

Information Documents are not authoritative. Information Documents are for information purposes only and are intended to provide guidance. In the event of any discrepancy between an information document and any authoritative document¹ in effect, the authoritative document governs.

1 Purpose

This information document relates to the following authoritative documents:

- Section 205.1 of the ISO rules, *Offers for Operating Reserve*;
- Section 205.2 of the ISO rules, *Issuing Dispatches for Operating Reserve*;
- Section 205.3 of the ISO rules, *Restatements for Operating Reserve* (“Section 205.3”);
- Section 205.4 of the ISO rules, *Regulating Reserve Technical Requirements and Performance Standards* (“Section 205.4”);
- Section 205.5 of the ISO rules, *Spinning Reserve Technical Requirements and Performance Standards* (“Section 205.5”);
- Section 205.6 of the ISO rules, *Supplemental Reserve Technical Requirements and Performance Standards* (“Section 205.6”); and
- Section 302.1 of the ISO rules, *ISO Directives* (“Section 302.1”).

The purpose of this information document is to assist market participants in understanding the operating reserve market. This information document is likely of most interest to market participants who currently provide or may in the future provide operating reserve.

2 Operating Reserve

Operating reserve acts as a safety net, making extra power available to help balance the supply of, and demand for, electricity in real time and stabilizing and protecting the interconnected electric system in the event of unforeseen problems.

There are two types of operating reserve: 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 supply and demand 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. Further details on regulating reserve can be found in Information Document #2013-006R, *Regulating Reserve*.

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, energy storage resource, or the disruption of one of the interconnections that links Alberta to a neighboring jurisdiction.

Contingency reserve is further divided into spinning reserve and supplemental reserve.²

¹ “Authoritative documents” is the general name given by the AESO to categories of documents made by the AESO under the authority of the *Electric Utilities Act* and associated regulations, and that contain binding legal requirements for either market participants or the AESO, or both. Authoritative documents include: the ISO rules, the reliability standards, and the ISO tariff.

² Supplemental reserve is sometimes referred to as non-spinning reserve in jurisdictions outside Alberta.

Additional details on spinning reserve and supplemental reserve can be found in Information Document #2013-007R, *Contingency Reserve*.

3 Eligibility to Participate in the Operating Reserve Market

Operating reserve may be provided by pool assets with eligible regulating reserve, spinning reserve, or supplemental reserve resources. Eligibility criteria are found in subsection 3(1) of Section 205.4, Section 205.5, and Section 205.6. The pool asset must be qualified by the AESO to participate in the operating reserve market in accordance with subsection 4(1) of Section 205.4, Section 205.5 and Section 205.6, as applicable.

In determining the amount of real power a resource is eligible of providing, the AESO considers many factors, including whether the resource participates in a remedial action scheme. If a pool asset participates in a remedial action scheme, it may not be able to provide operating reserve when the remedial action scheme is armed.

3.1 Energy Storage Resource Eligibility

The AESO expects energy storage resources (“ESR”s) participating in the operating reserve markets to follow the eligibility and performance criterion set out in Section 205.4, Section 205.5 and Section 205.6.

(i) Regulating Reserve:

- (a) The minimum size of the ESR to participate in the regulating reserve market is 15 MW and the ESR is required to be connected to the interconnected electric system on the alternating current side of the network. For example, an ESR could have a range of +/- 7.5 MW where the 7.5 MW of the charging and 7.5 MW of the discharging capability will provide 15 MW of regulating reserve. The pool participant applies for the MWh rating of the ESR for which it is seeking qualification.
- (b) It is the pool participant’s responsibility to manage the state of charge³ and positioning of its ESR such that the ESR can meet the performance requirements of Section 205.4.

(ii) Spinning Reserve:

- (a) The minimum size of the ESR to participate in the spinning reserve market is 10 MW and the ESR is required to be connected to the interconnected electric system on the alternating current side of the network. For example, an ESR could have a range of +/- 5 MW where the 5 MW of the charging and 5 MW of the discharging capability will provide 10 MW of spinning reserve. The pool participant applies for the MWh rating of the ESR for which it is seeking qualification.
- (b) It is the pool participant’s responsibility to ensure that the ESR is responsive to over frequency as well as under frequency excursions of the interconnected electric system. It is also paramount to ensure that the ESR is specifically responsive when it is charging and does provide frequency response based on the droop setting and value changed in the system frequency.
- (c) It is the pool participant’s responsibility to manage the state of charge and positioning of its ESR such that it can meet the performance requirements of Section 205.5.
- (d) The ESR frequency response calculation and examples of the frequency response are included in Appendix 1. The examples are demonstrated for the 10 MW, 40 MWh and 0 mHz dead band ESR with a droop = 5%.

³ Further information on state of charge can be found in ID #2020-013, *Energy Storage Guidance Document*.

(iii) Supplemental Reserve:

- (a) The minimum size of the ESR to participate in the supplemental reserve market is 5 MW. For example, an ESR could have a range of +/- 2.5 MW where the 2.5 MW of the charging and 2.5 MW of the discharging capability will provide 5 MW of the supplemental reserve. The pool participant applies for the MWh rating of the ESR for which it is seeking qualification.
- (b) It is the pool participant's responsibility to manage the state of charge and positioning of its ESR (when it receives a dispatch) such that it can meet the performance requirements of the supplemental reserve service.

3.2 Energy Storage Resources

Generally, the maximum operating range of an operating reserve resource for regulating reserve, spinning reserve or supplemental reserve, is the difference between the maximum authorized discharging power and the maximum authorized real power. That is, an energy storage resource, if qualified, may participate in the operating reserve market with qualified volumes that span the energy storage resource's full range of operation. For example, an asset with a maximum capability of 5 MW in the energy market could potentially have a maximum reserve in the operating reserve market of up to 10 MW, subject to meeting the technical requirements, if the asset is offering its entire operating range (both charging and discharging) for operating reserves.

4 Procurement in the Operating Reserve Market

Under Alberta's electricity market framework, the AESO is the sole buyer of operating reserve (regulating reserve, spinning reserve, and supplemental reserve). The AESO's objective is to procure operating reserve in a transparent, competitive, and well-documented manner.

Each day the AESO procures operating reserve day-ahead from pool participants through Alberta Watt Exchange Limited ("Watt-Ex"), which is a for-profit third party clearing house. Watt-Ex enters into an Ancillary Services Exchange Customer Agreement ("Watt-Ex Agreement") with pool participants who offer supply into the operating reserve market and the AESO who bids to purchase the operating reserve. Pool participants receive payment directly from Watt-Ex for operating reserve sold, and in turn, the AESO receives an invoice for the operating reserve procured and settles financially with Watt-Ex. The cost of operating reserve procurement flows through to all power consumers through the ISO tariff.

The exchange operated by Watt-Ex offers complete transparency of all transactions with all pool participants, but allows sellers to remain anonymous to one another and to the buyer.

4.1 Active and Standby Reserve

The AESO procures active and standby volumes of each type of operating reserve. The AESO uses the terms "active" and "standby" to differentiate the timing and order in which dispatches for operating reserve are issued.

The AESO procures enough active operating reserve to meet the volume requirements set out in Alberta Reliability Standard BAL-002-WECC-AB1-2, *Contingency Reserve*. Normally, all active reserve volumes are dispatched to ensure these requirements are met at all times.

The purpose of standby operating reserve is to provide additional operating reserve for use when the volume of operating reserves for which dispatches have been issued in the active market is insufficient to meet the real-time operating and reliability requirements of the interconnected electric system. Often, this insufficiency occurs when a resource with an active contract has a forced outage and is unable to provide the active reserve volume that the AESO has procured. The AESO issues dispatches for all pool assets in the active portfolio before issuing dispatches for any pool assets from the standby portfolio. There is a standby portfolio of pool assets for each type of operating reserve procured in the operating reserve market.

4.2 Block Procurement

The AESO's approach to buying operating reserve is described as block procurement. Operating reserve is purchased in four time offer blocks, as follows:

- (a) On peak means the period from 07:00 to 22:59:59;
- (b) Off peak means the period from 00:00 to 06:59:59 and from 23:00 to 23:59:59;
- (c) AM super peak means the period from 05:00:00 to 07:59:59; and
- (d) PM super peak includes the period from 16:00:00 to 23:59:59 in November, December and January and in all other months the period from 17:00:00 to 23:59:59.

The volumes procured in each of these offer blocks are consistent across all hours in the block.

Only active regulating reserve is purchased for super peak blocks, while all three types of operating reserve (i.e., regulating, spinning, and supplemental reserve) are procured for the on peak and off peak time blocks.

4.3 Forecasting

The *7 Day Forecast of Operating Reserves Volumes* report estimates the volume of operating reserve the AESO anticipates will be required from the current day to 7 days forward. This report can be found on the [AESO website](#). The forecast is updated daily and the volumes procured each day can change according to the forecast.

Table 1 below provides an example of how the AESO procures active regulating reserve based on data from September 21, 2011. As described above, active regulating reserve is procured for four time blocks – on peak, off peak, AM super peak, and PM super peak. The AESO first procures the minimum volume forecast in each of the on peak and off peak time blocks. In the example portrayed in Table 1, the AESO would procure 135 MW for the off peak time block and 150 MW for the on peak time block. The AESO then procures the additional active regulating reserve volume for the AM super peak and the PM super peak time blocks. In the example portrayed in Table 1, the AESO would procure 65 MW for the AM super peak time block and 20 MW for the PM super peak time block.

Table 1 – Example Forecast of Operating Reserve Volumes

Date	Time Period	Active			Standby		
		RR	SR	SUP	RR	SR	SUP
09/21/2011	00:00 to 00:59:59	135	225	225	100	105	35
09/21/2011	01:00 to 01:59:59	135	225	225	100	105	35
09/21/2011	02:00 to 02:59:59	135	225	225	100	105	35
09/21/2011	03:00 to 03:59:59	135	225	225	100	105	35
09/21/2011	04:00 to 04:59:59	135	225	225	100	105	35
09/21/2011	05:00 to 05:59:59	200	225	225	100	105	35
09/21/2011	06:00 to 06:59:59	200	225	225	100	105	35
09/21/2011	07:00 to 07:59:59	215	257	257	100	105	45
09/21/2011	08:00 to 08:59:59	150	257	257	100	105	45

Legend
Off peak
On peak
AM super peak
PM super peak

09/21/2011	09:00 to 09:59:59	150	257	257	100	105	45
09/21/2011	10:00 to 10:59:59	150	257	257	100	105	45
09/21/2011	11:00 to 11:59:59	150	257	257	100	105	45
09/21/2011	12:00 to 12:59:59	150	257	257	100	105	45
09/21/2011	13:00 to 13:59:59	150	257	257	100	105	45
09/21/2011	14:00 to 14:59:59	150	257	257	100	105	45
09/21/2011	15:00 to 15:59:59	150	257	257	100	105	45
09/21/2011	16:00 to 16:59:59	150	257	257	100	105	45
09/21/2011	17:00 to 17:59:59	170	257	257	100	105	45
09/21/2011	18:00 to 18:59:59	170	257	257	100	105	45
09/21/2011	19:00 to 19:59:59	170	257	257	100	105	45
09/21/2011	20:00 to 20:59:59	170	257	257	100	105	45
09/21/2011	21:00 to 21:59:59	170	257	257	100	105	45
09/21/2011	22:00 to 22:59:59	170	257	257	100	105	45
09/21/2011	23:00 to 23:59:59	155	225	225	100	105	35

Note: RR = regulating reserve, SR= spinning reserve, and SUP=supplemental reserve

4.4 Timing of Operating Reserve Procurement

Operating reserve is procured one day in advance of when it is required. Procurement does not occur on weekends and holidays; therefore, procurement for the weekend (Saturday, Sunday and Monday) takes place on Friday. Since the market is closed on Sunday, Monday is included in the weekend. On holidays, the AESO procures operating reserve on the last business day before the holiday. If a holiday occurs in conjunction with a weekend, then the AESO procures operating reserve for the holiday in addition to the weekend.

The daily schedule for offer submission is set by Watt-Ex. Watt-Ex receives submissions from 09:00 am through to 10:10 am as follows:

- (a) in the case of offers for active regulating reserve for the on peak and off peak periods, no later than 09:10 am on the business day before the day that the offer is effective;
- (b) in the case of offers for active regulating reserve for the super peak periods, no later than 09:20 am on the business day before the day that the offer is effective;
- (c) in the case of offers for active spinning reserve, no later than 09:30 am on the business day before the day that the offer is effective;
- (d) in the case of offers for active supplemental reserve, no later than 09:40 am on the business day before the day that the offer is effective;

- (e) in the case of offers for standby regulating reserve, no later than 09:50 am on the business day before the day that the offer is effective;
- (f) in the case of offers for standby spinning reserve, no later than 10:00 am on the business day before the day that the offer is effective; and
- (g) in the case of offers for standby supplemental reserve, no later than 10:10 am on the business day before the day that the offer is effective.

The order of market closure is related to the technical requirements for each product. Regulating reserve has the strictest technical requirements and is; therefore, the highest value product. Supplemental reserve has the least restrictive technical requirements and is; therefore, the lowest value product.

The sequential closing of the market ensures that if a pool participant fails to sell their entire highest value product (i.e., regulating reserve), they have an opportunity to sell any remaining capacity in other operating reserve markets (i.e., spinning reserve, then supplemental reserve).

4.5 Trade Cancellations

A trade cancellation can occur in the active and standby markets for any product for reasons outlined in the Watt-Ex Agreement.

4.6 Internal Controls for Procurement of Operating Reserve

The procurement of operating reserve is governed by AESO policy. Once a year, or whenever changes to any relevant policies occur, the AESO is required to sign an acknowledgement letter indicating they have read, understood, and are in compliance with the policies that govern AESO practices.

On a daily basis, the AESO's Settlement and Risk department monitors trading activity. Watt-Ex transactions are scrutinized for compliance with the Watt-Ex Agreement and all internal risk management guidelines.

5 Pricing

5.1 Active Reserve Market

The AESO bids for a volume of operating reserve defined as either on peak, off peak, AM super peak, or PM super peak, at a price that is at a discount or at a premium to the pool price.

Pool participants submit their price and quantity offers into the operating reserve market for each product at a discount or a premium to the pool price, referred to as indexing to the pool price. When the market closes, offers are sorted based on price, and the lowest priced offers that fill the AESO's bid quantity are selected. The highest priced offer that satisfies the quantity required is referred to as the marginal or clearing offer.

For active operating reserve, a pool participant is paid the pool price plus the equilibrium price. The equilibrium price is the average of the AESO bid price and the marginal offer.

$$\text{Equilibrium Price} = (\text{Bid} + \text{Marginal Offer})/2$$

The seller is not required to pay the AESO if pool price + \$X is negative. For example, for an equilibrium price of \$X, the AESO pays Max (0, pool price + \$X) times quantity.

When the AESO issues a directive for contingency reserve or a dispatch for regulating reserve to a pool participant to provide the real power offered for operating reserve, the pool participant is paid the current pool price for the real power they are providing, in addition to the payment they receive for providing the operating contingency reserve.

The general process for trading on Watt-Ex is illustrated in this example:

The AESO needs to buy 100 MW of on peak spinning reserve and the AESO's bid price is \$10. Here are the offers:

- Offer 1: 10 MW at -\$10 (Pool Price plus -\$10)
- Offer 2: 30 MW at -\$5 (Pool Price plus -\$5)
- Offer 3: 40 MW at \$0 (Pool Price plus \$0)
- Offer 4: 10 MW at \$5 (Pool Price plus \$5)
- Offer 5: 10 MW at \$10 (Pool Price plus \$10)
- Offer 6: 25 MW at \$15 (Pool Price plus \$15)
- Offer 7: 30 MW at \$20 (Pool Price plus \$20)

In this example, the marginal offer is Offer 5 (\$10) because it is the last offer, when combined with Offers 1, 2, 3 and 4, that makes up the quantity of 100 MW the AESO requires. The equilibrium price is then calculated as the average of the AESO's bid and the marginal offer. In this example, the equilibrium price is $(\$10 + \$10)/2 = \$10$.

For on-peak hour ending X, pool price is \$31. The payment the AESO makes to pool participants providing active operating reserve for hour ending X is $\$10 + \$31 = \$41/\text{MW}$.

If the pool participant subsequently receives a directive or, in the case of regulating reserve, is receiving a control signal, the pool participant also receives the pool price for the real power provided.

5.2 Standby Reserve Market

The standby market utilizes a two-part pricing model with a premium price and an activation price.

- (i) Premium Price – the price paid to the seller to provide the AESO the option to call on the operating reserve if required.
- (ii) Activation Price – the price paid to the seller if the AESO issues a dispatch for the operating reserve.

The AESO clears the market using a blended price formula, which ranks the standby offers based on the following algorithm:

$$\text{Blended Price} = \text{Premium} + (\text{Activation \%} \times \text{Activation Price})$$

Activation percentages are based on historical product activation rates for on peak and off peak hours. They are subject to change as market conditions change. If there is a change, the AESO gives notice to market participants.

If 2 blended prices are equal, the AESO selects the offer that was submitted to the Watt-Ex system first until its quantity requirements are filled.

When the contingency reserve provider receives a directive to provide a quantity of contingency reserve, the provider continues to receive the activation price and also receives the pool price for the real power provided.

After a dispatch for regulating reserve, the provider continues to receive the activation price and also receives the pool price for the real power provided.

The standby operating reserve merit order sorts all the standby quantities procured for each product from lowest activation cost to highest activation cost. The lowest cost quantities are activated first. The AESO only issues dispatches for the quantity required to address the deficiency in active operating reserve.

6 Merit Order

The AESO uses the ancillary service merit order to determine how dispatches are issued. The ancillary service merit order is sorted by supply type, type of operating reserve, and the maximum contract amount for each pool asset that has submitted an offer. The ancillary service merit order contains two supply types: active and standby. The AESO issues dispatches for all pool assets providing active operating reserve. Dispatches are only issued for pool assets providing standby reserve if required.

7 Dispatches and Directives

The AESO issues dispatches and directives by way of the Automated Dispatch and Messaging System. However, if the Automated Dispatch and Messaging System is unavailable, the secondary means of communication between the AESO and market participants is via telephone.

The AESO uses a two-step process to contact pool participants providing operating reserve:

(1) Dispatch for Operating Reserve

The AESO sends a dispatch for operating reserve to notify the pool participant to maintain additional capacity on its pool asset to ensure it can provide the additional real power to the interconnected electric system. The dispatch contains the following information for spinning reserve, supplemental reserve, and regulating reserve: the pool asset, the type of operating reserve, the capacity (MW) to be supplied, and the date and time the dispatch takes effect⁴.

For regulating reserve, the additional capacity is the regulating reserve range. The regulating reserve resource provides real power response to set point changes within the given range as governed through its automatic generation control.

(2) Directive for Contingency Reserve

If required, the AESO sends a contingency reserve directive to a previously dispatched pool participant to notify the pool participant to provide the additional real power to the interconnected electric system.

Under normal market conditions, the contingency reserve directive is effective for one (1) hour. Under abnormal market conditions, such as supply shortfall, the AESO may issue a directive for more than one hour.

If the asset is not able to respond to a directive, the pool participant is required to: proactively provide notice to the AESO as soon as practicable pursuant to subsections 4(1) and 4(2) of Section 301.2; submit a restatement to reflect the operating state of the pool asset pursuant to subsection 3(4) of Section 205.3; and potentially submit a Notification of Force Majeure if the failure to respond to the directive is a result of a force majeure as defined in the Watt-Ex Agreement. Refer to subsection 9 below for additional detail on force majeure events.

7.1 Conscript of Operating Reserve

The AESO may conscript non-contracted operating reserve by issuing a directive when all contracted operating reserve has been dispatched in accordance with Section 301.2. If the AESO deems this out of market action to be necessary, the conscripted pool asset would receive a directive. The pool participant is compensated in accordance with the ISO tariff for the non-contracted amount provided.

7.2 Concurrent Energy and Operating Reserve

If the AESO issues dispatches for a pool asset to provide both operating reserve capacity and energy in the energy market for the same period, then the AESO deducts the MW quantity of such operating reserve capacity from the available capability of the pool asset for the purposes of determining the MW quantity of the energy market dispatch.

⁴ For further information see the ADaMS Pool Participant Manual available on the ADaMS.

7.3 Failure to meet Dispatch or Directive requirements

Failure to respond to a dispatch in accordance with the performance requirements in Section 205.4, Section 205.5, and Section 205.6 may result in remedies under the Watt-Ex Agreement, (i.e. claw back of payment to the pool participant for the operating reserve during the hour in question and assessment of liquidated damages).

Failure to respond to a directive in accordance with the performance requirements in Section 205.5 and Section 205.6 may result in remedies under the Watt-Ex Agreement. The remedies may include a claw back of payment to the pool participant for the operating reserve during the hour in question, an 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 Watt-Ex 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. However, payment may still be clawed back for the service not provided. Please refer to subsection 9 for more information on submitting a Notification of an Event of Force Majeure to the AESO.

8 Restatements and Substitutions

Pool participants that are providing operating reserve may restate the quantity of MW they are able to provide in accordance with subsections 3(1), 3(2), and 3(3) of Section 205.3 and must restate the quantity of MW in certain circumstances in accordance with subsections 3(4) and 3(5) of Section 205.3.

A pool participant may be pre-approved to substitute operating reserve from one pool asset to another within its portfolio under certain circumstances as outlined in subsection 4 of Section 205.3. An asset that is pre-approved to provide a type of operating reserve can only substitute with other assets within its portfolio that are also qualified by the AESO to provide that type of operating reserve. The pre-approval is a standing arrangement unless there is a compliance issue or a change to the asset that will affect the operating reserve capability. In any event, the substituted volume should not exceed the asset's qualified capacity for the type of reserve.

9 Notification of Event of Force Majeure

In accordance with the terms of the Watt-Ex Agreement, a pool participant must notify the AESO within two business days if a failure to supply the operating reserves is a result of an Event of Force Majeure. The notification form for submitting an event of force majeure, available on the AESO website, contains an area for the pool participant to explain how the event satisfies the definition of Event of Force Majeure in the Watt-Ex Agreement. The AESO expects the explanation to sufficiently describe the event, cause of the event, when the event was discovered, what was known at the time of the event at the operating reserve was offered, and whether and how the event was out of the reasonable control of the pool participant which could not have been avoided through the use of good electric industry practice.

When an Event of Force Majeure occurs, the pool participant remains subject to the restatement requirements of Section 205.3. Where a portion of the contracted operating reserves is subject to the Event of Force Majeure, the remaining volume are still subject to the requirements of ISO rules, including, as applicable, the dispatch and directive performance requirements of Section 205.4, Section 205.5, and Section 205.6.

Appendices

Appendix 1 – ESR Frequency Response Calculation

Revision History

Posting Date	Description of Changes
2024-04-05	Administrative amendments to align with Energy Storage ISO Rule amendments and definitions. Subsection 4 was also updated to provide more detail on procurement in the operating reserve market.
2020-06-19	Addition of subsection 3.1 to provide clarity for energy storage resources Addition of Appendix 1 Administrative edits for clarity
2018-02-01	Revisions to align with amended ISO rules related to operating reserve in effect as of February 1, 2018, and addition of subsection 9
2016-09-28	Administrative amendments
2014-12-23	Initial release

Appendix 1
 ESR Frequency Response Calculations

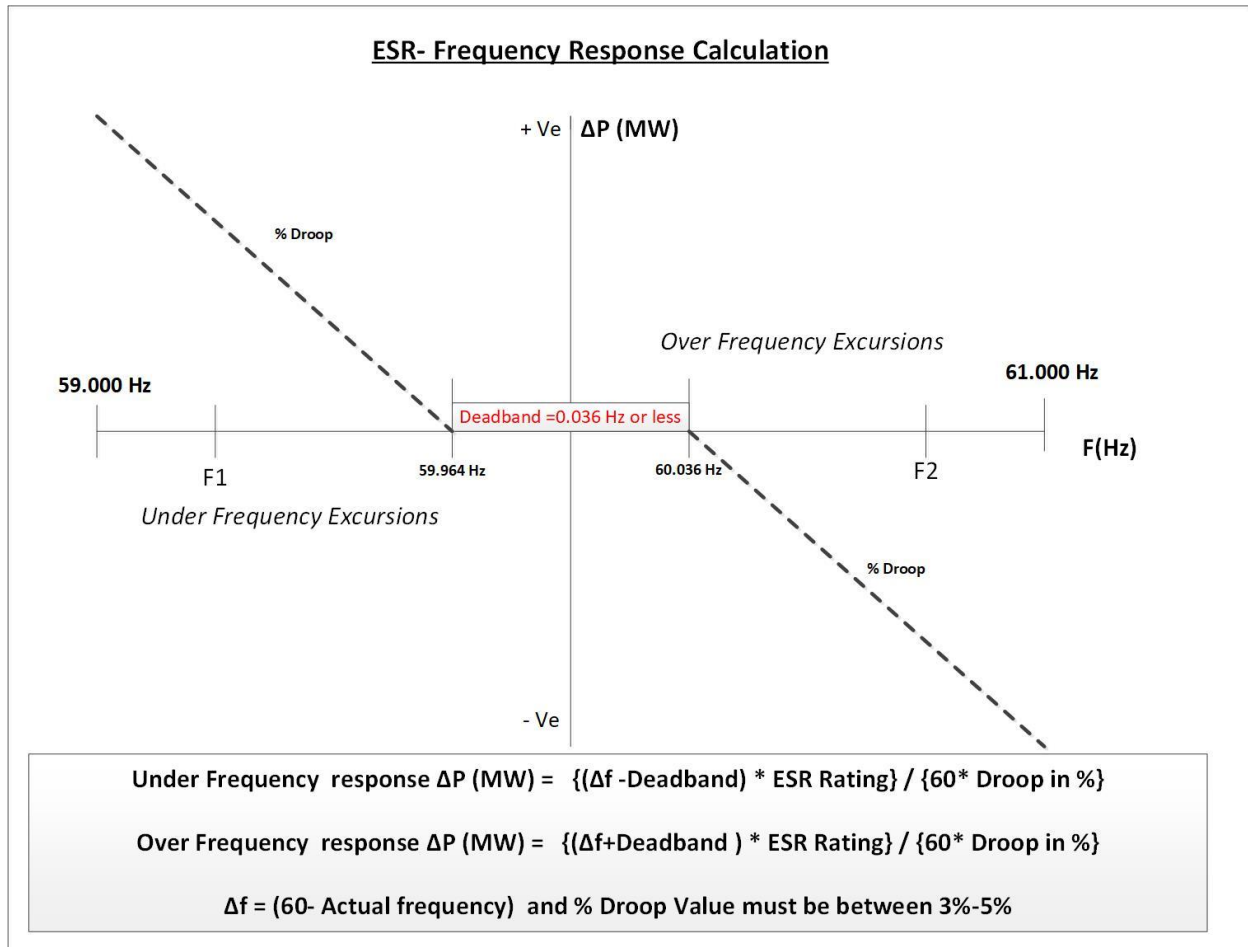


Figure 1 – ESR Frequency Response

Example

Frequency response calculations for an ESR rated at 10 MW, 40 MWh, Dead band 0mHz and a frequency droop of 5 %, for 1 Hz system frequency excursions.

Under frequency response formula:

$$\begin{aligned} \Delta P \text{ (MW)} &= \{(60 - F1-0) * \text{ESR Rating}\} / \{60 * \text{Droop in \%}\} \\ &= \{(60 - 59) * 10\} / \{60 * 0.05\} \\ &= 3.33 \text{ MW} \end{aligned}$$

Over frequency response formula:

$$\begin{aligned} \Delta P \text{ (MW)} &= \{(60 - 61+0) * \text{ESR Rating}\} / \{60 * \text{Droop in \%}\} \\ &= \{(60 - 61) * 10\} / \{60 * 0.05\} \\ &= -3.33 \text{ MW} \end{aligned}$$

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

Table 1 – Under Frequency Response

Frequency Value (Hz)	Frequency Excursion (Δf , 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

Table 2 – Over Frequency Response

Frequency Value (Hz)	Frequency Excursion (Δf, 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