Purpose of Document and Request for Feedback

This is an overview of the short-term qualification and technical requirements for energy storage facility participation in the operating reserves (OR) market. Applicability of Alberta Reliability Standards (ARS) to energy storage facilities is also considered in this document.

In order to provide energy storage projects with clarity for participation in the markets under the existing Authoritative Documents (prior to the implementation of the longer-term changes), the AESO has assessed the current Authoritative Documents and identified areas that could benefit from further clarity, based on questions being asked by the current energy storage project developers.

The AESO intends to provide this additional clarity to stakeholders by developing or updating a series of Information Documents related to the current AESO Authoritative Documents. The AESO wishes to ensure that it has considered the perspectives of interested stakeholders prior to the finalization of the content of these Information Documents.

The AESO values stakeholder feedback and invites stakeholders to provide input to the AESO on the questions set out in the associated Stakeholder Comment Matrix on or before **May 7, 2020**.

The AESO will review and consider stakeholder feedback as well as use the conclusions and rationale set out in this overview document in the development or updating of Information Documents related to current AESO Authoritative Documents to provide clarity for energy storage participants in the short-term.

Clarity that cannot be provided within the current legislative and Authoritative Document structure will be considered as part of the long-term storage integration phase outlined in the AESO Energy Storage Roadmap[1]. It is expected that the AESO's longer term storage work will result in changes to the Authoritative Documents, both to provide specific clarity as it relates to storage and to consider the uniqueness of energy storage.

1. Background

In August 2019, the AESO published the Energy Storage Roadmap. This roadmap was developed to set out the plan to integrate energy storage facilities, given that current legislation and AESO Authoritative Documents do not fully contemplate the unique attributes and challenges associated with energy storage participation. Four market participants have submitted requests to connect their energy storage facilities to the Alberta Interconnected Electric System (AIES) with 2020-21 in-service dates (ISDs). In order to accommodate these ISDs, two deliberate phases of implementation work have been developed within the AESO Energy Storage Roadmap:

1. A short-term phase to support and enable connection projects requesting 2020-21 ISDs within the current AESO Authoritative Documents; and,
2. A long-term implementation phase specifically covering changes to AESO Authoritative Documents and the AIES and market systems.

[1] https://www.aeso.ca/assets/Uploads/Energy-Storage-Roadmap-Report.pdf

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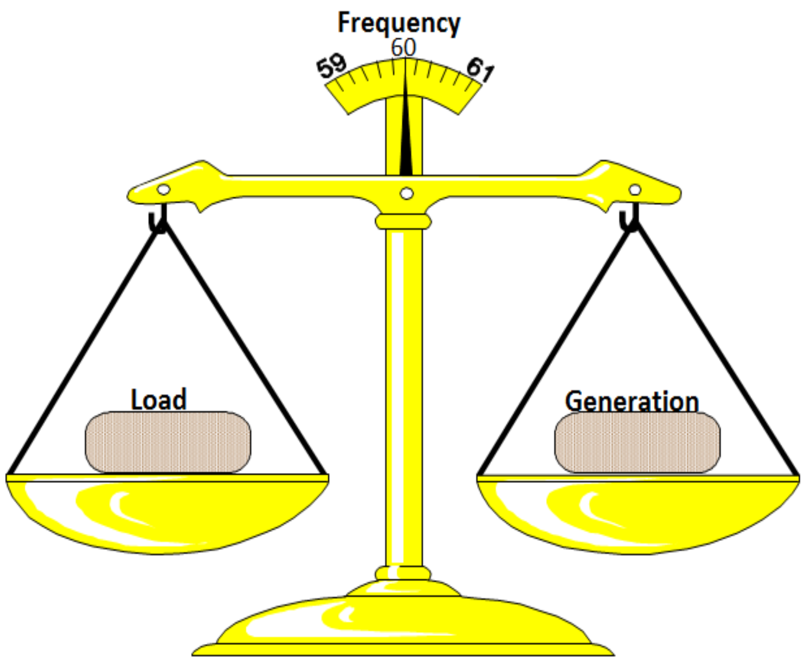
2. Operating Reserves

Operating Reserves act as a safety net, making extra power available to help balance the supply and demand of electricity in real time. Operating Reserves also stabilize and protect the interconnected electric system in the event of unforeseen problems. There are two types of Operating Reserves: Regulating Reserve and Contingency Reserve. Each type of Operating Reserve performs a unique function and has unique technical requirements.



2.1 Regulating Reserve

Regulating Reserve is used to provide a balance between generation and load within the AESO's balancing authority area, while maintaining the interchange schedule on the interconnections with British Columbia and Montana at the nominal frequency of 60 Hz.

2.2 Contingency Reserve

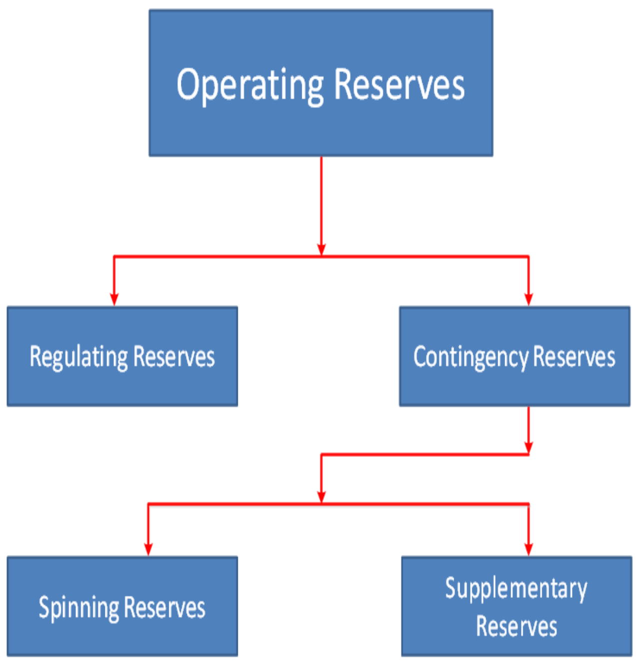
Contingency Reserve is used to restore the balance between the supply of and demand for electricity following a contingency or unforeseen event threatening the reliable operation of the interconnected electric system. Contingencies can include events such as the sudden loss of a generating unit or the disruption of one of the interconnections that link Alberta to a neighboring jurisdiction. Contingency Reserve is further divided into Spinning Reserve and Supplemental Reserve.

2.2.1 Spinning Reserve

A type of Contingency Reserve that is immediately and automatically responsive to system frequency deviations through the action of an appropriate governor or control system (primary frequency response).

2.2.2 Supplemental Reserves

Supplemental reserves are a type of the Contingency Reserve that is (a) generation capable of being connected to the AIES and providing supply within ten (10) minutes; or (b) load connected to the AIES which can be reduced within ten (10) minutes.



3. Energy Storage Terminology

Energy storage resources (ESR) have unique characteristics and with proper engineering design and construction, they may be able to qualify to participate in the Operating Reserve market by meeting necessary technical requirements. Depending upon various parameters such as the type of grid connection, operating philosophy and technical characteristics, energy storage resources will be eligible to participate in the specific Operating Reserve Market (Qualification).

A few of the commonly known and well understood ESR terminologies are described below:

3.1 Rated Energy MWh

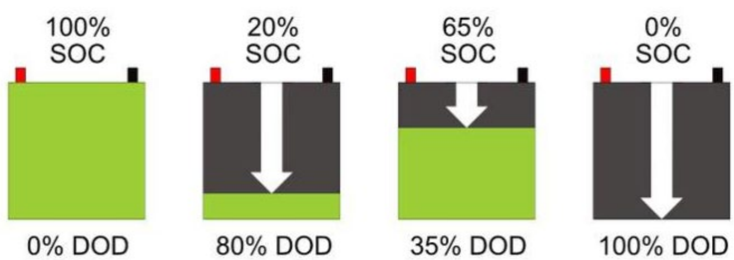
Rated energy is the amount of energy stored in the ESR. If an ESR has a 40 MWh energy rating and the size of the inverter is 10 MW, it is capable of discharging 10 MW for duration of 4 hours. Engineering design of the ESR components will be based on the maximum 10MW charging and 10MW discharging from this resource.

3.2 Rated MW

Rated MW is the maximum discharging power that an ESR can provide at a given time. This is limited by the rating of the inverter, in the example above, it is 10MW.

3.3 State of Charge

State of Charge (SOC) is the level of charge of an ESR relative to its capacity. The units of SOC are percentage points (0% = empty; 100% = full). An alternate form of this measure is the depth of discharge (DoD), which is the inverse of SOC (100% = empty; 0% = full).



4. Type of Energy Storage Resource's Grid Connection

An ESR can be connected to the grid in different configurations. Depending upon the energy storage technology selected and mode of operation, an ESR can be operating in an AC coupled mode or in a DC coupled mode in the system. Standalone ESRs are primarily coupled on the AC side of the grid whereas an ESR in a hybrid facility may get connected on either the AC or DC side of the grid.

4.1 AC Coupled ESR

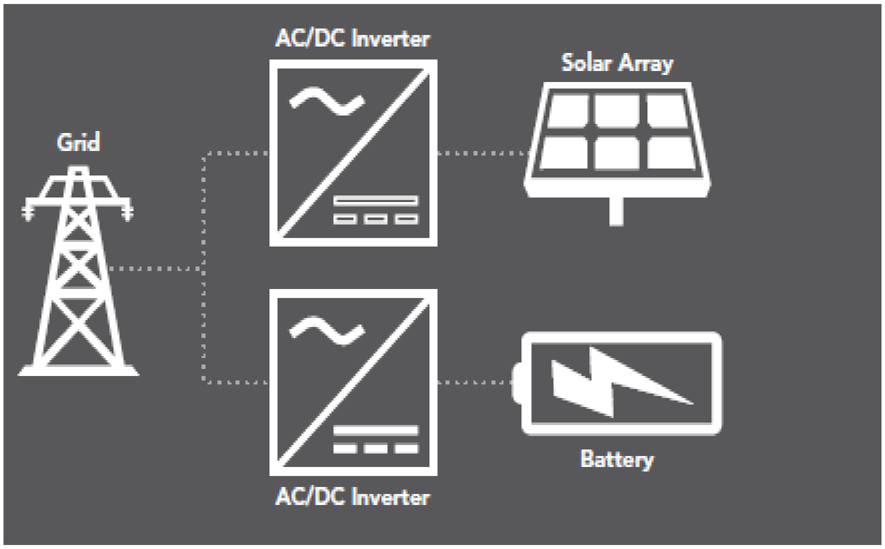
An AC coupled ESR is connected on the AC side to the grid as shown in Figure 1[2]. An AC connected ESR will able to exchange AC power to and from the grid. It will also be able to respond to system over and under frequency excursions by absorbing power from the grid and delivering power to the grid, respectively as required.

Normally, an AC connected ESR uses a Power Conversion System (PCS) which is the combination of an inverter (DC to AC) and a converter (AC to DC). The PCS allows the ESR to charge from the grid and discharge to the grid. The design of the AC connected ESR makes it suitable for all the three types of Operating Reserves - Regulating Reserve, Spinning Reserve and Supplemental Reserve.

[2] https://www.energy-storage.news/blogs/go-big-go-dc-an-in-depth-look-at-dc-coupled-solar-plus-storage

Figure 1 shows an ESR connected on the AC side of the grid. Depending upon the engineering design, the ESR can operate independently from the solar aggregated generating facility and can exchange (charge / discharge) power with the grid.

Figure 1: AC Coupled ESR



4.2 DC Coupled ESR

In hybrid facilities, the ESR has an option to connect on the AC side or on the DC side of the Inverter. The DC coupled ESR is connected on the DC side of the Inverter and charges strictly from a source of power, a solar aggregated generating facility, for example, as shown in Figure 2[3]. Grid power is never used to charge the ESR. In the example, a single common Inverter is used between the ESR and the solar aggregated generating facility, which converts power from DC to AC but not from AC to DC. Usually, in such configurations, the entire aggregated generating facility and the ESR is controlled through a single centralized plant controller. The single plant controller will ensure charging of the ESR from the aggregated generating facility as well as manage power output from the Inverter to the grid. Since the ESR is DC coupled, it usually cannot detect changes in frequency and hence unable to respond to frequency changes, it will be able to participate in the Supplemental Reserve market only.

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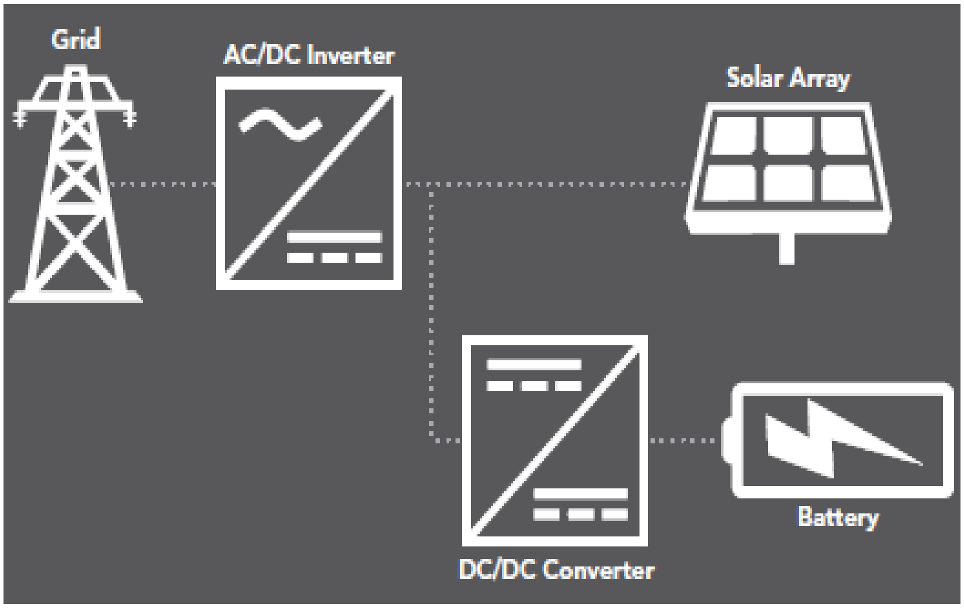
[3] https://www.energy-storage.news/blogs/go-big-go-dc-an-in-depth-look-at-dc-coupled-solar-plus-storage

Figure 2: DC Coupled ESR



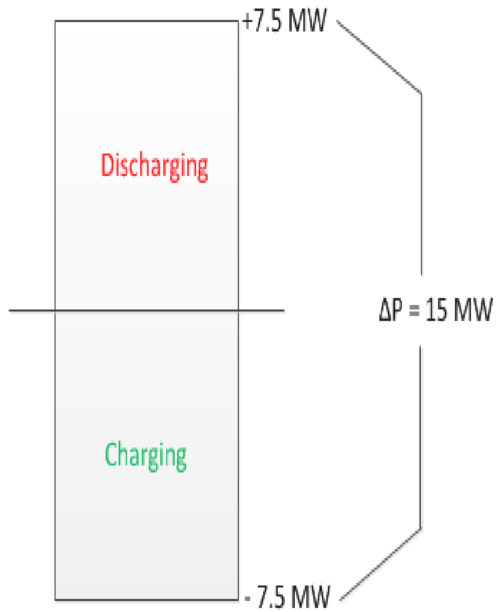
5 Eligibility to Participate in the Operating Reserves

5.1 Regulating Reserves Qualification

Regulating Reserve is used to provide a balance between generation and load within the AESO's balancing authority area, while maintaining the interchange schedule on the interconnections with British Columbia and Montana at a frequency of 60 Hz. Regulating Reserve is provided by partially loaded, synchronized Regulating Reserve resources that are able to immediately respond to automatic generation control (AGC) signals from the AESO system coordination center, and that have an appropriate governor or control systems such that the resources are frequency responsive. An ESR with the ability to respond to AGC signals from the AESO and a suitable frequency responsive control system will be able to participate in this service.

Regulating Reserve may be provided by a resource that meets the eligibility criteria per Section 205.4 of the ISO Rules, *Regulating Reserve Technical Requirements and Performance Standards* ("Section 205.4"). The Resource must be qualified by the AESO to provide Regulating Reserve in accordance with Section 205.4.

Under Section 205.4, in the case of an ESR, the maximum operating range of a Regulating Reserve resource is usually the difference between the maximum authorized discharging power (MADP) value and the maximum authorized charging power (MACP).



5.2 Technical Requirements for Regulating Reserve

The ESR which is seeking to be qualified in order to participate in the Regulating Reserve service must meet the requirements in Section 205.4 including:

- Minimum size of the ESR to participate in the Regulating Reserve (RR) market is +/- 7.5MW. The 7.5 MW of charging and 7.5 MW of discharging capability will meet the 15 MW minimum size threshold requirements for Regulating Reserve qualification.
- The ESR must be connected to the AC side of the AIES network as a DC coupled ESR cannot detect changes in frequency and therefore unable to respond to frequency changes.
- The MWh rating of the storage resource can be determined by the market participant depending on the project.
- Along with the minimum size requirements the ESR is also required to fulfill technical requirements as stated below:
    - The ESR must stay at high limit/ low limit for a period of up to sixty (60) minutes;
    - Follow the latest AGC signal within no more than (a) 28 seconds of receiving an AGC signal; and (b) 40 seconds of receiving an AGC signal reversal;
- The ESR must be equipped with a control system that:

    (i) is responsive to both over frequency and under frequency system events;

    (ii) has a total deadband of equal to or less than 0.036 Hz;

    (iii) has a droop setting equal to or greater than 3% but less than or equal to 5%;

    (iv) has no time delays, ramp characteristics or other control settings that prevent the Regulating Reserve resource from providing an immediate, automatic and sustained response to system frequency deviations;

(v) has a sample rate of at least 20 samples per second;

(vi) has a resolution of at least 0.004 Hz;

(vii) is not acting as a governor or control system for more than one regulating reserve resource; and

(viii) continues to be responsive to AGC signals during system frequency deviations between 58.9 Hz and 61 Hz.

5.3 Performance Standards of Regulating Reserves

During normal automatic generation control operation, the AESO AGC master controller issues MW set point signals that are representative of the real power level that the asset is required to ramp to. A set point signal to increase the real power level may follow a previous set point signal to increase the real power level, and similarly, a set point signal to reduce the real power level may follow a previous set point signal to reduce the real power level.

MW set point signals may also include reversals, where a set point signal to increase the real power level follows a set point signal to reduce the real power level, or a set point signal to decrease the real power level follows a set point signal to increase real power level. The automatic generation control master controller may issue reversals as often as every four (4) seconds. The ESR must meet the performance requirements as mentioned under Section 205.4.

The ESR which is qualified to participate in the Regulating Reserves is also required to be responsive to the system frequency excursions, i.e. during AGC operation if system frequency goes below normal operating range, the ESR has to discharge more MW (or reduce MW charging) to the grid and vice-versa. The ESR should be responsive when it is in charging mode as well as in discharging mode and provide frequency response based on the droop setting of the ESR and change in system frequency.

The AESO requires visibility to resources providing regulating reserves in addition to ensuring that resources meet the required technical requirements. Therefore, in order to participate in the Regulating Reserve market, the pool participant has to also comply with Section 502.8 of the ISO rules, *SCADA Technical and Operating Requirements*.

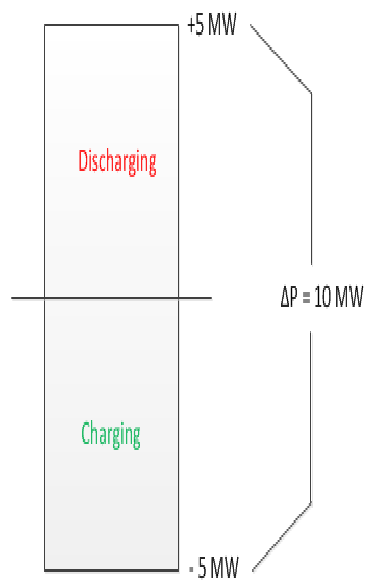
5.4 Spinning Reserve Qualification

Spinning Reserves are used to obtain primary frequency response (controller action to generate more power or discharge when the system experiences under frequency events and generate less power or charge when system experiences over frequency events) during system frequency. Additionally, Spinning Reserves help restore balance between the supply and demand for electricity following an unexpected event affecting the reliable operation of the interconnected electric system, such as the sudden loss of a generating unit or a disruption to one of the interties linking Alberta to a neighboring jurisdiction, also called tertiary response.

Spinning Reserves are the fastest acting Contingency Reserve resources and typically it comes from generators which are synchronized to the AIES that have room to increase or decrease generation. With unique characteristics of the ESR and with an effective controller system, an ESR may be eligible to provide Spinning Reserves.

When directed, the ESR, in accordance with Section 205.5 of the ISO rules, *Spinning Reserve Technical Requirements and Performance Standards* (“Section 205.5”) must deliver real power or a change in real power, ΔP, to the AIES within ten minutes of receiving a directive to provide the power to restore system frequency. The ESR should be responsive when it is in charging mode as well as in discharging mode and provide frequency response based on the droop setting of the ESR and change in system frequency.

Spinning Reserve may be provided by a resource that meets the eligibility criteria requirements in Section 205.5. Spinning Reserve resources require a control system that dynamically responds to a change in frequency to provide an automatic primary frequency response. Typically, the maximum Spinning Reserve range of the ESR is the difference of the maximum authorized discharging power (MADP) value and the maximum authorized charging power (MACP).



5.5 Technical Requirements for Spinning Reserve

The ESR which is seeking to be qualified in order to participate in the Spinning Reserve service must meet the requirements in Section 205.5, including:

- Minimum size of the Energy Storage Resource (ESR) to participate in the Spinning Reserve (SR) market is +/- 5MW. The 5 MW of charging and 5 MW of discharging capability will meet the 10 MW minimum size threshold requirements for SR qualification.
- The ESR must be connected on the AC side of the AIES network as a DC coupled ESR cannot detect changes in frequency and therefore unable to respond to frequency changes.
- The MWh rating of the storage resource can be determined by the market participant depending on the project.
- The ESR must have the capability to provide a change in power, ΔP, (MW volume contracted for) for the period of sixty (60) minutes.
- The ESR must be equipped with a control system that:

  (i) is responsive to both over frequency and under frequency system events;

(ii) has a total deadband of equal to or less than 0.036 Hz;

(iii) has a droop setting equal to or greater than 3% but less than or equal to 5%;

(iv) has no time delays, ramp characteristics or other control settings that prevent the Spinning Reserve resource from providing an immediate, automatic and sustained response to system frequency deviations;

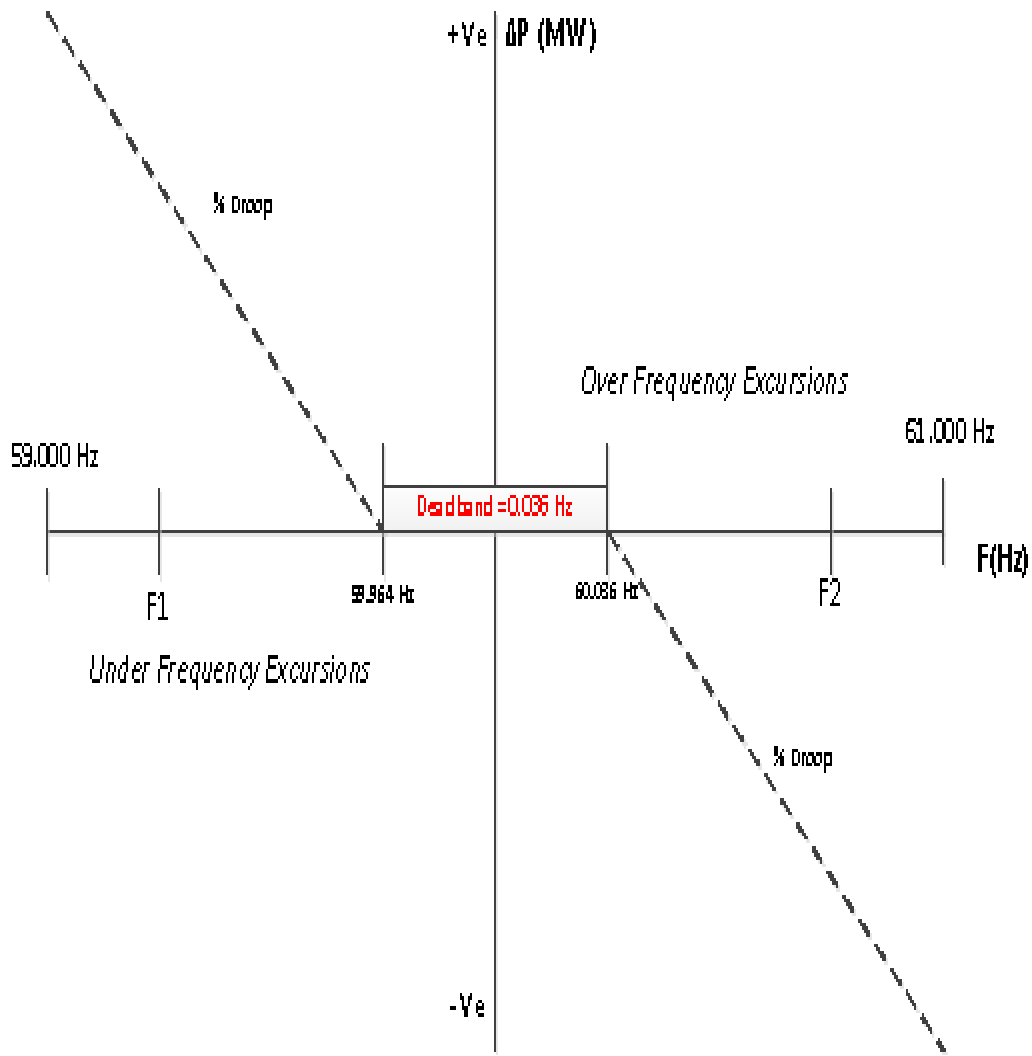
(v) has a sample rate of at least 20 samples per second;

(vi) has a resolution of at least 0.004 Hz; and

(vii) is not acting as a governor or control system for more than one spinning reserve resource.

5.6 Frequency Response Calculation for Spinning Reserve Resource

ESR- Frequency Response Calculation



Under Frequency response ΔP (MW) = {(60- F1) * ESR Rating} / {60* Droop in %}

Over Frequency response ΔP (MW) = {(60-F2) * ESR Rating} / {60* Droop in %}

% Droop Value must be between 3%-5%

5.7 Frequency Response Calculation Example for Spinning Reserve Resource

Example of frequency response calculation for an ESR with MW Rating of 10MW, 40MWh and Droop = 5% for 1Hz system frequency excursions:

Under Frequency response:

ΔP (MW) = {(60- F1) * Rated ESR MW Capacity} / {60* Droop in %}
= {(60- 59) * 10} / {60* 0.05}
= 3.33 MW

Over Frequency response:

ΔP (MW) = {(60- 61) * Rated ESR MW Capacity} / {60* Droop in %}
= {(60- 61) * 10} / {60* 0.05}
= -3.33 MW

Based on the above formulas, the tables below highlight frequency response for different system frequency excursions:

Under Frequency Response:

Frequency Value	Frequency Excursion (Delta_f, Hz)	Response in MW (ΔP)
59	1	3.33
59.05	0.95	3.17
59.1	0.9	3.00
59.15	0.85	2.83
59.2	0.8	2.67
59.25	0.75	2.50
59.3	0.7	2.33
59.35	0.65	2.17
59.4	0.6	2.00
59.45	0.55	1.83
59.5	0.5	1.67
59.55	0.45	1.50
59.6	0.4	1.33
59.65	0.35	1.17
59.7	0.3	1.00
59.75	0.25	0.83
59.8	0.2	0.67
59.85	0.15	0.50
59.9	0.1	0.33
59.964	0.036	0.00
60	0	0.00

Over Frequency Response:

Frequency Value	Frequency Excursion (Delta_f, Hz)	Response in MW (ΔP)
60.036	-0.036	0.00
60.05	0.05	-0.17
60.1	0.1	-0.33
60.15	0.15	-0.50
60.2	0.2	-0.67
60.25	0.25	-0.83
60.3	0.3	-1.00
60.35	0.35	-1.17
60.4	0.4	-1.33
60.45	0.45	-1.50
60.5	0.5	-1.67
60.55	0.55	-1.83
60.6	0.6	-2.00
60.65	0.65	-2.17
60.7	0.7	-2.33
60.75	0.75	-2.50
60.8	0.8	-2.67
60.85	0.85	-2.83
60.9	0.9	-3.00
60.95	0.95	-3.17
61	1	-3.33

5.8 Performance Standards for Spinning Reserves

The ESRs intending to participate in the Spinning Reserve service are required to meet the performance requirements under Section 205.5. When the AESO issues a dispatch to provide Spinning Reserve, the qualified resource is required to move into position such that it is capable of providing the real power (MW) set out in the dispatch.

In each Spinning Reserve directive, the AESO indicates the requested real power quantity, the remaining quantity of Spinning Reserve capacity and the time the directive was issued. The real power (MW) quantity must be provided within 10 minutes from the time when the directive was received, and maintained according to the performance requirements when responding to a directive to provide spinning reserve as detailed in Section 205.5.

During an under frequency event, if a Resource has already provided some or all of the requested real power quantity through the action of an appropriate governor or control system, that quantity may be considered as part of the directive response to meet the requested real power quantity. Even if the frequency returns to normal, the total requested real power quantity must continue to be supplied in accordance with Section 205.5.

The ESR will need to be responsive when it is in charging mode as well as in discharging mode and provide frequency response based on the droop setting and change in system frequency.

The AESO requires visibility to resources providing spinning reserves in addition to ensuring that resources meet the required technical requirements. Therefore, in order to participate in the Spinning Reserve market, the pool participant has to also comply with Section 502.8.

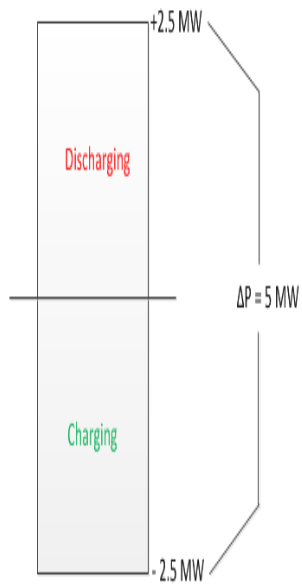
5.9 Supplemental Reserve Qualification

Supplemental Reserves (SUP) are used to restore the balance between supply and demand for electricity following an unexpected event affecting the reliable operation of the AIES, such as the sudden loss of a generating unit or a disruption to one of the interties linking Alberta to a neighboring jurisdiction.

Supplemental Reserves provide capacity that the AESO system controller can call on with short notice to correct any imbalance. Supplemental Reserve is similar to Spinning Reserve except that providers of Supplemental Reserve are not required to be synchronized to the grid and not required to respond to system frequency excursions.

These Reserves can come from the supply side (generators increasing their output to the system) or from the demand side (load curtailment by reducing demand from large electrical consumers). ESRs can use charging mode or discharge mode or a combination of both to provide this service. The real power, or the change in real power, in MW, must be delivered to the AIES within ten minutes of receiving a directive to provide the power to replace a loss of supply on the system by the Supplemental Reserves as set out in Section 205.6 of the ISO rules, *Supplemental Reserve Technical Requirements and Performance Standards* (“Section 205.6”).

Supplemental Reserve may be provided by resources that meet the eligibility criteria set out in Section 205.6. Pool participants can apply to the AESO to provide Supplemental Reserves by completing and submitting the application form on the AESO’s website.



5.10 Technical Requirements for Supplemental Reserve

The ESR intending to participate in the Supplemental Reserve service must meet the eligibility requirements in Section 205.6, including;

- Minimum size of the ESR to participate in the Supplemental Reserve (SUP) market is +/- 2.5 MW. The 2.5 MW of charging and 2.5 MW of discharging capability will meet the 5 MW minimum size threshold requirements for SUP qualification.
- The ESR can be connected either to the AC or DC side of the AIES network.
- The MWh rating of the storage resource can be determined by the market participant depending on the project.
- The ESR must have the capability to provide a change in power, ΔP, (MW volume contracted for) for the period of sixty (60) minutes.

5.11 Performance Standards of Supplemental Reserves

The ESRs willing to participate in the Supplemental Reserve service are required to meet the performance requirements under Section 205.6. When the AESO issues a dispatch to provide Supplemental Reserve, the qualified resource is required to move into a position such that it is capable of providing the real power set out in the dispatch within the timing requirements in Section 205.6.

In each Supplemental Reserve directive, the AESO indicates the requested real power quantity, the remaining quantity of Supplemental Reserve capacity and the time the directive was issued. The real power (MW) quantity must be provided within 10 minutes from the time when the directive was received, and maintained according to the performance requirements when responding to a directive to provide supplemental reserve as detailed in Section 205.6.

The AESO requires visibility to resources providing supplemental reserves in addition to ensuring that resources meet the required technical requirements. Therefore, in order to participate in the Supplemental Reserve market, the pool participant has to also comply with Section 502.8.

5.12 Failure to Meet Operating Reserve Dispatch or Directive Requirements

Failure to respond to a dispatch or directive in accordance with the performance requirements in Section 205.4, Section 205.5 and Section 205.6 may result in a claw back of payment to the pool participant for the Operating Reserve during the hour in question, assessment of liquidated damages, and pursuit of the event as a potential ISO rule contravention.

When failure to comply with a dispatch or directive is a result of an Event of Force Majeure as defined in the supplier agreement and the pool participant notifies the AESO within two business days of the occurrence, then both liquidated damages and pursuit as an ISO rule contravention may be waived.

Given the operating characteristics of an ESR, there are two possibilities of operating states when the ESR in the operation and providing Operating Reserves:

- the diminishing of State of Charge (SOC) while discharging real power, MW, leading to a state when the SOC=0% (or minimum SOC), resulting in the inability to continue to deliver the contracted MW; or
- the inability to continue to absorb real power, MW, from the grid when the State of Charge (SOC) is at 100% (or maximum SOC) while in a charging mode.

The pool participant will be responsible for managing the SOC for their ESRs.

In the event the ESR is unable to continue to meet the obligations of its contracted Operating Reserve service, the pool participant may substitute the appropriate volume (MW) to another one of its qualified Operating Reserve assets, or be required to restate. Unlike the energy market, there is no concept of acceptable operational reason (AOR) in the operating reserves market. If the pool participant is unable to substitute, it may be required to pay liquidated damages which the AESO may incur while replacing the required Operating Reserve amount. Force Majeure conditions apply in the OR market as appropriate but the loss of charge or the inability to charge will not be considered as a Force Majeure condition.

5.13 Applicability of Alberta Reliability Standards

ESRs usually involve multiple battery and inverter stacks, and hence would be considered as aggregated generating facilities (AGFs) and would therefore need to be greater than 67.5 MW (or 75 MVA) in order to meet the bulk electric system (BES) threshold applicability for Alberta Reliability Standards (ARS).