Capital Power
1200-10423 101 Street NW
Edmonton, AB T5H 0E9

December 30, 2021

Dennis Frehlich
Vice President, Grid Reliability
Alberta Electric System Operator (AESO)
Calgary Place, 2500, 330 - 5th Avenue SW
Calgary, AB T2P 0L4

RE: Economic and Technical Analyses of the Most Severe Single Contingency (MSSC)

Dear Mr. Frehlich

As part of the AESO's Evaluation of the MSSC engagement, Capital Power is providing you this letter and two further analyses (attached) covering technical and economic considerations on the MSSC.

Background

At the '*Evaluation of MSSC Stakeholder Engagement Session*' on November 4, 2021, the AESO presented a review of the current MSSC limit and its analyses of costs and benefits of increasing the MSSC limit. On November 30, 2021, Capital Power submitted feedback to the AESO stating its concerns regarding the MSSC, including how the imposition of a limit restricts supply options that could otherwise contribute to reliability, reduce consumer costs, and the FEOC operation of Alberta's market.

Respectfully, the AESO's preliminary economic analysis is flawed and incomplete in that it does not adequately consider the characteristics and performance of the existing and future power system. A particular deficiency is that the AESO's analysis fails to consider or acknowledge any potential benefits of an increased MSSC.

In Capital Power's view, the AESO must carefully consider any decisions on an MSSC limit in relation to its obligations to reasonably provide system access, operate an unconstrained energy market, plan and operate the system reliably, adhere to reliability compliance, and support intertie restoration. The regulatory and policy principles that Capital Power believes should apply and govern the assessment of allowing for increases to the MSSC are included in Capital Power's comments, and the accompanying analyses are intended to augment the November 30, 2021 response.

Capital Power has a significant interest in the MSSC as the current limit of 466 MW is set based on the size of Genesee 3. The AESO's current MSSC limit of 425 MW when the province is islanded impacts Genesee 3's operations, and if the AESO does not increase the limit, will restrict Capital Power's Genesee 3 uprate of a mere 6 MW to 472 MW set for Q2-2022.

More importantly Capital Power's Genesee Repowering Project for units 1 & 2 are restricted to the current MSSC limit of 466MW. Each of the two repowered units have the capability to provide 716 MW to Alberta's wholesale electricity market by utilizing best-in-class technology and are expected to set a new standard for gas generation efficiency in Canada. Furthermore, there are significant environmental benefits expected from the project, including reduction in emissions associated with coal-fired power generation. To allow the repowered units to operate up to their intended capacity in accordance with the current MSSC limit, Capital Power is investing an additional $195 M for a 203 MW / 203 MWh battery storage system and developing operating plans to ensure that in the event of either combined cycle unit coming offline, no more than the MSSC limit will be lost. If the MSSC limit is increased, the full value of the repowered units and battery would be unlocked for consumers by increasing competition and reducing prices in the energy and ancillary services markets.

The AESO adopting a MSSC limit impedes the development of larger, more efficient generating units which will ultimately result in higher costs for consumers. Capital Power's position is that the AESO must develop plans and strategies to increase the MSSC value. Furthermore, the AESO must evaluate the MSSC based on a regular and comprehensive system review rather than imposing a static MSSC limit. This review must provide certainty for developers (i.e. not create a risk that the MSSC would decrease) and also support development of generation in Alberta. Attached to this letter and as described further below, Capital Power has retained economic and technical expertise to provide further analyses for the AESO's consideration.

Technical Assessment

The attached report titled "*Most Severe Single Contingency Evaluation*" by Next Phase Power (see Attachment A) provides a high-level technical assessment regarding the prospect of increasing the level of the Most Severe Single Contingency (MSSC) from the perspective of system planning, the energy transition, and operational performance of the Alberta Interconnected Electric System (AIES). This report analyzes what the MSSC would be for varying levels of generation additions within Alberta, including the location and size, so system reliability and stability can be preserved, and provides options to determine the MSSC rather than relying on a static and historic value.

The report findings indicate that larger generators can address the AESO concerns related to renewable integration challenges and inconsistent system response by providing reliable, high capacity-factor, and dispatchable energy to support renewable energy delivery and providing services like inertia, which the AESO has indicated is declining. Instead of imposing a static limit that restricts the development of larger generators, the AESO should determine and update the overall value of MSSC based on a regular and comprehensive system review similar to other planning processes, pursue potentially new ancillary services that would support a higher MSSC (e.g. fast frequency response) and conduct further analysis and stakeholder engagement early in 2022 to evaluate the benefits increasing the MSSC more fully
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Economic Assessment

The attached report titled "*Economic Impact of Increasing the Static MSSC Value*" by Similan Consulting (see Attachment B) discusses the economic considerations involved in increasing the MSSC limit and provides analysis that supplements the AESO's preliminary counterfactual analysis. This report supplements the initial analysis performed by the AESO by extending the analysis to a forecast basis (2024 to 2030) and including the addition of larger generating units into the market to evaluate their impact on pool prices and consumer surplus.

The report findings indicate that by increasing the MSSC limit, savings in pool energy charges exceed increases in operating reserve costs by an order of magnitude. Specifically, the results of increasing the MSSC by 100 MW and 200 MW result in a decrease in net charges to consumers decrease by an average of $162M and $277M per year, respectively.

Capital Power's Battery Addition

Capital Power highlights that while the battery it is developing is intended to mitigate the impact of the AESO not increasing the MSSC on the Repowering Project it only does so to the winter average capacity. Depending on ambient temperatures the Repowering Project may still be limited, and typically at times when the system requires the most capacity (for example, cold, winter days as were experienced during late December 2021 where the AESO was in supply shortfall). As such, the battery addition to Genesee does not absolve the AESO from addressing the MSSC.

Further, the battery addition highlights some of the impacts and opportunities illustrated in the *Economic Assessment* provided. Notably, the additional battery cost on the Repowering Project aligns with the findings that configuration changes increase the marginal cost of capacity, resulting in an increase to the overall market price that consumers pay. Further, the battery, if made available to the broader ancillary market would be an ideal candidate for a future fast frequency response service that could be used to facilitate larger generation projects than the current MSSC limit allows (as discussed in the *Technical Assessment*) and used for other ancillary services, further improving the system reliability. The *Economic Assessment* shows that it would be competitive in those markets.

We appreciate the AESO allowing this additional opportunity to provide feedback on the MSSC. It is a critical topic for development of generation projects in Alberta and it is essential that the AESO contemplate all angles of the issue, particularly given the pace of transformation that is occurring due to electrification and decarbonization efforts. Thank you for your consideration. Please don't hesitate to contact me at 403.540.6087 if you have questions or would like to discuss this submission further.

Regards,

<*Sent Electronically*>

Matthew Davis
Director, Regulatory

Cc: Daniel Jurijew, VP, Government Relations, Regulatory & Environmental Policy

Next Phase Power Inc.

Most Severe Single Contingency Evaluation

An Evaluation and Review of the 'Most Severe Single Contingency' Level

on the Alberta Interconnected Electric System

Prepared for: Capital Power

Prepared by: Next Phase Power Inc.

December 30, 2021

Executive Summary

All power systems are undergoing fundamental and long-term changes in load growth, generation development, and transmission system expansion. Power systems always evolve, however future change will accelerate, be more substantial, and be specifically influenced by the energy transition.

Transmission and system planning will be more focused on managing change in a consistent and orderly manner. The determination of the Most Severe Single Contingency (MSSC) is part of this evolution.

A significant example of the changes taking place is the retirement of coal generation.

Gas turbines (GT's) in various configurations, possess several desirable characteristics of coal plants such as a high-capacity factor, dispatchability, inertia, and size while delivering power with far less carbon emissions. Further, GT's can be installed relatively quickly (with a corresponding fuel source), all within the robust infrastructure associated with the retired coal sites. Gas turbines are easily scalable to larger sizes at these sites without exceeding local transmission congestion or constraint levels. The assets adjacent to the coal plants possess significant capability to evacuate large amounts of power.

The development of renewable energy can also support the retirement of coal and can be built to take advantage of economies of scale. Unlike coal (retiring) or gas, renewable projects do not (yet) possess the inherent characteristics of dispatchability and inertia.

As the energy transition proceeds, transmission and system planning will need to be responsive to change. The MSSC should evolve and new services such as Fast Frequency Response (FFR) promoting reliability need to be reviewed regularly and modified within the context of meeting these new challenges.

The Alberta Electric System Operator (AESO) has initiated a review and consultation of the MSSC on the Alberta Interconnected Electric System (AIES). The previous update of the MSSC was in 2015. The AESO held an information session with stakeholders on November 4, 2021.

This report addresses questions and issues identified by Capital Power regarding a limit proposed by the AESO which may impede development of generation in the province by not considering reasonable modifications to the MSSC value. The AESO has provided limited analysis which does not fully address the potential benefits of a higher MSSC.

The overall conclusion is the AESO should not use a static MSSC value; rather the MSSC value should be determined based on a regular and comprehensive system review similar to other planning processes.

It is recommended that the AESO conduct further analysis and stakeholder engagement early in 2022 to evaluate the benefits increasing the MSSC more fully, with specific consideration of the findings in this report.

Contents

1. Objectives and Approach

This report titled '*Most Severe Single Contingency Evaluation'* provides a high-level technical assessment of the Alberta Interconnected Electric System (AIES) in the context of providing reasonable options regarding the prospect of increasing the level of the Most Severe Single Contingency *(*MSSC). The evaluation is performed from the perspective of system planning, the energy transition, and operational performance within the Alberta Electric System Operator's (AESO) MSSC consultation.

The goals of the evaluation are to determine what the appropriate MSSC would be for varying levels of generation additions within Alberta, including the location and size. More specifically the goal is to preserve system reliability and stability and provide options to determine the MSSC rather than relying on a static and historic value.

This report approaches the MSSC issue from an overall system perspective. The development of a representative level of MSSC is critical to power system security. The report considers:

- New drivers for the growth of load;
- The growth of generation to serve the load;
- The retirement, and subsequent lower carbon replacement, of coal generation to maintain balance; and
- A high-level view of the transmission topology and its role in supporting system security.

The report addresses the MSSC by generally considering the historic and existing levels of MSSC and the corresponding system performance. Then, given the inevitability of load and generation growth due to the energy transition and many possible future outcomes, the report discusses reasonable approaches to determine the MSSC as new and potentially larger capacity resources are integrated into the overall planning, energy transition, and operational performance paradigm.

AESO continues to prepare the AIES for short-, mid-, and long-term project developments, such as generation, load growth, tie-line development, and the application of storage, to name a few. As such, the integration and optimization of these system elements which recognizes the full and future utilization of capacity, energy, inertia, and ancillary services from these resources can be achieved by regularly evaluating and adjusting mechanisms like MSSC.

Of note, much of the evaluation contained within this report has a foundation based on future power system electrification due to the energy transition. The electrification of the system is the result of the transfer of fossil fuel or refined petroleum product production or consumption energy processes to less carbon intensive solutions using electricity.

2. Background

The power system is responding to numerous changes. These changes are being experienced within Alberta and around the world. Changes within North America are not new. For example, FERC 888 and 889 introduced a deregulated electricity model more than 25 years ago which caused dramatic change.

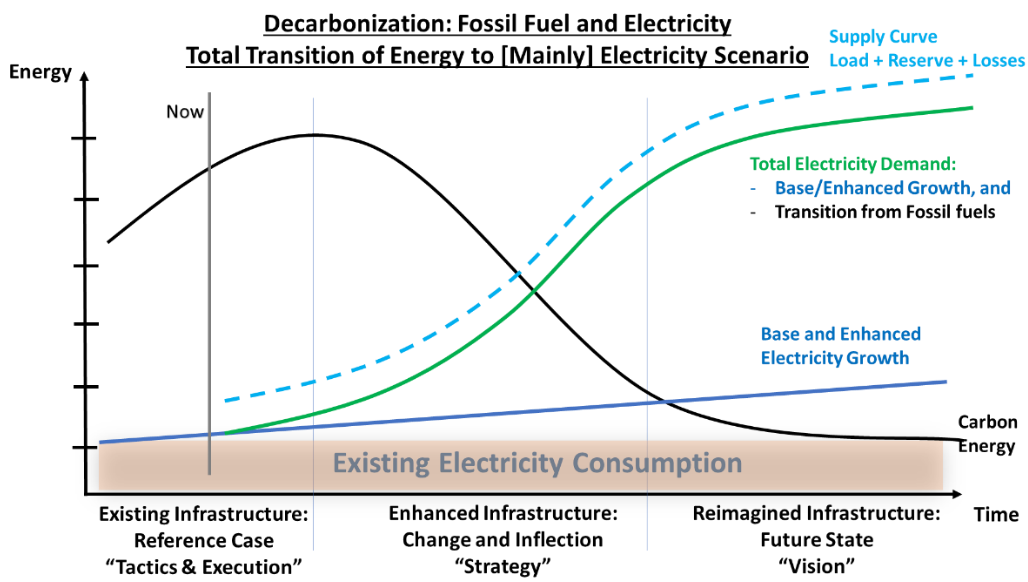
Current system changes are different in nature. For example, right now, load growth includes:

- Traditional inputs and drivers such as seasonal effects and housing growth;
- Variations such as crypto mining, EV charging, and enhanced greenhouse operations; and
- Energy transition and a trend towards electrification, which adds electrical load to the system by reducing fossil fuel usage.

It should be noted, the load factor in Alberta is among the highest in North America.

The system change discussed is generally captured in the scenario shown in Figure 1.

Figure 1 – System Transformation Scenario, Decarbonization



Reducing fossil fuel usage will affect both electrical demand and supply, even if some load is adopted by hydrogen or some other low carbon or carbon neutral source. The full extent of the changes is not yet certain. Within Alberta, the challenge will be to find ways to continue to always serve load while coal fired generation is retired from the system, intermittent renewable generation is added, and developers seek to decarbonize firm natural gas-fired generators through innovations such as carbon capture and sequestration (CCS).

To serve the electrical load reliably, critical attributes are necessary to operate the grid. Some of these attributes are:

- **Resource adequacy:** ensuring sufficient capacity and energy are available to always meet demand. This requires understanding the dispatchability of assets and the interruptible nature of wind and solar.
- **Reliability attributes:** ensuring that there is enough flexibility in the system to respond to contingencies. This includes other attributes such as inertia.

- **Power system inertia:** In an electric system, the rotating energy contained in all synchronously connected electrical machines (generators and motors), move at the same frequency, and provides inertia. The inertia acts to stabilize system frequency against rapid change such as the loss of generation. During a generation contingency, the frequency of the grid tends to decrease. The rotating mass contained in the machines provides an inherently valuable service which slows the rate of frequency decay and assists in the recovery from a frequency event.

With the ongoing energy transition, and to maintain resource adequacy, additional power generation will be required. This can be achieved in the following ways:

- Large gas turbines and combined cycle units which are replacing coal generation can accommodate new load growth with firm generation or act as peaking plants, backing up intermittent generation sources. These generators provide the reliability attributes and inertia the system operator is familiar with today. These are also desirable candidates for CCS, and Hydrogen (H_2) in support of net-zero objectives.
- Adding renewables typically providing intermittent generation (wind/solar), to support load growth (but may require further backup with energy storage or dispatchable generation to provide capacity). These units are being constructed in wind and solar rich areas, which may not necessarily be close to where the existing transmission system has been developed.
- Existing interties are being utilized to a higher capacity and much closer to their design limits.

More specifically, gas turbines are currently replacing much of the coal fleet and possess similar characteristics such as size, dispatchability, capacity factor, inertia, and location. Moreover, new gas turbine generation can be constructed more quickly than transmission lines and, in more locations, though developers have looked to leverage existing connections more than green-field developments (e.g., Milner, Genesee Repower, and so on). This replacement strategy is attractive as new efficient (and lower carbon) generation can be built to a comparable or larger size (to allow for growth) and can reduce the prospect of stranding existing system assets, especially when the generation is developed in locations where coal has or will soon be retired. It should be noted, Alberta is one of several jurisdictions in North America which is transitioning from a high percentage of coal fired generation. The transition does favor a similar (like-for-like) replacement in generation for the sake of operational continuity.

Of note, where gas turbines replace coal units, the existing infrastructure appears to have sufficient evacuation capacity (within both the AC and DC systems) to take advantage of larger replacement generation sources. *The replacement strategy means, in at least the short to mid-term timeframe, the need to build new transmission to accommodate high-capacity factor and dispatchable generation is reduced or avoided.* Remedial action schemes (RAS), load shed, and protection solutions can be applied to prevent thermal, voltage, and dynamic stability consequences in specific situations.

Historically, base loaded coal-fired generation has supplied benefits such as inertia which has been a valuable tool available to provide intrinsic system support and flexibility. The development of wind, solar, and small distributed sources (e.g., LM6000, LM2500, reciprocating engines) don't possess the same reliability attributes (e.g., inertia) the system operator is familiar with having in abundance. Whereas the transition to larger natural gas fired units (i.e., larger frame turbines and combined cycle configurations) do provide similar attributes. Unlike with coal, these units are more likely to cycle on (providing inertia) and off-line (not providing inertia) based on market conditions for energy as there is no market for attributes such as inertia. Over the short to mid-term (up to 20 years) it is reasonable to expect inherent system advantages like inertia will still be required to maintain system reliability while load growth ramps up and renewable energy continues to innovate to provide system benefits. System operations will have to consider how the transition in the energy composition of the system and how generators commit units will affect the system and may initiate additional conversations, studies, and market reviews in the future.

One of the high-level outcomes of the energy transition is the growth of the power system as it off-loads fossil fuel usage. Many of these new loads will provide new sources of reliability attributes such as frequency responsive load shedding. Similarly, energy storage will provide new opportunities to evaluate how system security can be maintained. In Table 1, a high-level representation of the load growth through the energy transition is shown. As illustrated in the table, electrical loads' interaction with system security can be interpreted and leveraged in several ways.

Table 1: Load Growth and MSSC

	Normal Load Growth	Enhanced Load Growth	Growth Due to Transition
Growth Drivers	Traditional growth on the AIES	Newer load: Crypto mining, data centers, greenhouses, warehouses	Future Load: Fossil fuel transition from Commercial, Industrial, Transportation, and Residential sectors
Load Shed: Mitigation and Attributes	Currently offering LSSi, etc. load for shedding	Crypto mining & warehouses may offer more diverse load opportunities and volumes	Each sector will offer load; growth is significant so volumes may be larger
Storage Characteristics & Opportunities	Storage can be used selectively to reduce load or improve performance	Storage can facilitate quick connections to the system, participate in rapid load shed programs, inject power, etc.	Storage can enable transition of industry sectors, reduce congestion, reduce rate expansion, improve performance, etc.
Expected Annual Growth	<3%	<3%	>5%

There is incentive from all levels of government to make environmental changes to reduce carbon emissions. From an electrical load and generation perspective, the system is set to grow dramatically even in scenarios demonstrating modest energy transition. Almost certainly, the growth of conventional and renewable generation, and the size of individual units to maintain supply service, will grow considerably.

Finally, the transmission system has historically, and will in the future, act as a platform to enable a balance between load and generation and provide secure and reliable operation of the AIES. The system will move power and access any number of power system attributes like ancillary services, inertia, and other control areas, to name a few. As the transmission system evolves and responds to the addition of new load and generation, at times, transmission outages may isolate a generator or group of generators from the system, resulting in a larger effect on the AIES. The energy transition is highlighting a timing mismatch between long duration transmission development and the velocity (and agility) of project expansion associated with the energy transition. As the system continues to expand more rapidly in the future, these aggregate events may challenge system performance more often as the development of the transmission system, its operations, and associated protection schemes tries to catchup. Developing processes to increase the responsiveness (for example, a regular and comprehensive review of the MSSC and the need for new products or services) will allow the AESO to have more generation responsive products prior to triggering new transmission investment.

3. MSSC Definition and Determination

Typically, the MSSC level is defined as the maximum loss of supply the transmission system can withstand while remaining compliant with reliability standards and maintaining customer load continuity. Further, the MSSC may be the result of the loss of generation or the loss of a transmission line or intertie which may lead to the subsequent loss of generation.

In Alberta, the existing MSSC level of 466 MW refers to the net output of the largest historical generator, Genesee 3 (GN3), within Alberta. Studies were [presumably] performed to confirm the system would maintain stable and reliable if GN3 experienced a forced outage. The development of a mechanism like MSSC must also adhere to legislative requirements like the Transmission Regulation (T-Reg) and the Electric Utility Act.

The items contained within the technical and legislative framework is foundational for the MSSC.

3.1. MSSC Definition

Below are the definitions of MSSC within Alberta from 2015 and the current definition from 2021, and the NERC definition:

Prior definition (2015):

> *MSSC refers to the most severe single contingency generator or supply loss on the AIES which may occur as a result of a generator trip or the loss of a transmission line that subsequently leads to the simultaneous loss of generation*.[1]

Current definition (2021):

> *The Most Severe Single loss of supply Contingency that the power system can absorb without impacting reliability and tripping customer load.*

NERC Definition:

> *The Balancing Contingency Event, due to a single contingency identified using system models maintained within the Reserve Sharing Group (RSG) or a Balancing Authority's area that is not part of a Reserve Sharing Group, that would result in the greatest loss (measured in MW) of resource output used by the RSG or a Balancing Authority that is not participating as a member of a RSG at the time of the event to meet Firm Demand and export obligation (excluding export obligation for which Contingency Reserve obligations are being met by the Sink Balancing Authority).*

Regarding the definitions above, the proposed [2021] definition appears to be taking a static approach to the MSSC. It does not appear to address the magnitude, scope, or mitigation of the contingency. It appears to be at odds with the AESO's Reliability Standard BAL-002-AB-3 of; "*The ISO must develop, review, and maintain annually, and implement an operating process as part of its operating plan to determine its most severe single contingency and make preparations to have contingency reserve equal to, or greater than the ISO's most severe single contingency available for maintaining system reliability*."

[1] AESO (June, 2015) https://www.aeso.ca/assets/Uploads/Most-Severe-Single-Contingency-MSSC-document-for-ARC-June2015-v2.pdf page 3.

3.2. MSSC Methodology Review

The determination of the MSSC involves understanding the interplay of numerous elements within the power system. Further, power systems are connected through interties, so a consistent definition and approach to determining the MSSC within a region is important so treatment is uniform through the interconnected areas. Mismatches on definitions of services between control areas will become an alignment issue.

The level of MSSC in any jurisdiction is dependant on several factors. These factors include:

- System Generation: size (individual or grouped), location, configuration, prime mover, or contingency reserves;
- Transmission topology;
- Interties: capacity, number of ties, location, reserve agreements; and
- Protection and RAS: automatic systems which would be enabled during a large system event to arrest the decline of frequency, voltage, or reduce the level of damaging power flows.

Determining the MSSC based on the AESO's 2021 definition of would involve studying the AIES and its accompanying power flow model and discovering the largest generating units, the largest amount of generation which would be disconnected following the outage of a transmission element (for example, a line or transformer, or combined on a RAS), or the largest import into Alberta from an adjacent system over one of Alberta's interties.

The MSSC would, in most cases, correspond to the largest level of supply or generation which would be affected and automatically disconnected under a single event.

Given the competitive and dynamic power producer industry within Alberta, and the short discussion above regarding the determination of MSSC, it would make sense to develop a robust process to calculate MSSC, and then if needed, adjust it on a regular basis for the benefit of the overall operational performance of the power system. In addition to a regular review, a comprehensive MSSC study prior to the introduction of a new (and large) supply option being approved within the project connection process would make sense. As an example, it is relatively easy to scan the project list regularly to identify potential candidates which may fit the MSSC process. Examples highlighting a prospective approach include Capital Power's two generation requests which are presently in front of the AESO. The addition of these projects should trigger a review of the MSSC.

The first project is the 'Genesee 3 (GN3) Uprate' scheduled to increase GN3's output to 472 MW which is currently in stage 5 of the AESO connection process and is set to be completed in the second quarter of 2022. The completion of the GN3 upgrade would result in a 6 MW increase to the MSSC. The second project is the Genesee 1&2 repowering to 716 MW in a 1:1 combined cycle configuration with an in-service date of 2024. This project has been approved by the Alberta Utilities Commission and is progressing through the AESO's connection process. These projects replace the retired coal energy, capacity, and ancillary service attributes; their placement is imminent. As such it is timely for the AESO to be reviewing the MSSC.

Applying a static value of MSSC based on a historical and soon-to-be-uprated generator capacity level [to be applied post GN3's coal to gas conversion] may not adequately represent or recognize the identity and performance of the existing and future power system. Without examining these types of changes affecting MSSC, the AESO may be missing an opportunity to evaluate possible performance improvements on the power system. Like so many other cases, the Genesee site is expected to provide energy, capacity, and ancillary services for the long term as a coal unit location converted to run on natural gas. Further, the site may be repowered to a larger capacity value should market conditions warrant extending even further benefits to the AESO and the overall system within a defined environmental context.

In summary, if a developer submits a supply option exceeding the historical MSSC level, the use of this historic MSSC level mitigates the project's potential benefits and economies of scale by dictating a reduction in its size or adding cost by mandating configuration changes such as energy storage or less efficient designs.

Alternative approaches to a static MSSC approach are shown in Table 2. A dynamic or representative value of MSSC can be determined regularly or based on a perceived new generation or intertie addition greater than the existing MSSC level.

Technical considerations include inertia requirements for spinning / non-spinning generation, effects of varying levels of storage, reserve requirements, transmission congestion, etc. Additional considerations might include fast frequency response (for example, ERCOT) instead of or in addition to a more generic product like Load Shed Support for imports (LSSi) that only supports import flows on the tie over the MSSC.

3.3. MSSC Review: Approach for Alternatives:

Below, a short inventory of several alternative approaches is provided to determine the MSSC.

Table 2 – Alternatives to Determine MSSC

Alternative	Benefit	Drawback
Status quo which includes requiring configuration changes to projects (including adding batteries as part of the configuration) to maintain a 466 MW MSSC	• MSSC already in place	• Does not represent a true picture of system capacity • Does not incent efficient or innovative generation • Increases project and overall cost • Efficient capacity unable to take advantage of economies of scale to reduce customer costs • Adding storage at each site is a not uniform approach and is subject to uneven and disjoint planning • Potential seams and alignment issues with NERC • Projects must conform to older (and outdated) MSSC values
Increment MSSC from 466 MW in uniform steps	• More accurately represents a growing system • Regular review and adjustments allow flexibility in generation additions	• Regular reviews require specialized study and effort
Determine MSSC based on largest proposed generator or intertie addition or modification	• Accurately and regularly represents a growing system • Regular review and adjustments are based on actual project proposals • Alignment with NERC	• Mitigation strategies may have to be developed in concert with MSSC upgrades and the execution of these strategies may not be immediately obtainable
Enabled by newer technologies (batteries, highly controllable loads), evaluate the creation of an ancillary service to support higher levels of the MSSC (e.g., use of FFR)	• Can be added on or off site • Storage devices can react quickly to system events • The multi-purpose role of storage can rapidly fulfill reliability needs, smooth voltage, and arrest frequency decline • Can leverage existing LSSi design	• Requires AS product definition and competitive process developments
Upgrade Existing Ties	• Relatively easy to upgrade on existing ties lines once ROW has been granted • Inside the station changes are quick	• Conductor, voltage level, technology can be costly • Re-evaluate studies – costly, time consuming
Build new ties	• Interties mitigate risk, allow economic power trades	• Long duration, requires regulatory alignment between jurisdictions, payback, seams issues
More protection, AS, RAS	• Low-cost alternative, can leverage broad supply mix to support reliability requirements	• Finding load shed providers or other technology providers that can meet technical requirements • If can be done for existing 466 MW / intertie, can be done for larger site development

4. Reliable Operations

Alberta, like all other jurisdictions, seek to continuously improve their reliable operations within NERC.

With the legislative and technical framework in place, the next step is to perform scenario analysis which reflects the ongoing and evolutionary change underway as the system grows. Scenario based decision making helps identify technological and economic (and other) uncertainties. These scenarios can then be modeled. By examining a range of scenarios, decisions can be made based in the input assumptions and the corresponding results.

Load reduction and transmission [intertie] line flow management due to system contingencies is a well-established method to provide system security and reliability for unexpected events on the power system. These mechanisms seek to provide a stable balance between generation (and/or intertie access) and system load, allow timely restoration of service to customer demand following an event, and ultimately set the stage for the safe reconnection of transmission and interconnection ties.

Below is a description of notable reliability measures which have been developed for the AIES and why an alternative approach to determining the MSSC is warranted for reliability purposes.

4.1. Interconnection Operation

Prior to 1985, the loss of a 350 MW generator within Alberta for example, would result in system frequency dipping to below 58.9 Hz, and would require the intervention of interruptible load contracts as well as operating reserves to support system frequency. The addition of the 500 kV AC interconnection (1201L) in 1985 with BC provided a significant improvement in reliability by supporting power frequency stability. The drawback was the 1201L line (WECC Path 1) was an all-or-nothing connection; when Path 1 was out of service for any reason, Alberta was isolated from the Western Electric Coordinating Council (WECC). In 2013, the commissioning of the Montana-Alberta Tie Line (MATL) further increased Alberta's integration with the WECC. However, due to the interconnected nature of the lines within the WECC, the loss of 1201L will result in the simultaneous loss of MATL; in essence, the loss of 1201L and MATL can be considered a single contingency. All MSCC scenarios and determinations regarding tie line flow acknowledge margins required for reserve capacity.

The 150 MW back-to-back DC tie with Saskatchewan does not affect the MSSC due to its size and its non-synchronous nature.

4.2. Contracted Services

The AESO has implemented several countermeasures (LSSi and underfrequency load shed (UFLS)) to provide a foundation of continuous secure and reliable operation of the AIES for the loss of generation or imported power. The benefit these measures provide is the ability to ensure the power system can seamlessly recover from known contingencies.

In addition to providing developers a reasonable opportunity to connect to an unconstrained transmission system, developing and maintaining the wholesale market, and reliably operating the grid, the AESO has a legislated obligation to increase the tie line flow to match the design rating on Alberta's intertie with BC. Products like LSSi assist in meeting this obligation. Customers contracted under LSSi agree to install equipment to disconnect prescribed quantities of load quickly following the sudden and unexpected loss of imports on the interties.

The sudden loss of imported power will result in a decline in system frequency from the nominal 60 Hz and if left unattended, could result in a widespread loss of electrical load. The rapid shedding of load is meant to arrest, and then provide recovery in an orderly manner, from frequency decline. LSSi is used to reduce frequency risk under higher intertie flow.

The AESO has recently engaged in a pilot project to evaluate energy storage assets providing a similar service, but only in support of imports. Prior to the LSSi product, the AESO had procured a more generic load shed service (LSS) product that was used for frequency deviations regardless of the cause.

UFLS is an automatic underfrequency load reduction program used to maintain the security of the AIES during generation, transmission, and intertie contingencies which affect system frequency. The goal of UFLS is to be used as a last resort mechanism to maintain system continuity, prevent local and widespread outages, and protect transmission system elements through rapid load reduction.

Inertia assists in maintaining frequency levels during events, but as mentioned earlier it historically has been available in abundance to the system controller. As such, inertia has not been quantified or valued in the same way as a contracted service such as operating reserves (regulating, spinning, non-spinning). The incremental and (potential) ongoing loss of inertia will require additional scenarios and system studies to evaluate future services which can address system performance and growth.

The need to evaluate and enable mechanisms like MSSC, and correspondingly, associated infrastructure like generation and transmission facilities is driven by the growth of load. With the growth in loads able to provide system services (see Table 1) and increased use of energy storage there is ample reason to evaluate new or modified contracted services as part of ongoing evaluation and determination of the MSSC.

4.3. Discussion: Evaluation and Execution of Reliability and the MSSC

The planning and operation of the AIES is the role of the AESO[2]:

> *"The AESO provides the function of the Independent System Operator and is tasked with providing for the safe, reliable and economic operation of the Alberta Interconnected Electric System (AIES) and promoting a fair, efficient and openly competitive market for electricity. Ongoing stakeholder consultation and engagement with the industry allows the AESO to steward the evolution of Alberta's electricity market."*

The growth of the AIES, both on the generation and demand side, occurs largely through the efforts of developers and large customers. In response to retiring generation, load growth, and the pursuit of innovation, developers make substantial investments in infrastructure under existing rules, standards, and guided by the direction of the AESO through the connection process. The addition of generation, for example, depends on the investment climate, economies of scale, specific expertise in generation development, as well as other factors.

For renewable projects, the lower capacity factor, lack of easy dispatchability, and the economy of scale lends itself to larger projects as the energy transition evolves. These projects have non-persistent outputs but will at times provide full capacity to the system.

On the other hand, the development of gas turbines, especially located at sites which previously held coal units, are leveraging existing assets; the full utilization of these sites (to avoid asset stranding) is a cost effective and efficient method to utilize existing facilities. Further, an expectation of significant load growth makes large generation sites more desirable for both planning and operating the system.

[2] www.aeso.ca, Guide to understanding Alberta's electricity market.

As such, and with the AESO's legitimate pursuit of new Fast Frequency Response (FFR) services, it makes sense to adjust the MSSC approach to accommodate scenarios such as new single source generation or aggregate generation sites larger than 466 MW to accommodate generation developers' potentially larger sites.

As mentioned above, inertia in the power system is a valuable and inherent protection advantage the power system possesses by virtue of the rotating energy contained with the synchronously connected generators and motors. The larger the rotating the machine, the more inertia is available. Wind energy possesses very little inertia and PV solar energy possesses none. There is a very strong incentive to add synchronous machines to the power system for the next number of years to provide inertia and system support during the energy transition.

Referring to section 5.1 in the "*2011-001R-ATC-and-Transfer-Path-Management*"[3] document, the AESO determines real-time inertia based on the amount of load shed service and the British Columbia / Montana (BC/MT) net schedule. "*…If the ratio exceeds an established threshold value, the import available transfer capability may be reduced and a new available transfer capability may be calculated to ensure that the threshold is not exceeded."*

Inertia formula = (BC/MT net schedule – dispatches issued for LSSi) / real-time system inertia

Of interest are two items. Firstly, more system inertia enables more import. The outcome presumably favors the addition of more rotating generation in Alberta. Economically, it makes sense to have larger stations of gas turbines, and the location which can accommodate more generation is where the coal retirements are occurring. Secondly, the inherent power system protection which comes with generators possessing inertia assists system stability during periods of upset on the grid. The inertia formula appears to promote the updating of the MSSC.

4.4. Recent Reliability Concerns

Over the past two years, the Alberta Interconnected Electric System (AIES) has experienced six notable disturbance events related to the synchronously connected Alberta tie lines. These events seem related to low system inertia exacerbated by relatively poor primary frequency response when the interties with British Columbia and Montana have tripped, and/or contingencies have occurred on the Alberta grid. Some of these events have resulted in the activation of the province's Under-Frequency Load Shed (UFLS) program. While these contingencies do raise some questions in the immediate term, the interconnection forced outage rates of approximately 4 events per year are consistent with recent norms. These outages are being reviewed by the AESO; the findings should provide additional clarity to the development of the MSSC in the future.

5. Path to Determine Future MSSC

The power systems in North America will inevitably grow due to 'normal' expansion as is being traditionally forecasted, enhanced growth such as crypto farms, and also due to energy transition growth. The energy transition will include a transfer of energy from industry, commercial activity, transportation, and residential use to other less carbon intensive forms of energy production and consumption like electricity.

[3] https://www.aeso.ca/assets/Information-Documents/2011-001R-ATC-and-Transfer-Path-Management.pdf

As we move from several independent and diverse sets of energy sources (electricity and fossil fuels) and limited prime movers (gas plants, nuclear, renewable, hydro, et al) many different aspects of the power system will be examined in different ways based on planning, operations, and compliance, to name a few. The evolution of NERC compliance requirements will provide more guidance regarding contingency mitigation.

Inherent in the review will be an examination of concepts such as MSSC as the industry considers other approaches to critical areas of system performance such as reliability and security.

5.1. Discussion: Evolution of the MSSC

The foundation of the MSSC is a consideration of how robust a power system is based on the loss of the most significant resource. Historically, power systems have been planned and modelled to integrate new facilities based on lowest cost balanced with reliable operation, access to a primary fuel source, the economies of scale, and scalability or the ability to incorporate more growth in a particular area.

Its reasonable to assume the growth of electrical load will accelerate in the next 20 years due to the energy transition. The transition of load will occur based on sector (transportation, residential, commercial, and industrial areas) but also on location, priority, and natural alignment with other changes. As such, the service of the new electrical load will need to coincide with generation development.

For example, heavy industrial load currently served by fossil fuels with a high load factor will need support from a responsive, high-capacity factor, and dispatchable energy source. And based on the nature of the industrial load, the source may be large and in areas not currently well served by electricity. A good example is hard rock mining load located some distance from electrical services.

As such, the need to develop larger generation will need consideration. And with the transition of fossil fuel load in other sectors, there may be more opportunity to engage LSSi or similar products to shed load and/or inject supply while the larger generation sites are constructed. Of note is some larger generation sources will coexist with load making the net or apparent generation lower.

For these reasons, *the current proposal of a static MSSC perspective will evolve and need to consider a dynamic approach involving regular reviews and updates*. While the MSSC is aligned with a certain level of contingency reserves as per BAL-002, as the load grows and the energy transition increases, it is likely the MSSC will not drive the level of contingency reserves in Alberta as already the AESO regularly procures over 466 MW of contingency reserves.

5.2. Possible Future Services

FFR is another automatic and rapidly acting mechanism to provide transmission reliability service caused by the sudden loss of imports from the Alberta—B.C. Intertie and the Montana—Alberta Tie Line. FFR is currently provided by load shedding through LSSi.

The AESO is pursuing new technology and developing an FFR pilot project to procure services which meet defined technical and eligibility requirements. The procurement of FRR in the context of an increased MSSC makes sense.

Progress is being made in several areas and within several markets to support the development of new services and technology to address the changing nature of the power system. For example, ERCOT already has created a FFR service critical to maintain the reliability and security of the power system through a market mechanism. Several other markets are doing the same. Storage devices could potentially also provide complimentary services to mechanisms like MSSC, UFLS, and others by providing rapid deployment of frequency response services. To innovate the existing market and test ahead of actual usage, the AESO could begin to evaluate these services within an overall framework and transition in new products as existing ones like inertia may be declining.

Future development of interties to adjacent jurisdictions may assist Alberta in governing the reliability of the power system, including the management of the MSSC issue. Given the extended periods of time it takes to plan, design, and develop regulatory alignment on tie lines, the intertie solution is not addressed in the context of this report.

5.3. Opportunities for Increasing MSSC

Although we are experiencing a reduction in inertial machines within the power system in Alberta as coal generation is being reduced, an opportunity has presented itself in some areas of the system.

The opportunity to construct large gas turbines in areas where fossil fuel generation is currently being developed can cover not only the transition but provide system inertia for other transitions which involve renewable and non-synchronous generation. With these machines, new ancillary services can be developed to support primary frequency control. Where economic and technically advantageous, new [and cost effective] storage solutions can be integrated into new generation sites. Again, these conversion sites can take advantage of existing transmission infrastructure and reduce carbon emissions in a coincident manner.

6. Discussion, Conclusions, and Recommendations

6.1. Discussion

A critical area of system security in the power system is how to prevent large scale outages during periods of system upset. Knowing there will be contingencies on the system, ongoing scenario analysis in the form of system studies are performed to ensure risk is identified, quantified, and mitigated. One obvious area of risk is: what is the single largest event affecting system reliability? The MSSC addresses this risk directly.

If a loss of generation or the loss of critical transmission initiates a severe contingency, then automatic and high-speed action is required to mitigate, contain, or ensure an orderly (local) shutdown to maintain overall system continuity and rapid re-constitution of the overall system. Innovative solutions while we transition the power system will also assist in a secure system.

Since 1998, Alberta has initiated an independent project process, through deregulation, where new generators, loads, and transmission facilities considered and evaluated prior to connection to the AIES. Recently, the magnitude of change due to the energy transition has taken hold, and more projects are expected. With the transition, and transfer of fossil fuel energy to (in large part) electricity, electrical load and generation will grow in tandem, and transmission development will join the two.

Almost certainly, through economies of scale or technological efficiency, larger generators, large aggregate groups of generators connected through single contingency transmission elements, or high-capacity intertie connections will occur. It is reasonable to address these large-scale transmission level additions in a coherent, integrated, and system wide manner. In other words, within a traditional transmission planning context. As the system decarbonizes, grows, and evolves over the next decades, it is also reasonable to maintain some similar operating characteristics to smooth the transition, maintain reliability and security, and preserve familiar operating norms where it is reasonable to do so.

6.1.1. The AESO

The AESO appears concerned increasing the MSSC will expose the system and customers to higher risk. Further, the AESO has indicated recent UFLS events are related to "*increased penetration of renewable resources and DERs, declining inertia, inconsistent system response, and generation pull-back*", and "*Increasing MSSC levels increases the probability of UFLS events until mitigation plans are implemented and proven effective*".

Recently, the AESO has proposed a static MSSC, effectively creating a limit on the size of generation that can be developed. The proposal is markedly different than the previous direction given in 2015.

The AESO leads several roles within the AIES, including transmission planning, project development, market operation, system operation, and reliability compliance. In order to provide the foundation for a secure and reliable system, the AESO employs numerous policies, procedures, and technical solutions.

Finally, the AESO also adheres to fundamental obligations within Alberta including the T-Reg, EUA, and other responsibilities.

6.1.2. Evolution of the AIES

The power system in Alberta is changing as more incentive to reduce carbon emissions occurs. Due to normal load growth and growth associated with the energy transition, load, generation, the transmission system, and possibly intertie capacity will grow. To match large load growth, it is reasonable to expect large generating stations [and flow on interties] will continue to be developed as they possess the economies of scale for developers to build generation. These developments also include economic benefits for consumers.

6.1.3. Generation Replacement

Larger generation replacements for coal, like building similar size or larger GT's, has the following advantages:

- Similar characteristics such as capacity factor, dispatchability, and inertia;
- Reduced need for immediate transmission solutions and associate costs;
- Virtually no constraint or congestion – utilizing existing facilities means less stranded assets; and
- A low carbon transition period to ensure high levels of system reliability and cost-effective operation while we continue to pursue long term net zero carbon goals.

The development of a regular and comprehensive review of the MSSC and the use of resources and services like inertia, and UFLS, and new resources like FFR, provide a forward-looking framework to support coherent and reliable operation of the system under the guidance of the system controller during what is likely to be dramatic future growth.

6.2. Conclusions

Below are the conclusions of '*Most Severe Single Contingency Evaluation*'.

The loss of the largest supply of electricity on the power system is a significant event, especially with the size of the existing and proposed generators on the system. In the past two years, forced outages on Alberta's synchronized tie lines correspond to and align with long term average forced outages.

To balance the building of large generators to match large load growth, good procedures, and technical solutions, mechanisms like MSSC, allow the system to operate reliably even if a large loss of generation or supply were to occur. The replacement of existing generation will be fulfilled by lower emission gas turbines and by renewable energy.

Renewable energy does not possess physical characteristics like inertia, an inherent advantage which 'comes' with generators including coal and GT units.

Technology advances like FFR can support system operation if MSSC levels are increased. For the foreseeable future, larger generators (especially GT's) can address the AESO's concerns related to renewable additions, declining inertia, and inconsistent system response and provide reliable, high capacity-factor, and dispatchable energy to support renewable energy delivery and provide services like inertia, which the AESO has indicated is declining.

With the expansion of the AIES underway due to the energy transition, the AESO's role is imperative and instrumental in studying the system and updating the MSSC on a regular basis.

Specifically, the AESO (or a qualified consultant under the AESO's direction) should determine and update the overall value of MSSC based on a regular and comprehensive system review similar to other planning processes, continue to work with interconnected partners and developers, and ensure sufficient reliability items like operating reserves are available to address system issues.

By adding to and continuing to develop an enhanced connection process to address the existing and prospective issues, a common and successful approach can be developed with all stakeholders.

In addition to the conclusions above, the AESO should continue to allow imports to exceed the 466 MW MSSC limit through the use of mechanisms like LSSi, UFLS, and innovative products like FFR.

6.3. Recommendations

Below are specific recommendations in four areas based on the preceding discussions and conclusions.

- **Foundation**: The AESO should continue to assess and update ongoing changes to load, generation, and topology and update system models with appropriate project information. The AESO should also continue to ensure alignment with the T-Reg, EUA, tariff, and other statutory obligations.

- **Execution**: *It is recommended the AESO should continue to engage in industry discussions related to evaluating increases to the MSSC*. The AESO should conduct further stakeholder engagement early in 2022 to evaluate the benefits of, and options to, increasing the MSSC. The scope of the analysis can be developed with specific consideration of the findings in this report. The AESO should establish a process for implementing a regular and comprehensive review of the MSSC based on changes in Alberta's supply development. Specifically, the AESO should develop a framework to perform comprehensive scenario analysis, including the MSSC, in a context which recognizes and reflects the continuous change associated with the energy transition, the evolution of the AIES, existing methods (including statutory obligations), and Alberta's alignment with our interconnected neighbors, developers, and other stakeholders. Once a framework is developed, the initial analysis and evaluation can be performed within the next year, at which time the AESO could determine the appropriate MSSC level and issue contracts for additional requirements of contingency reserves (including load shed / fast frequency response services). Subsequent analysis can proceed on a regular basis or as new supply options or significant changes occur on the AIES.
- **Security**: Utilize the numerous tools, methods, and standards available and perform the system security analysis with consideration to a balance between overall cost and reliability.
- **Innovation**: Consider existing contingency reserve services and investigate future/innovative mitigation such as FFR to address system performance associated with an increased MSSC value considering the growth and evolution of the AIES.

Similan Consulting

Economic Impact of Increasing the MSSC Value

Prepared for
Capital Power Corporation

Prepared on
December 30, 2021

Similan Consulting

Alberta Power | Advisory | Optimization | Analytics

Economic Impact of Increasing the MSSC Value

Executive Summary

The AESO engaged industry stakeholders to request feedback regarding potential changes to the MSSC value. On November 4, 2021, the AESO presented to industry its Most Severe Single Contingency (MSSC) Evaluation for Alberta[1]. The presentation included technical and economic considerations involved in increasing the MSSC value. This memo focuses on the economic considerations involved in increasing the MSSC value and provides analysis that supplements the AESO's preliminary counterfactual analysis.

The AESO's preliminary counterfactual focused on the economic impact that a reduction of import flows resulting from increasing the MSSC value would have had on historical pool prices, contingency reserve and LSSi[2] costs (for the years 2016 to 2020). This report supplements the initial analysis performed by the AESO by extending the analysis to a forecast basis (2024 to 2030) and including the addition of larger generating units into the market to evaluate their impact on pool prices and consumer surplus. The findings in this report indicate that increases in the MSSC value (where each 1 MW reduction in the total transfer capability result in the addition of 2 MW of combined cycle capacity) result in consumer surplus.

[1] https://www.aeso.ca/assets/Uploads/grid-related-initiatives/MSSC/Evaluation-of-MSSC-Nov.-4-2021.pdf

[2] LSSi: Load Shed Service for imports

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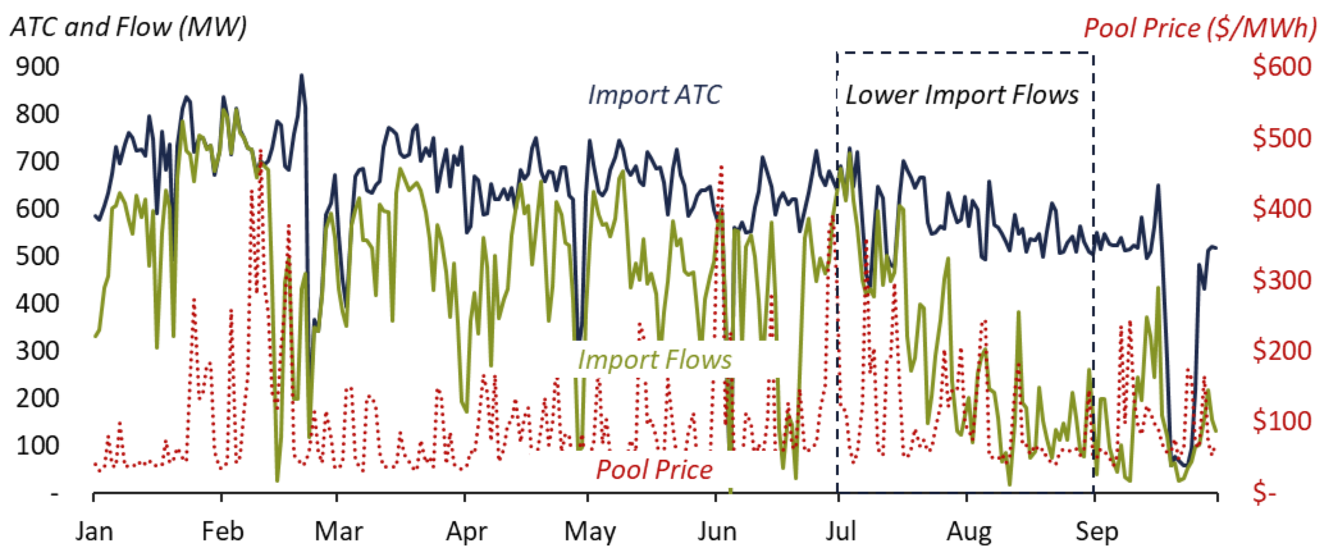
AESO's Counterfactual Analysis

The AESO performed preliminary counterfactual analysis to assess the impact of increasing the MSSC value. Using historical data from 2016 to 2020 (inclusive), the analysis estimated the change in pool prices and contingency reserve and LSSi costs caused by an increase in the MSSC value. The analysis assumed that a change in the MSSC value would reduce the Available Transfer Capability (ATC) of the BC and MATL tie-lines. However, the analysis did not include the offsetting effect from adding larger generating units into the market. Given the assumptions made by the AESO, the analysis estimates the impact of lowering the ATC of the BC and MATL tie-lines (on a lookback basis), which as expected results in a reduction to consumer surplus.

One underlying assumption made by the AESO in their counterfactual analysis is that tie-line flows are equivalent to zero dollar offers. While import offers into the energy market are priced at zero dollars, the offer volume is an economic decision (imports are not subject to the must-offer rule) that considers the expected pool price of Alberta. Evidence of this is observed in Figure 1, which shows the ATC and import flows for the BC and MATL tie-lines from January to September 2021 (from mid-July to the end of August, the flows dropped in response to higher Mid-C prices).

The decision in front of the AESO is not to reduce the ATC of the BC and MATL tie-lines in isolation, but to increase the MSSC value to accommodate larger generating units, specifically, the two Genesee repowered combined cycle units. The Genesee repowered combined cycle units are impacted by the 466 MW MSSC level due to their large size and 1-on-1 configuration, which as will be shown in later sections is the most economically efficient. This report offers a broader forward-looking analysis that considers the price impact of adding 2 MW of 6,700 kJ/MWh heat rate generation into the Alberta supply mix for every 1 MW reduction in the ATC of the BC and MATL tie-lines.

Figure 1 – BC and MATL ATC and Flows vs. Pool Prices (January to September 2021)



Economic Impact of Increasing the MSSC Value

Table 1 below shows the average (2024-2030) impact to consumers from Increasing the MSSC value. Two economic impacts were considered in the analysis: (1) the change in pool prices resulting from a reduction in ATC of the BC and MATL tie-lines and increase in generating capacity at Genesee; and (2) the incremental cost of operating reserves resulting from the increase in the MSSC based on 2016-2020 averages (Table 2).

The results of increasing the MSSC by 100 MW and 200 MW, respectively, may be summarized as follows:

- Pool prices decrease by $2.9/MWh and $5.3/MWh
- Pool energy charges to consumers decrease by $173M and $314M
- Operating reserves costs increase by $11M and $37M
- Net charges to consumers decrease by $162M and $277M

Savings in pool energy charges exceed increases in operating reserve costs by an order of magnitude. The decrease in pool prices is expected as net supply is increased when the MSSC value is increased (2 MW of 6,700 kJ/MWh heat rate generation is added for every 1 MW reduction in the ATC of the BC and MATL tie-lines).

Table 1 – Average Impact of Increasing the MSSC Value (2024-2030)

		Status Quo	MSSC Increase +100 MW	MSSC Increase +200 MW	Comments
Genesee Repower Capacity	*MW*	466	566	666	
MSSC	*MW*	466	566	666	
Increase in MSSC	*MW*	0	100	200	
Impact on Imports					
Average ATC	*MW*	677	652	552	Recalculation of BC/MATL ATC for 2020
Change in Import Volumes	*GWh*	0	-283	-583	Similan foreast model output
Market Impact					
Pool Price	*$/MWh*	$67.4	$64.5	$62.1	Similan forecast of Avg. Pool Prices for 2024-30
Market Price Impact	*$/MWh*	$0.0	-$2.9	-$5.3	
System Load	*GWh*	59,460	59,460	59,460	Avg. metered energy from 2016-2020
Pool energy charges	*$M*	$0	-$173	-$314	System load multiplied by the market price impact
Operating Reserves Impact					
Increase in CR Volume	*%*	0	8%	26%	AESO estimate[1]
OR Costs[1]	*$M*	143	154	180	Assumes OR Costs proportional to CR volumes
OR Impact	*$M*	$0.0	$11	$37	
Total Impact to Consumers	***$M***	**$0**	**-$162**	**-$277**	

Notes:

[1] Most Severe Single Contingency (MSSC) Evaluation for Alberta (Nov. 4, 2021)

[2] Status Quo assumes Avg. Operating Reserve costs from 2016 to 2020 of $143M

Table 2 – Operating Reserve and Ancillary Service Costs

	2016 Recorded	2017 Recorded	2018 Recorded	2019 Recorded	2020 Recorded	Period Average
Operating Reserve and AS Cost						
Operating Reserves *($ millions)*	66.4	80.7	235.8	187.1	144.8	143.0
Other Ancillary Service Costs *($ millions)*	26.8	34.3	41.9	25.8	37.7	33.3
OR and other AS costs *($ millions)*	**93.2**	**115.0**	**277.7**	**212.9**	**182.5**	**176.3**
Metered Energy *(GWh)*	58,504	60,010	61,017	59,652	58,118	59,460
OR and other AS costs *($/MWh)*	1.13	1.34	3.86	3.14	2.49	2.4
Average Pool Price *($/MWh)*	18.3	22.2	50.3	54.9	46.7	38.5
OR and Other AS costs *(as % of Pool Price)*	**6.2%**	**6.1%**	**7.7%**	**5.7%**	**5.3%**	**6.2%**

Sources:

- AESO Business Plan and Budget Proposals from 2019 to 2022
- AESO 2021 ISO Tariff Update, AESO 2022 ISO Tariff Update and Rider J Amendment Application

Pool Price Forecast at Different MSSC Value

Table 3 below shows the pool price impact of increasing the MSSC from its current levels (“Status Quo”) to 566 MW (“+100 MW”) and 666 MW (“+200 MW). The price forecast includes a maximum capability increase of 2 MW at Genesee for every 1 MW reduction in the ATC of the BC and MATL tie-lines (1 MW: 0.8 MW at BC and 0.2 MW at MATL). The analysis shows that a 200 MW increase in the MSSC results in a $5.3/MWh reduction in pool prices from 2024 to 2030.

Table 3 – Pool Price Impact of Increasing MSSC Value

	Pool Price Forecast ($/MWh)			**Variance** ($/MWh)	
		MSSC Increase[2]		**MSSC Increase**	
Year	**Status Quo**[1]	**+100 MW**	**+200 MW**	**+100 MW**	**+200 MW**
2024	$56.4	$55.7	$55.3	-$0.7	-$1.1
2025	$61.7	$59.6	$57.6	-$2.1	-$4.1
2026	$66.3	$63.1	$60.3	-$3.2	-$6.0
2027	$73.8	$69.9	$66.2	-$3.9	-$7.6
2028	$69.9	$66.4	$63.9	-$3.5	-$6.0
2029	$68.7	$65.3	$62.8	-$3.4	-$5.8
2030	$74.8	$71.2	$68.5	-$3.6	-$6.3
Average	$67.4	$64.5	$62.1	-$2.9	-$5.3

Notes:

(1) MSSC remains at current levels (466 MW)

(2) Forecast assumes that each 100 MW MSSC increase enables a 200MW increase in Maximum Capability at Genesee

Policy Implications of MSSC Value

Maintaining the MSSC at current levels may delay the retirement of coal-to-gas units to the detriment of more efficient units. Capital Power is conducting FEED studies to add carbon capture and underground storage (CCUS) to the Genesee repowering project, which could materially reduce the carbon emissions from this project as early as 2026 (up to 3M tCO2e per year[3]). Holding the MSSC at current levels results in policy signaling that is contrary to current Federal and Provincial decarbonization goals as it limits the development of larger scale projects that take advantage of economies of scale. The likely outcome of maintaining the current MSSC level is a combination of higher pool prices and/or higher emissions.

Enabling the construction of larger units by increasing the MSSC value is also consistent with the latest energy transition pathways, which largely rely on electrification to meet emission targets. The report "Canada's Energy Future 2021" published by the Canada Energy Regulator in December 2021[4] states:

> *"Compared to the past two decades when electricity use grew very slowly, electricity demand grows quickly over the projection period in the Evolving Policies Scenario. This increase is driven by increased electrification of the energy system. Total electricity demand increases by 44% from 2021 to 2050, or by about 245 terawatt hours (TWh)"*

Absent a higher MSSC value, load growth driven by electrification will eventually lead to higher volumes of contingency reserves as 3-and-3 requirements[5] will exceed the MSSC during more hours. Increases in contingency reserve volumes to accommodate a higher MSSC would then be (in principle) temporary. Electrification based load growth will require the addition of new firm supply to the market. Allowing larger units to be built into the market can lower long-run marginal cost as will be shown in the next section.

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[3] https://www.capitalpower.com/media/media_releases/capital-power-and-enbridge-collaborate-to-reduce-co2-emissions-in-alberta/

[4] https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2021/canada-energy-futures-2021.pdf

[5] AL-002-WECC-AB1-2

Impact of MSSC Value on Long-Run Marginal Costs

Similan conducted a preliminary assessment of the MSSC value impact on long run marginal costs. The analysis assumed 1-on-1 combined cycle capital costs as a proxy for long run marginal costs[6].

Capital and variable costs of units sized 460 MW (largest unit size that can operate under the current MSSC value) were compared to those of units sized 660 MW (largest unit that could be accommodated after a 200 MW increase to the MSSC value). The analysis was done using industry benchmarks and public information from projects under construction or recently completed.

Table 4 shows the impact of CCGT size on capital and variable costs. An increase in overnight costs of $175-240/kW was estimated when project sizes decreased from 660 MW to 460 MW. This results in an increase in net-revenue requirements of $3.7-5.1/MWh on a spark spread basis. Compared to larger 660 MW units, smaller 460 MW units have higher heat rates by 200 to 325 kJ/MWh, resulting in higher fuel and carbon compliance costs of $1.1-3.8/MWh. The resulting impact of limiting project sizes from 660 MW to 460 MW is that capture prices need to be $4.9-8.9/MWh higher for smaller projects to earn the same investment returns.

The resulting pool price impact from enabling larger unit sizes can offset increases resulting from higher operating reserve requirements associated with an increased MSSC value. Smaller projects can result in higher pool prices by $3.7-6.8/MWh (assuming 100% of the capture price requirements are passed on to consumers), whereas increases in operating reserve requirements resulting from an increased MSSC are in the order of $0.6/MWh. Additionally, the cost of providing operating reserves should decrease over time as will be shown in the next section.

[6] For similar project sizes, 1-on-1 combined cycle plants had lower overnight costs and heat rates.

Table 4 – Impact of MSSC Level on Combined Cycle Economics

Economic Impact of CCGT size (460 to 660 MW)				
Capital Cost Impact		Low	High	***Source:***
Capital Cost Impact	*$/kW*	175	240	Industry benchmarks and Similan Analysis
Net-Revenue Requirement	*$/kW-yr*	25	34	Similan Analysis
Capacity Factor	*%*	76%	76%	AESO's 2021 Long Term Outlook
Spark Spread Requirement	*$/MWh*	3.7	5.1	
Variable Cost Impacts				
Heat Rate Difference	*kJ/MWh*	200	325	Industry benchmarks and Similan Analysis
Emissions Impact	*gCO2e/kWh*	10.2	16.6	Similan Analysis
Gas Price	*$/MWh*	3.0	3.0	
Carbon Price	*$/tCO2e*	50.0	170.0	
Fuel Costs	*$/MWh*	0.6	1.0	
Carbon Compliance	*$/MWh*	0.5	2.8	
Variable Cost Impact	*$/MWh*	1.1	3.8	
Impact of CCGT Size (460 to 660 MW)				
Capital Costs	*$/MWh*	3.7	5.1	
Variable Costs	*$/MWh*	1.1	3.8	
Total	***$/MWh***	**4.9**	**8.9**	

Long-run Cost of Contingency Reserves

The cost of Li-On battery storage has been dropping at a rapid pace over the last decade. Per Bloomberg NEF, battery pack costs have dropped 83% since 2013[7]. Alberta has seen the addition of 3 battery storage projects in the last year, with two of these projects being selected in the AESO's Fast Frequency Response (FFR) Pilot Competition.

Table 5 shows net-revenue target estimates for Alberta storage projects, based on recently built or announced projects. The table shows that based on overnight costs between $700/kWh and $1000/kWh, battery storage can meet its net-revenue targets with ancillary service contract payouts in the $18-23/MWh range.

Figure 2 shows the payout[8] of ancillary services from 2016 to 2021 year to date overlayed with the range of target ancillary service payout for battery storage. The figure shows that ancillary service contract payouts generally exceed the target payouts required by battery storage to meet its target investment returns.

Looking ahead, capital costs for battery storage projects are expected to continue decreasing (Figure 3). The technical specifications of battery storage projects make them ideal for the provision of operating reserves and their declining costs suggest that the cost of operating reserves should drop over time.

Table 5 – Net-Revenue Targets for Alberta Battery Storage Projects

		$700/kWh(1)	$1000/kWh(2)
Battery Storage Net-Revenue			
Capital Returns *(12% unlevered)*	*$/kWh-yr*	$107	$148
O&M(3)	*$/kWh-yr*	$44	$44
Net-Revenue Target	*$/kWh-yr*	$151	$192
Ancillary Services Payout Target	***$/MWh***	**$18.2**	**$23.0**

Sources:

(1) TransAlta Summerview Windcharger capital cost ($14.5M for 20 MWh of storage)

(2) Capital Power projected Genesee battery cost ($195M for 210 MWh of storage)

(3) NREL: Cost Projections for Utility Scale Battery Storage: 2021 Update

[7] https://www.bloomberg.com/news/articles/2021-11-30/even-the-battery-boom-can-t-escape-world-s-supply-chain-woes

[8] Payout was calculated hourly as the greater of zero and the pool price plus the product index

Figure 2 – Ancillary Services Payout

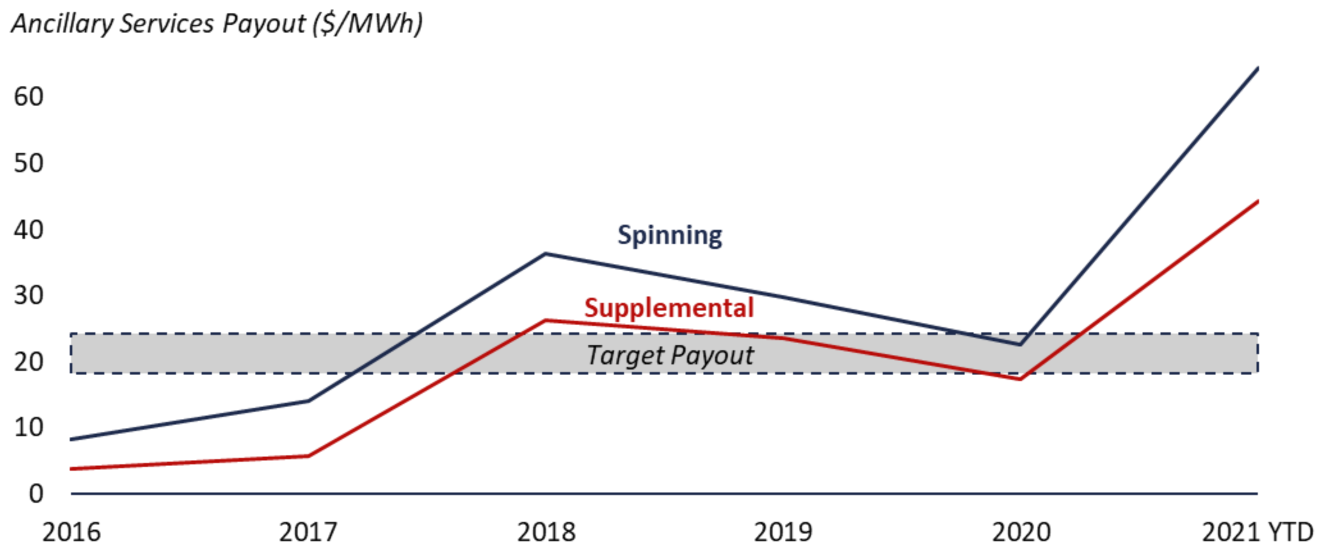
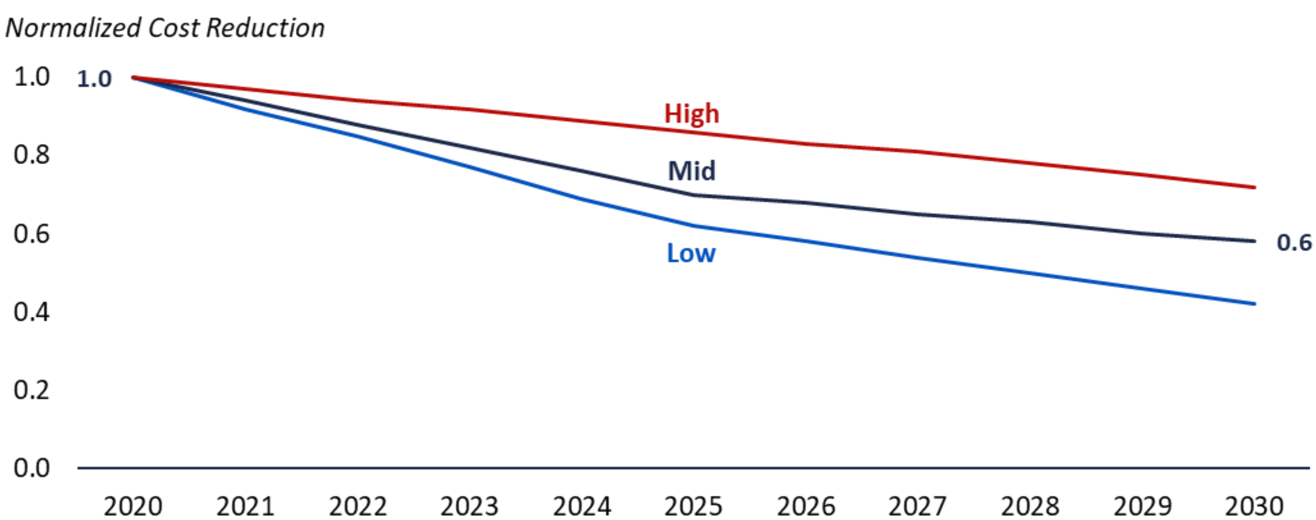


Figure 3 – Normalized cost reductions for a complete 4-hour battery system



Source: *NREL - Cost Projections for Utility-Scale Battery Storage: 2021 Update*