is selected.
2. **Some 240 kV transmission lines have a utilization exceeding 100 per cent.** These transmission lines rely on operational mitigation measures, such as remedial action schemes or emergency ratings, to allow the reliability margin to extend beyond their line capacity. However, these measures bring added complexity and/or cost and can only be used in specific applications. They should be used sparingly, as relying on these measures extensively can introduce more challenging reliability concerns and operational challenges.

3. **500 kV lines are designed for bulk power transfer and to provide a strong system backbone.** Given the purpose and nature of these lines, they are typically voltage or transient stability limited and are therefore not intended to reach a high thermal utilization.

4.1.3 Correlation to Transmission Developments

Another general observation of overall system utilization results is that there is a positive correlation between planned transmission developments and high utilization, as illustrated with the orange points in Figure 8. However, as discussed in Section 2, high utilization alone is not a sufficient driver to justify any transmission development. There are other factors that need to be evaluated for transmission development planning, such as:

1. A line with relatively **high utilization** might have:
   - Sufficient operational mitigation solutions in place to manage the risk of congestion or other reliability requirements
   - Limited forecasted growth in the planning horizon
2. A line with relative **lower utilization** might:
   - Have been justified to accommodate forecasted gradual growth in the planning horizon
   - Be limited by system constraints, such as voltage or transient stability
   - Be the first step within a larger system plan that will result in higher utilization, while still reducing the risk of potential future congestion

Therefore, while high utilization could be an indicator of needed transmission system development, on its own it is not a sufficient driver to justify such development. It needs to be studied in detail and its reasonableness needs to be assessed within Alberta's regulatory framework through a Needs Identification Document.[10]

4.2 Application of Results

With the completion of the inaugural utilization assessment, the AESO offers the following key points for future guidance:

- The assessment will be conducted annually to the extent stakeholders find this assessment informative. This approach will generate long-term utilization metrics and trends over the next years.
- The results will be used to monitor areas with high utilization and potentially calibrate our models for planning studies.
- The results can be used as supplementary data to support decision making (the results on their own are not a sufficient driver to justify transmission development).
- This analysis will not be extended to include 69 kV and 138 kV transmission lines.

[10] *Transmission Regulation*, Section 11

5 Summary

The AESO has developed utilization metrics to facilitate a common understanding of this complex, multi-faceted subject, and to provide transparent communication about utilization. The discussions on utilization concepts are summarized as follows:

- Transmission utilization and transmission capability are the same concept viewed from different perspectives. Utilization is the portion of capacity already used, while capability is the remaining portion of capacity to accommodate future needs. Importantly, unutilized capacity is not necessary the result of “over-building”—in many cases it is the intended result of appropriate infrastructure planning and development.
- The transmission system must be planned with a reliability margin to accommodate outages—utilization goes beyond flows on the transmission system.
- Very high (close to 100 per cent) overall transmission system utilization is not—and should not be—the intended target for the planning and development of transmission infrastructure. A balanced approach is required to enable future growth opportunities and energy system transitions.
- In addition to common utilization metrics, the utilization of any specific line needs to be assessed in its own context considering its own specific situation, such as system constraints.

The AESO’s implemented solution for transmission system utilization consists of:

- The model and process to calculate basic common transmission line-by-line utilization metrics based on thermal rating and single contingences.
- The interactive transmission utilization map is used to enable effective, transparent and in-context communication and to enable context-based assessments.
- Utilization should be assessed within the context of forecasted gradual growth of installed generation or load and/or other specific situations such as system constraints.

Using implemented solution, AESO conducted the 2022 utilization assessment. The key findings are:

- The basic transmission utilization metrics reflect the overall general utilization pattern of the transmission system across the 240 kV and 500 kV network.
- The basic transmission line-by-line utilization metrics results show a balanced result, ranging from low utilization (high capability) to high utilization. This reflects the nature of transmission system infrastructure planning to consider both the current and future situations and balance the tradeoffs between them. This balance should ensure that the transmission system is able to provide the necessary capacity to meet current and future power demand, while maintaining operational reliability and flexibility, and adapting to changing economic, regulatory and market conditions.

Appendix A | Transmission System Utilization Results

This appendix provides the line-by-line results. Contextual comments are provided for transmission lines with a utilization, as defined in Section 2.5, below 40% and select transmission lines with a utilization above 70%.

Line	Description	Utilization (%)	Assessment Comments
1005L	Milo 356S - 1005AL Tap	136	Operational mitigation measures, including RAS, allow the utilization to exceed 100%. There are a significant number of connection projects in the South Region that would increase the utilization of this line. Transmission developments to add capacity margin for the South Region are currently being studied.
926L	Sundance 310P - Benalto 17S	117	Operational mitigation measures allow the utilization to exceed 100%. Clearance mitigation will increase the capacity in the future.
916L	Sarcee 42S - East Calgary 5S	115	Operational mitigation measures allow the utilization to exceed 100%. There are a significant number of connection projects in the South Region that would increase the utilization of this line. Transmission developments to add capacity margin for the South Region are currently being studied.
922L	Sundance 310P - Benalto 17S	112	Same comment as '926L (Sundance 310P - Benalto 17S)'
1036L	Travers 554S - Milo 356S	109	Same comment as '916L (Sarcee 42S - East Calgary 5S)'
1087L	Cassils 324S - Newell 2075S	106	Same comment as '916L (Sarcee 42S - East Calgary 5S)'. For this line, operational mitigation measures include adjusting the EATL power order.
240BA2	Bellamy - Argyll	105	Operational mitigation measures allow the utilization to exceed 100%. City of Edmonton Transmission Reinforcement (P7078) will increase the capacity margin allowing for load growth in the area.
985L	Janet 74S - SS-25	104	Same comment as '916L (Sarcee 42S - East Calgary 5S)'
1003L	Janet 74S - SS-25	104	Same comment as '916L (Sarcee 42S - East Calgary 5S)'
995L	Brazeau 62S - 995AL Tap	103	Operational mitigation measures allow utilization to exceed 100%
1056L	Ellerslie 89S - Argyll	100	Same comment as '240BA2 (Bellamy - Argyll)'
923L	Milo 356S - Newell 2075S	95	There are a significant number of connection projects in the South and Central East Regions that would increase the utilization of this line. Central East Transfer-Out (P7001) will increase the capacity margin allowing for generation growth in the area. Also, transmission developments to add capacity margin for the South Region are currently being studied.
1005AL	1005AL Tap - Little Bow 991S	93	The line capacity was sized based on the TVS1 asset's maximum capability.
935L	Cassils 324S - Milo 356S	93	Same comment as '923L (Milo 356S - Newell 2075S)'
908L	Ellerslie 89S - Petrolia	93	
WATL	Sunnybrook 510S - Crossings 511S	93	
921L	Lamoureux 71S - Cloverbar	92	

Line	Description	Utilization (%)	Assessment Comments
1005L	Picture Butte 120S - 1005AL Tap	92	There are a significant number of connection projects in the South Region that would increase the utilization of this line. Transmission developments for the South Region are currently being studied to add capacity margin.
909L	Ellerslie 89S - Dome	90	
901L	Janet 74S - 901AL Tap	90	
9L46	Pemukan 932S - Lanfine 959S	87	There are a significant number of connection projects in the Central East Region that would increase the utilization of this line. Central East Transfer-Out (P7001) will increase the capacity margin allowing for generation growth in the area.
9L100	Anderson 801S - Sheerness 807S	86	The line capacity was sized based on the SH2 asset's maximum capability.
918L	Beddington SS-162 - Johnson 281S	86	
9L99	Sheerness 807S - Anderson 801S	86	The line capacity was sized based on the SH1 asset's maximum capability.
9L16	Tinchebray 972S - Cordel 755S	85	Same comment as '9L46 (9LA46 Tap - Lanfine 959S)'
995L	Benalto 17S - 995AL Tap	83	
909L	Sundance 310P - Dome	81	
937L	Langdon 102S - East Calgary 5S	81	
936L	Langdon 102S - East Calgary 5S	80	
9L79	Battle River 757S - Cordel 755S	80	The line capacity was sized based on the BR5 asset's maximum capability.
9L20	Nevis 766S - Cordel 755S	76	Same comment as '9L46 (9LA46 Tap - Lanfine 959S)'
9L74	Dover 888S - Birchwood Creek 960S	76	
934L/9L934	Ware Junction 132S - Anderson 801S	75	Same comment as '9L46 (9LA46 Tap - Lanfine 959S)'
9L58	Dover 888S - Ruth Lake 848S	75	
950L/9L950	Ware Junction 132S - Anderson 801S	75	Same comment as '9L46 (9LA46 Tap - Lanfine 959S)'
1048L	Peigan 59S - Windy Flats 138S	73	
1049L	Peigan 59S - Windy Flats 138S	73	
967L	North Lethbridge 370S - Windy Flats 138S	73	
968L	North Lethbridge 370S - Windy Flats 138S	73	
905L	Wabamun 19S - North Calder 37S	73	
912L	Red Deer 63S - Nevis 766S	73	Same comment as '9L16 (Tinchebray 972S - Cordel 755S)'
1002L	Jenner 275S - Amoco Empress 163S	72	

Line	Description	Utilization (%)	Assessment Comments
1054L	Deerland 13S - Heartland 12S	72	
901L	Red Deer 63S - 901AL Tap	71	
906L	Benalto 17S - Sarcee 42S	71	
1098L	Jasper - Poundmaker	71	
9L59	Anderson 801S - 9LA59 Tap	71	
940L	North Lethbridge 370S - Picture Butte 120S	71	
919L	Sundance 310P - Sagitawah 77S	69	
9L59	Tinchebray 972S - 9LA59 Tap	69	
1044L	Jasper - Petrolia	69	
EATL	Heathfield 2029S - Newell 2075S	69	
1148L	Whitla 251S - Shamrock 1018S	69	
914L	Gaetz 87S - Red Deer 63S	69	
929L	Janet 74S - Hazelwood 287S	68	
1109L	SS-65 - SS-25	68	
1080L	SS-65 - SS-25	68	
989L	Sundance 310P - Sagitawah 77S	68	
1045L	Jasper - 1045AL Tap	68	
924L	Langdon 102S - Milo 356S	68	
1209L	Ellerslie 89S - Genesee	67	
1203L	Keephills 320P - Sunnybrook 510S	67	
943L	Deerland 13S - Amelia 108S	67	
1041L	North Lethbridge 370S - Travers 554S	67	
1027L	Josephburg 410S - Ursus 430S	66	
1055L	Argyll - Petrolia	65	
942L	Lamoureux 71S - Bannerman 681S	65	
927L	Langdon 102S - Milo 356S	64	
932L	Janet 74S - Beddington SS-162	64	
1088L	Cassils 324S - Newell 2075S	63	
925L	Red Deer 63S - Janet 74S	63	

Line	Description	Utilization (%)	Assessment Comments
955L	Peigan 59S - Goose Lake 103S	63	
956L	Peigan 59S - Goose Lake 103S	63	
1112L	Saunders Lake 289S - Ellerslie 89S	63	
1140L	Saunders Lake 289S - Ellerslie 89S	63	
1061L	Heartland 12S - Bannerman 681S	62	
1046L	Sundance 310P - Cherhill 338S	61	
9L09	Dover 888S - Joslyn Creek 849S	61	
9L08	Dover 888S - Joslyn Creek 849S	61	
1083L	Red Deer 63S - Wolf Creek 288S	61	
1034L	Bowmanton 244S - Cassils 324S	61	
902L	Wabamun 19S - Sundance 310P	61	
930L	North Calder 37S - Poundmaker	60	
914L	Saunders Lake 289S - Bigstone 86S	60	
9L57	Livock 939S - Birchwood Creek 960S	60	
1081L	Benalto 17S - Johnson 281S	59	
1035L	Bowmanton 244S - Newell 2075S	59	
1042L	Blackspring Ridge 485S - Travers 554S	59	
1202L	Ellerslie 89S - Keephills 320P	59	
9L10	Brintnell 876S - Livock 939S	59	
L9900	Kearl 9900S - McClelland 957S	59	
1038L	Foothills 237S - Windy Flats 138S	59	
1037L	Foothills 237S - Windy Flats 138S	59	
1082L	Red Deer 63S - Hazelwood 287S	58	
914L	Bigstone 86S - Gaetz 87S	58	
1043L	Harry Smith 367S - Keephills 320P	58	
190L	Benalto 17S - Keephills 320P	57	
903L	Benalto 17S - Keephills 320P	57	
1106L	SS-65 - Foothills 237S	57	
1107L	SS-65 - Foothills 237S	57	

Line	Description	Utilization (%)	Assessment Comments
9L23	Ruth Lake 848S - Salt Creek 977S	56	
933L/9L933	Ware Junction 132S - Anderson 801S	56	
1052L	West Brooks 28S - Cassils 324S	55	
1051L	West Brooks 28S - Cassils 324S	55	
928L	Benalto 17S - Sarcee 42S	55	
913L	North Barrhead 69S - Cherhill 338S	55	
948L/9L948	Hansman Lake 650S - Paintearth 863S	55	
240BA3	Bellamy - Argyll	55	
910L	Saunders Lake 289S - Wolf Creek 288S	55	
1045AL	Keephills 320P - 1045AL Tap	54	
920L	Lamoureux 71S - Castledowns	51	
9L70	Oakland 946S - Anderson 801S	51	
9L97	Oakland 946S - Anderson 801S	51	
946L	Ellerslie 89S - East Edmonton 38S	49	
997L	Lamoureux 71S - Ursus 430S	49	
931L	Ware Junction 132S - West Brooks 28S	49	
1075L	Ware Junction 132S - West Brooks 28S	49	
1057L	Ellerslie 89S - Summerside	49	
908L	Ellerslie 89S - 908AL Tap	48	
900L	Red Deer 63S - Benalto 17S	48	
994L	Goose Lake 103S - Fidler 312S	48	
9L01	Ruth Lake 848S - Thickwood Hills 951S	48	
964L	Bowmanton 244S - 964AL Tap	47	
915L	East Edmonton 38S - Cloverbar	47	
947L	Ellerslie 89S - Cloverbar	46	
939L/9L939	Sagitawah 77S - Louise Creek 809S	46	
938L/9L938	Sagitawah 77S - Louise Creek 809S	46	

Line	Description	Utilization (%)	Assessment Comments
9L30	Dover 888S - Thickwood Hills 951S	46	
951L	Ware Junction 132S - Jenner 275S	45	
944L	Ware Junction 132S - Jenner 275S	45	
9L112	Dover 888S - Thickwood Hills 951S	45	
9L913	North Barrhead 69S - Mitsue 732S	45	
908L	East Edmonton 38S - 908AL Tap	45	
966L/9L966	Hansman Lake 650S - Pemukan 932S	44	
1059L	East Edmonton 38S - 1059AL Tap	43	
9L22	Heart Lake 898S - Whitefish Lake 825S	42	
920L	North Calder 37S - Castledowns	42	
1058L	Summerside - Lambton	42	
1120L	Josephburg 410S - Amelia 108S	42	
9L05	Little Smoky 813S - Louise Creek 809S	41	
9L02	Little Smoky 813S - Louise Creek 809S	41	
1072L	Castle Rock Ridge 205S - Goose Lake 103S	41	
9L80	Battle River 757S - Cordel 755S	41	
9L960	Deerland 13S - Whitefish Lake 825S	41	
9L961	Deerland 13S - Whitefish Lake 825S	41	
9L27	Paintearth 863S - Cordel 755S	40	
9L66	Muskeg River 847S - Joslyn Creek 849S	40	
9L56	Wabasca 720S - Brintnell 876S	40	The 240 kV path from Dover 888S to Louise Creek 809S consists of five 240 kV lines in series. This configuration provides redundancy and improves reliability for the connected substations. The utilization is limited by system constraints, such as voltage, and more constrained lines along this and the parallel paths, such as 9L74 and 9L58, that limit the inflow and outflow capacity of the Fort McMurray (25) planning area. The path provides capacity margin for future load and generation in the Fort McMurray area, such as P2082, which will increase the utilization of this path.
1064L	Langdon 102S - Janet 74S	39	These are a double circuit line to provide redundancy and improve reliability for the Calgary area. The flow is dependent on level of import/export with BC, the dispatch level of WATL, and the generation in the South region.
1065L	Langdon 102S - Janet 74S	39	

Line	Description	Utilization (%)	Assessment Comments
1011L	Amoco Empress 163S - Cypress 562S	39	This is a double circuit line to provide redundancy and improve reliability for the substations in the Empress area. It also provides capacity margin for future load and generation growth in the area.
9L93	Tinchebray 972S - Halkirk 615S	38	This is a radial line to provide system access to Halkirk 615S in an economical way. Its utilization depends on the generation at the substation.
1059L	1059AL Tap - Lambton	38	This line provide redundancy and improves reliability for the substations in the Edmonton area. It also provides capacity margin for future load and generation growth in the area.
9L43	Dover 888S - Mckay River 874S	38	This is a short radial line to provide system access to MacKay River 874S in an economical way. Its utilization depends on the load and generation at the substation.
953L/9L953	Nilrem 574S - Cordel 755S	38	This is a double circuit line to provide redundancy and improve reliability for the connected substations. It also provides capacity margin for future load and generation growth in the Central East area, which has a significant number of connection projects. However, the utilization is limited by system constraints such as the area's transfer out capability, which will be increased by the Central East Transfer-Out transmission development (P7001).
9L56	Wabasca 720S - Mitsue 732S	38	Same comment as '9L56 (Wabasca 720S - Brintnell 876S)'
945L	Jenner 275S - Cypress 562S	37	Same comment as '1011L (Amoco Empress 163S - Cypress 562S)'
9L24	Lanfine 959S - Oakland 946S	37	Having a 240 kV loop from Oakland 946S to Hansman Lake 650S provides redundancy to increase the local area's reliability. It also provides capacity margin for future load and generation growth in the area. For example, asset LAN1 has recently energized and P1567 is under construction - both will increase the utilization of this path. However, the utilization is limited by system constraints such as the area's transfer out capability, which will be increased by the Central East Transfer-Out transmission development (P7001).
9L81	Heart Lake 898S - Whitefish Lake 825S	36	This is part of a double circuit line to provide redundancy and to improve reliability. The line connects the Northeast with the rest of the province. The path provides capacity margin for future load and generation in the Fort McMurray area, such as P2082, which will increase the utilization of this path.
1053L	Ware Junction 132S - Cassils 324S	36	Same comment as '953L/9L953 (Nilrem 574S - Cordel 755S)'
983L	Bowmanton 244S - 983AL Tap	35	The utilization of the path from Bowmaton 244S to Whitla 251S is limited by both voltage constraints in the area and by the higher utilization of 1034L and 1035L. Bowmanton 244S Substation Voltage Support Project (P7083) will reduce the voltage constraints allowing for increased utilization. Assets FMG1, CYP1, and CYP2 have recently energized and will increase the utilization of this path. Also, there many additional connection projects in the area.
983L	Whitla 251S - 983AL Tap	35	Same comment as '983L (Bowmanton 244S - 983AL Tap)'
9L15	Wesley Creek 834S - Brintnell 876S	34	Same comment as '9L56 (Wabasca 720S - Brintnell 876S)'
9L45	Kinosis 856S - Kettle River 2049S	34	The 240 kV path from Ruth Lake 848S to Heart Lake 898S consists of five 240 kV lines in series. This configuration provides redundancy and improves reliability for the connected substations. The utilization is limited by system constraints, such as voltage, and more constrained lines along this and the parallel paths, such as 9L74 and 9L58, that limit the inflow and outflow capacity of the Fort McMurray (25) planning area. The path provides

Line	Description	Utilization (%)	Assessment Comments
			capacity margin for future load and generation in the Fort McMurray area, such as P2082, which will increase the utilization of this path.
964L	Whitla 251S - 964AL Tap	34	Same comment as '983L (Bowmanton 244S - 983AL Tap)'
9L990	Leismer 72S - Kettle River 2049S	34	Same comment as '9L45 (Kinosis 856S - Kettle River 2049S)'
12L85	Heartland 12S - Heathfield 2029S	34	These are short double-circuit radial lines to connect EATL to the system. Double circuit provides redundancy to increase EATL's AC side reliability. Their utilization is a function of EATL's utilization and lines were sized for the planned EATL bi-pole development. Also see comment for '1239L (Genesee - Sunnybrook 510S)'.
12L70	Heartland 12S - Heathfield 2029S	34	
9L85	Kinosis 856S - Salt Creek 977S	33	Same comment as '9L45 (Kinosis 856S - Kettle River 2049S)'
9L101	McClelland 957S - Secord 2005S	33	Having a 240 kV loop from Joslyn Creek 849S to Salt Creek 977S provides redundancy to increase the local area's reliability and its utilization depends on the load and generation in the local area. The loop also provides capacity margin for future load and generation growth in the area. However, the utilization is limited by system constraints, such as voltage and more constrained lines, that limit the inflow and outflow capacity of the Fort McMurray (25) planning area.
9L84	Black Fly 934S - Salt Creek 977S	32	Same comment as '9L101 (McClelland 957S - Secord 2005S)'
1086L/9L47	Heart Lake 898S - Round Hill 852S	32	The 240 kV path from Thickwood Hills 951S to Heart Lake 898S consists of four 240 kV lines in series. This configuration provides redundancy and improves reliability for the connected substations. The utilization is limited by system constraints, such as voltage, and more constrained lines along this and the parallel paths, such as 9L74 and 9L58, that limit the inflow and outflow capacity of the Fort McMurray (25) planning area. The path provides capacity margin for future load and generation in the Fort McMurray area, such as P2082, which will increase the utilization of this path.
1239L	Genesee - Sunnybrook 510S	30	500 kV lines are designed for bulk power transfer and to provide a strong system backbone. Given the purpose and nature of these lines, they are not intended to reach a high thermal utilization as they are typically voltage or transient stability limited.
1238L	Genesee - Sunnybrook 510S	30	
954L	Metiskow 648S - Hansman Lake 650S	30	This very short line is parallel to 885L and provides redundancy to increase the local area's 138 kV system reliability. Its utilization is constrained by the local 138 kV system.
1085L/9L55	McMillan 885S - Round Hill 852S	30	Same comment as '1086L/9L47 (Heart Lake 898S - Round Hill 852SS)'
9L32	Joslyn Creek 849S - Bitumount 941S	29	Same comment as '9L101 (McClelland 957S - Secord 2005S)'
9L32	Secord 2005S - Bitumount 941S	29	Same comment as '9L101 (McClelland 957S - Secord 2005S)'
9L69	Black Fly 934S - McClelland 957S	28	Same comment as '9L101 (McClelland 957S - Secord 2005S)'
9L89	McMillan 885S - Dawes 2011S	27	Same comment as '1086L/9L47 (Heart Lake 898S - Round Hill 852SS)'
901AL	East Crossfield 64S - 901AL Tap	27	This very short line connects the Airdrie area 138 kV system to 901L. Its utilization is a function of the local 138 kV system.
973L	Bickerdike 39S - Sundance 310P	27	This is a double circuit line to provide redundancy and improve reliability for the substations in the Hinton/Edson area. It also provides capacity margin for future load and generation growth in the area, such as Project 2032, which will increase the utilization of this path.
974L	Bickerdike 39S - Sundance 310P	27	

Line	Description	Utilization (%)	Assessment Comments
9L930	Heart Lake 898S - Leismer 72S	27	Same comment as '9L45 (Kinosis 856S - Kettle River 2049S)'
9L07	Thickwood Hills 951S - Dawes 2011S	26	Same comment as '1086L/9L47 (Heart Lake 898S - Round Hill 852SS)'
9L11	Wesley Creek 834S - Little Smoky 813S	26	This is part of the larger 240 kV ring in the Northwest to provide redundancy and improve reliability. The line provides capacity margin for future load and generation in the Northwest.
240CV5	Castledowns - Victoria	26	240CV5 is the circuit that brings 240 kV supply to the area. In the longer term when additional 240 kV source(s) are brought to the area to support additional load growth, the utilization of this line is anticipated to increase and provide redundancy and improve reliability.
1164L	Petrolia - Riverview	25	Same comment as '1059L (1059AL Tap - Lambton)'
957L	Leismer 72S - Christina Lake 723S	25	Having a 240 kV loop from Leismer 72S to Heart Lake 898S provides redundancy to increase the local area's reliability and its utilization depends on the load and generation in the local area. The loop also provides capacity margin for future load and generation growth in the area. However, the utilization is limited by system constraints, such as voltage and more constrained lines, that limit the inflow and outflow capacity of the Fort McMurray (25) planning area.
9L40	Mitsue 732S - Louise Creek 809S	25	Same comment as '9L56 (Wabasca 720S - Brintnell 876S)'
1206L	Ellerslie 89S - Heartland 12S	24	Same comment as ‘1239L (Genesee - Sunnybrook 510S)'.
1212L	Ellerslie 89S - Heartland 12S	24	
9L37	Marguerite Lake 826S - Whitefish Lake 825S	24	This is a double circuit line to provide redundancy and improve reliability for the substations in the Cold Lake area. It also provides capacity margin for future load and generation growth in the area.
9L36	Marguerite Lake 826S - Whitefish Lake 825S	24	
1139L	Harry Smith 367S - Riverview	23	Same comment as '1059L (1059AL Tap - Lambton)'
1090L	Christina Lake 723S - Jackfish 698S	23	Same comment as '957L (Leismer 72S - Christina Lake 723S)'
1214L	Keephills 320P - Keephills 320P	23	This is a short radial line to provide system access to Keephills 3 in an economical way. Its utilization depends on the generation at the substation. Also see comment for ‘1239L (Genesee - Sunnybrook 510S)'.
1099L	Jackfish 698S - Black Spruce 154S	22	Same comment as '957L (Leismer 72S - Christina Lake 723S)'
907L	Sagitawah 77S - Alberta Newsprint 122S	22	This is a radial line to provide system access to Alberta Newsprint 122S in an economical way. Its utilization depends on the load and generation at the substation.
1071L	Castle Rock Ridge 205S - Fidler 312S	21	This is double circuit line with 1072L and 994L which provides redundancy to increase the reliability of Castle Rock Ridge 205S and Fidler 312S. Its utilization is limited by the high utilization of 1048L and 1049L.
12L41	Sunnybrook 510S - Livock 939S	20	Same comment as ‘1239L (Genesee - Sunnybrook 510S)'. The line provides capacity margin for future load and generation in the Fort McMurray area, such as P2082, which will increase the utilization of this line.

Line	Description	Utilization (%)	Assessment Comments
971L	Conklin 762S - Black Spruce 154S	18	This is a short radial line to provide system access to Conklin 762S in an economical way. Its utilization depends on the load and generation at the substation.
1047L	Hansman Lake 650S - Nilrem 574S	18	Same comment as '953L/9L953 (Nilrem 574S - Cordel 755S)'
1117L	Heart Lake 898S - Ipiatik Lake 167S	18	Same comment as '957L (Leismer 72S - Christina Lake 723S)'
12L44	Thickwood Hills 951S - Livock 939S	18	Same comment as '12L41 (Sunnybrook 510S - Livock 939S)'
1115L	Black Spruce 154S - Pike 170S	15	Same comment as '957L (Leismer 72S - Christina Lake 723S)'
1116L	Pike 170S - Ipiatik Lake 167S	14	Same comment as '957L (Leismer 72S - Christina Lake 723S)'
1118L	Sunday Creek 539S - Black Spruce 154S	13	This is a short radial line to provide system access to Sunday Creek 539S in an economical way. Its utilization depends on the load and generation at the substation.
9L29	Oakland 946S - Coyote Lake 963S	12	This line provides capacity margin for future load and generation growth in the local area, but its utilization is constrained by the local 144 kV system. For example, assets HHW1, MIC1, TRH1, and WHE1 have recently energized - its utilization is anticipated to increase.
964AL	964AL Tap - Granlea 1024S	12	This is a new short radial line to provide system access to asset FMG1. Its utilization will significantly increase after the asset reaches commercial operation.
1059AL	East Industrial - 1059AL Tap	6	These are short double-circuit radial lines to provide system access to East Industrial in an economical way. Double circuit provides redundancy to increase the connection's reliability. Their utilization depends on the load at the substation.
908AL	East Industrial - 908AL Tap	5	
995AL	Willesden Green 68S - 995AL Tap	3	This is a short radial line to provide system access to Willesdengreen 68S in an economical way. Its utilization depends on the load at the substation.
9L39	Green Stocking 925S - Black Fly 934S	3	These are double-circuit radial lines to provide system access to Green Stocking 925S in an economical way. Double circuit provides redundancy to increase the connection's reliability. Their utilization depends on the load at the substation.
9L77	Black Fly 934S - Green Stocking 925S	3	
9L19	Amr02 937S - Birchwood Creek 960S	3	These are short double-circuit radial lines to provide system access to Amr02 937S in an economical way. Double circuit provides redundancy to increase the connection's reliability. Their utilization depends on the load at the substation.
9L28	Amr02 937S - Birchwood Creek 960S	3	
983AL	983AL Tap - Woolchester 1019S	2	This is a new short radial line to provide system access to asset CYP1 and CYP2. Its utilization will significantly increase after the assets reach commercial operation.
9L144	Yeo 2015S - Birchwood Creek 960S	1	This is a short radial line to provide system access to Yeo 2015S in an economical way. Its utilization depends on the load at the substation.
949L	Jenner 275S - Halsbury 306S	0	This is a new radial line to provide system access to asset JNR3 and Projects 1533 and 1698. Its utilization will significantly increase after these assets reach commercial operation.
1135L	Bickerdike 39S - Whisky Jack 1047S	0	These are new lines to provide system access to Project 2032. Their utilization will significantly increase after the asset reaches commercial operation.
1084L	Bickerdike 39S - Whisky Jack 1047S	0	
1168L	Bickerdike 39S - Whisky Jack 1047S	0	

Line	Description	Utilization (%)	Assessment Comments
9LA59	Garden Plain 1045S - 9LA59 Tap	0	This is a new short radial line to provide system access to asset GDP1. Its utilization will significantly increase after the asset reaches commercial operation.

Appendix B | Detailed Study Assumptions and Methodology

This appendix provides the detailed study assumptions and methodology for the transmission utilization 2022 assessment.

1 Study Scope and Assumptions

This section discusses the study scope, assumptions, and system model applied in the assessment. The information used in the assessment is based on the historical performance of the transmission system and will change over time. The AESO addresses this evolving system by regularly updating the assessment.

1.1 Study Scope

The scope of this assessment was selected based on the study objective— to estimate transmission system utilization.

1.1.1 Study Period

This assessment is an historical assessment that studied the 2022 calendar year. It provides an estimation of the transmission system utilization based on the existing system over the previous year.

1.1.2 Study Area

This assessment covered the entire AIES. All generating units, loads and transmission facilities are modelled.

1.1.3 Monitored Equipment

This assessment studied the utilization of transmission lines with a voltage equal to or greater than 240 kV. The assessment did not study transmission lines inside industrial system designation sites or interties.

1.1.4 Contingencies

This assessment studied the contingencies of ~1,500 different transmission facilities. This ensured the critical contingency and resulting reliability margin for each transmission line was captured.

1.2 Study Assumptions

Utilization was calculated using the following assumptions and historical data.

1.2.1 Transmission System Model

The interconnected electric system was modelled as per the installed transmission system on Dec. 31, 2022. Connection and system projects energizing after Dec. 31, 2022 were not included in the model.

1.2.2 Transmission Facility Ratings

The transmission facility ratings were provided by the respective Transmission Facility Owners (TFOs). The facility ratings as per Dec. 31, 2022 were used in the assessment.

1.2.3 Demand

The demand was modelled using the hourly historical metered demand for each measurement point. The hourly historical demand was assigned to its corresponding buses in the transmission system model.

1.2.4 Merit Order

The generating units were dispatched using hourly historical merit order data for each pool asset. The merit order determined the hourly pool asset dispatch, and the hourly dispatch was assigned to its corresponding generating units in the transmission system model. For some pool assets, the historical merit order data was modified to account for non-dispatchable generating units and generating units connected behind a measurement point.

1.2.5 Interties

The AIES is connected to British Columbia via WECC Path 1; to Saskatchewan via WECC Path 2; and to Montana via WECC Path 83. The interties were dispatched using the hourly historical schedule. In addition, the dispatches were constrained to each intertie's hourly historical available transfer capability.

1.2.6 HVDC Power Order

The HVDC power orders on WATL and EATL were selected to minimize the hourly pool price. This assumption minimizes the transmission system losses.

1.2.7 Project Inclusion

Since the transmission system was modelled as per Dec. 31, 2022, the transmission facilities for projects that energized during 2022 were modelled in every hour. However, since the demand and merit order use historical data, projects that energized during 2022 were effectively not included until they energized and had metered energy.

Connection and system projects energizing after Dec. 31 were not included in the studies.

1.2.8 Operational Mitigation Measures

The assessment did not model operational mitigations, such as remedial action schemes (RAS), emergency ratings or system reconfiguration.

2 Study Methodology

This section details the methodology used in this assessment.

2.1 DC Power Flow Solver

The assessment uses a DC power flow solver. The DC power flow solver simplifies the power flow equations to enable large studies across many hours. The main assumptions of the DC power flow solver used in this assessment are: (i) bus voltages are 1.0 p.u.; and (ii) the power flow equations are linear.

2.2 Process Overview

The methodology for calculating transmission utilization has three main steps:

1. **Create Power Flow Cases—**The first step is to create an historical hourly representation of the power system.
2. **Simulate Contingencies—**The second step is to calculate the potential post-contingency flow should the contingency occur for each contingency in each hour. This is equivalent to flow plus reliability margin in Section 2 of the report.
3. **Calculate Utilization—**The final step is to convert the hourly results calculated in step two into utilization statistics.

Each of these steps is explained in detail in the following sections.

2.3 Create Power Flow Cases

The first step was to create an historical hourly representation of the power system—a case was created for each hour (8,760 hours) in the study year. This step combined the historical data in Section 1.2, a model of the power system, and a cost minimization optimization problem.

The optimization problem:

1. Models the historical demand to its corresponding buses in the transmission system model.
2. Dispatches the most economical generating units using merit order data to minimize cost.
3. Optimizes the HVDC power order to minimize cost. Adjusting the HVDC power order to minimize losses reduces the dispatch on the marginal generating unit, which in turn minimizes the cost.
4. Solves the DC power flow equations (equality constraints) while respecting the N-0 facility ratings (inequality constraints).
5. Allows the power flow results to influence the economic dispatch. The optimization redispatches the generating units or HVDC power order away from the minimum cost point to respect the N-0 facility ratings in the most economical manner. This is the equivalent to constrained-down generation or transmission must run.

2.4 Simulate Contingencies

The second step was to simulate each contingency with each hour in hourly cases created in step one. A DC power flow solver was used to solve the post-contingency flows.

The standard process:

1. Select the study hour.
2. Apply the next contingency.
3. Solve the DC power flow.
4. Record the post-contingency power flows on each transmission line. This is equivalent to flow plus reliability margin in Section 2.5.

2.5 Calculate Utilization

The final step is to convert the hourly contingency-specific power flows calculated in step two into the transmission line utilization using the equation discussed in Section 2.5.

$$utilization = max(\frac{|flow| + reliability\ margin}{\text{thermal rating (capacity)}})$$

The key relationship between this equation and the methodology is (explained in Section 2.2):

$$flow + reliability\ margin = post\ contingency\ flow$$

The utilization of each transmission line is calculated for each hour and each contingency, and the maximum value is selected for each transmission line as its utilization.