Public

# SOE Monitoring Guidance

For Energy Limited DC/DM/DR Providers

v1.0 October 2024

NESO
National Energy System Operator

# Contents

# Overview

## Background on SOE monitoring

As part of the June 2024 EBR Article 18 consultation for Dynamic Response Services, new State of Energy (SOE) management and monitoring rules were put forward by NESO. These rules cover the assessment of SOE at bid stage and during delivery to ensure that units are offering suitable volumes for the full delivery of any contracted services while satisfying the SOE rules.

This document aims to provide additional background and clarifications on the methodology used for State of Energy monitoring regarding energy-limited DC/DM/DR providers.

## Overview of SOE monitoring

The SOE monitoring methodology implemented by NESO is based on comparing the SOE of a unit against a **Minimum State of Energy Requirement** value.

i. This lower boundary is calculated based on the requirements stated in Service Terms and reflects the minimum SOE level that the providers should hold. The SOE level maintained by the unit should always be no smaller than this lower boundary. If the SOE level of the unit falls below the lower boundary, the unit will fail the SOE assessment.

ii. When this lower boundary hits zero, due to extreme system conditions such as extended periods of high or low System Frequency deviation beyond 0.2 Hz above or below 50Hz, the provider is allowed to declare unavailability. Any associated penalties will be removed.

The assessment of SOE is performed using **Performance Monitoring data** submitted by the provider (20Hz/2Hz data). The specific columns used are soe_export_mwh and soe_import_mwh which specify the State of Energy.

Note: there is not a single case where the SOE monitoring suggests the SOE will be depleted completed by following the SOE rules for the current available DC/DM/DR performance data. Also, the offline study using 2020 frequency data suggest SOE will be depleted completed only in very rare conditions.

## Benefits of SOE monitoring

### No undeserved penalties.

Through SOE monitoring the risk of an asset not receiving payment while declaring unavailability due to depletion of SOE while correctly delivering response is eliminated. Previously such a situation could have resulted in the asset having a reduced availability factor and thus payment.

### Outcome based assessment.

The methodology implemented by NESO assesses the SOE management of providers by looking at the outcome of the actions taken by the providers rather than through the actions themselves. While actions must be interpreted, the results of the actions are more objective. Assessment of actions could require subjective judgements to determine when an action was sufficient, assessment of outcomes is objective and mathematical. This will result in a fairer assessment, compared to alternative action-based methodologies.

### Level playing field for all providers.

The SOE monitoring rules are based on parameters from the service terms which were determined at the inception of Dynamic Response Services. These parameters include Delivery Duration, **Contracted Response Energy Volume**, and **Energy Recovery**. The values of these parameters have not changed since the start of Dynamic Response Services. State of Energy monitoring ensures that the units can fulfil the operational requirements set out by these parameters.

### Compatible with previous guidance.

Before the implementation of SOE monitoring, NESO provided non-binding SOE management guidance to providers. The implemented methodology is compatible with the previous guidance. Providers that optimised their assets in accordance with the guidance can expect their optimisation strategies to pass current SOE monitoring.

# 1. Introduction

For energy limited DC/DM/DR providers, Paragraph 6.11 of the Service Terms specifies the rules for managing the State of Energy (SOE) of their units. These SOE management rules together with the **Reserved Capacity** at bid stage rules (Procurement Rules Paragraph 8.3.3) ensure that units must be capable of managing their SOE as required.

The SOE monitoring methodology implemented by NESO is based on comparing the SOE of a unit against a **Minimum State of Energy Requirement** value. This **Minimum State of Energy Requirement** value is calculated using the contract information and performance monitoring data of a unit. For units with bi-directional contracts, separate Minimum State of Energy Requirements are calculated for high frequency and low frequency response services. For units that are stacking response services, a single Minimum State of Energy Requirement is calculated for each direction.

The SOE management rules can be summarised and interpreted as follows:

1. At the start of the delivery period (EFA) the unit must satisfy a **Minimum State of Energy Requirement** which would allow the unit to deliver the **Contracted quantity**(s) for the maximum delivery duration (**Contracted Response Energy Volume**).
2. At the start of each Settlement Period the **Minimum State of Energy Requirement** is updated to reflect the loss in SOE caused by service activation.
3. If the **Minimum State of Energy Requirement** falls below **Contracted Response Energy Volume**, the **Minimum State of Energy Requirement** will increase at the earliest opportunity (by either the **Energy Recovery (ER)** volume or a lesser volume as determined by the rules).

At the start of each Settlement Period within a contracted EFA, the unit's reported State of Energy value (submitted in its performance monitoring data) is compared to the calculated Minimum State of Energy Requirement. If the reported SOE value is lower than the Minimum State of Energy Requirement, then the unit is deemed to fail SOE management.

# 2. Energy requirements of Dynamic Services

## Definitions

The table below shows and defines the parameters used in the calculations of energy requirements for units.

*Table 1: Energy Requirement parameters in dynamic services*

| Parameter | Units | Description |
|---|---|---|
| Contracted Response Energy Volume (REV) | MWh | Response unit should be capable of delivering at least this volume at the start of a contracted period (EFA) |
| Energy Recovery (ER) | MWh | Response unit should always be capable of recovering at least this volume of Energy in a settlement period (30min) |
| Settlement Period Recovery Volume | MW | Available capacity in MW (ER*2) needed to be able to recover the Energy Recovery volume in a settlement period (30min) |
| Reserved Capacity MW ($RC_{MW}$) | MW | Reserved capacity in MW needed to manage SOE |
| Contracted quantity ($Q_{contract}$) | MW | Contracted service volume |

## Calculations

The **Contracted Response Energy Volume** (REV) and **Energy Recovery** (ER) volumes are parameters that depend on the **Contracted quantity** ($Q_{contract}$) of the service(s) the unit is providing. The table below shows how the values are calculated for each service.

*Table 2: Calculated Energy Requirement parameters*

| | DC | DM | DR |
|---|---|---|---|
| REV | $Q_{contract_{DC}}\ [MW] * 15\ [min] = Q_{contract_{DC}} * 0.25\ [MWh]$ | $Q_{contract_{DM}}\ [MW] * 30\ [min] = Q_{contract_{DM}} * 0.5\ [MWh]$ | $Q_{contract_{DR}}\ [MW] * 60\ [min] = Q_{contract_{DR}}\ [MWh]$ |
| ER | $0.2 * REV = Q_{contract_{DC}} * 0.05[MWh]$ | $0.2 * REV = Q_{contract_{DM}} * 0.1\ [MWh]$ | $0.2 * REV = Q_{contract_{DR}} * 0.2\ [MWh]$ |

If a unit is contracted for more than a single service through stacking, the REV and ER volumes for the stacked services are the sum of the volumes as calculated for each of the contracted services.

## 3. Reserved Capacity at Bid Stage

### Motivation

The **Reserved Capacity** at bid stage defined in the Procurement Rules ensures that for any given offered quantity at bid stage for a given direction, a corresponding portion of the unit's capacity in the other direction is reserved for SOE management. This **Reserved Capacity** ensures that the unit will be capable of satisfying the **Energy Recovery (ER)** rule defined in the service terms without affecting its ability to deliver its contracted services.

The percentage to be reserved depends on the service that the unit is delivering and should be proportionate to the total capacity of the asset. The **Reserved Capacity** percentages for each service are defined as:

- Dynamic Containment (DC): 10% of the offered quantity
- Dynamic Moderation (DM): 20% of the offered quantity
- Dynamic Regulation (DR): 40% of the offered quantity

For units operating under a single directional contract, there is ample capacity available in the opposite direction to guarantee sufficient energy recovery as shown in Figure 1. Therefore, there is no need to reserve capacity in the bidding direction.

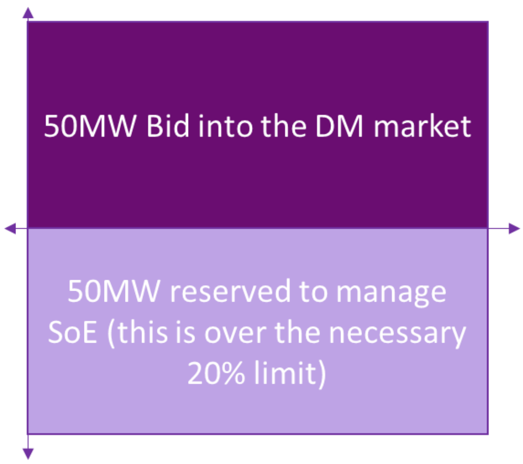


*Figure 1: Single directional contract of 50MWh asset for 50MW DM.*

However, this rule holds greater significance for units with bi-directional contracts, as they may lack excess capacity for energy recovery. To ensure sufficient headroom and footroom for energy recovery during service delivery, it is crucial for them to reserve the specified capacity based on the service they are providing as shown in Figure 2.


*Figure 2: Bi-directional contract of 50MWh asset for 40MW DM.*

The imposition of limitations on providers when submitting sell orders serves the purpose of ensuring their ability to fulfil the **Contracted Response Energy Volume (REV)** at the start of the EFA block. Overbidding, particularly with stacked contracts, can result in providers being unable to meet their contractual obligations. Hence, these limitations act as safeguards to prevent such scenarios.

## Derivation of percentages

To calculate the headroom or footroom that a unit needs to reserve to manage state of energy (SOE), we base our calculations on the minimum energy a provider needs to recover within a settlement period defined as ER. For a given Dx contract, the minimum **Reserved Capacity** in MW needed is calculated as:

$$RC_{MW} = ER * 2$$

Where $ER$ is the **Energy Recovery** volume.

In the rest of this section, we detail the calculation methodology of the **Reserved Capacity** percentages for each service.

### Dynamic Regulation

For DR, we have that REV:

$$REV_{DR} = \frac{60}{60} \times Q_{contract\,DR} = Q_{contract\,DR}$$

Where the units for $REV_{DR}$ are MWh. Then, it follows that the **Reserved Capacity** in MW ($RC_{MW}$) needed for a DR unit is defined as:

$$RC_{MW_{DR}} = (ER * 2)$$

Where

$$ER = REV_{DR} * 0.2 = Q_{contract_{DR}} * 0.2$$

Then, it follows that the

$$RC_{MW_{DR}} = Q_{contract_{DR}} * 0.2 * 2$$

Converting the above expression in percentage with respect to the **Contracted quantity** $Q_{contract_{DR}}$, we have

$$\% \, \boldsymbol{RC_{MW_{DR}}} = \frac{(Q_{contract_{\boldsymbol{DR}}} * \mathbf{0.2} * \mathbf{2})}{Q_{contract_{\boldsymbol{DR}}}} \times \mathbf{100} = \mathbf{0.2} * \mathbf{2} * \mathbf{100} = \mathbf{40\%}$$

## Dynamic Moderation

For DM, we have that REV:

$$REV_{DM} = \frac{30}{60} \times Q_{contract_{DM}} = 0.5 * Q_{contract_{DM}}$$

Then, the **Reserve Capacity** in MW ($RC_{MW}$) needed for a DM unit is defined as:

$$RC_{MW_{DM}} = ER * 2$$

Where

$$ER = REV_{DM} * 0.2 = 0.5 * Q_{contract_{DM}} * 0.2$$

Then, it follows that the

$$RC_{MW_{DM}} = 0.5 * Q_{contract_{DM}} * 0.2 * 2$$

Converting the above expression in percentage with respect to the **Contracted quantity** $Q_{contract_{DM}}$, we have

$$\% \, \boldsymbol{RC_{MW_{DM}}} = \frac{(\mathbf{0.5} * Q_{contract_{\boldsymbol{DM}}} * \mathbf{0.2} * \mathbf{2})}{Q_{contract_{\boldsymbol{DM}}}} \times \mathbf{100} = \mathbf{0.5} * \mathbf{0.2} * \mathbf{2} * \mathbf{100} = \mathbf{20\%}$$

## Dynamic Containment

For DC, we have that REV:

$$REV_{DC} = \frac{15}{60} \times Q_{contract_{DC}} = 0.25 * Q_{contract_{DC}}$$

Then, the **Response Capacity** in MW $(RC_{MW})$ needed for a DC unit is defined as:

$$RC_{MW_{DC}} = ER * 2$$

Where

$$ER = REV_{DC} * 0.2 = 0.25 * Q_{contract_{DC}} * 0.2$$

Then, it follows that the

$$RC_{MW_{DC}} = 0.25 * Q_{contract_{DC}} * 0.2 * 2$$

Converting the above expression in percentage with respect to the **Contracted quantity** $Q_{contract_{DC}}$, we have

$$\% \boldsymbol{RC_{MW_{DC}}} = \frac{(\mathbf{0.25} * Q_{contract_{\mathbf{DC}}} * \mathbf{0.2} * \mathbf{2})}{Q_{contract_{\mathbf{DC}}}} \times \mathbf{100} = \mathbf{0.25} * \mathbf{0.2} * \mathbf{2} * \mathbf{100} = \mathbf{10\%}$$

## General equation for Dx Service

The general equation that defines the **Reserved Capacity** percentage for any given contracted service is then generalised as follows:

$$\% \boldsymbol{RC_{MW_{Dx}}} = \frac{Dx\ delivery\ duration}{60} \times 0.2 \times 2 \times 100$$

where Dx delivery duration refers to DC, DM or DR delivery duration.

# 4. SOE Delivery Stage Monitoring Methodology

## Requirements

The data utilised for SOE monitoring is derived from the performance monitoring data submitted by providers. The information contained in the performance data relevant to SOE monitoring is shown in the table below. The full list of information is specified in the Service Terms Paragraph 15.4 and described in the Performance Monitoring CSV File Format document.

*Table 3: Performance Monitoring submission data*

| Parameter | Units | Description |
|---|---|---|
| Input Frequency | Hz | Frequency measured by the service provider |
| Availability | NA | Availability declaration of the unit |
| Active Power/demand | MW | Active power output or demand shown by metered data |
| Baseline | MW | Performance baseline which updates any operational baseline |
| State of Energy – export | MWh | Energy capacity available to the unit for export |
| State of Energy – import | MWh | Energy capacity available to the unit for import |

The SOE monitoring methodology uses values calculated in the performance monitoring process to assess the energy delivery caused by service activation over the course of each settlement period. The parameters used for this are described in the table below. The details on how these values of these parameters are calculated are available in Schedule 2 of the Service Terms.

*Table 4: Performance Monitoring calculated parameters*

| Parameter | Description |
|---|---|
| LFE | Maximum possible energy delivery for low frequency response given the input frequency. It corresponds to the upper performance bound. |
| HFE | Maximum possible energy delivery for high frequency response given the input frequency. It corresponds to the lower performance bound. |

## Algorithm Low Frequency

New parameters specifically for SOE monitoring are created by the SOE monitoring algorithm. Since the algorithm calculates the Minimum SOE Requirement for Low Frequency and High Frequency response separately, two sets of parameters are created.

Table below shows the parameters used to calculate the minimum SOE requirement for Low Frequency response contracts. The minimum SOE requirement value that is compared against the reported SOE level at the start of each settlement period comes from *soe_export_start* parameter.

Note: For convenience, we designate SP 1 as the initial SP of the EFA to be evaluated.

*Table 5 : Low Frequency response SOE monitoring parameters*

| Parameter | Description | Function of SP |
|---|---|---|
| LFE | Maximal total theoretical low frequency response energy delivery over the SP | LFE = the energy delivered by the $UB_{LF}$ during the SP |
| soe_export_start | Minimum SoE Requirement at the start of the SP | If SP is SP 1 of EFA then<br>soe_export_start = REV<br>else<br>soe_export_start = soe_export_end(SP-1) |
| soe_export_end | Minimum SoE requirement at the end of the SP | soe_export_end(SP) = soe_export_start(SP) + soe_export_adjust_SP4(SP) – LFE(SP) |
| soe_export_adjust_SP0 | SoE adjustment needed given current SP delivery | soe_export_adjust_SP0(SP) = min(LFE(SP)+soe_export_left, ER) |
| soe_export_adjust_SP4 | SoE adjustment implemented for current SP. (Passed on from SP-4). | If SP is SP<= 4 of EFA then:<br>soe_export_adjust_SP4 = 0<br>else:<br>soe_export_adjust_SP4 = soe_export_adjust_SP0(SP-4) |
| soe_export_left_over | Residual SoE adjustment by allowing for the minimum Energy Recovery requirement | If SP is SP1 of EFA:<br>soe_export_left_over(SP) = 0<br>else:<br>soe_export_left_over(SP)= SUM(LFE(SP1 to SP-1)) -SUM(soe_export_adjust_SP0(SP1 to SP-1)) |
| soe_export_flag | Indicates whether unavailability caused by SOE depletion due to delivery is allowed | If soe_export_start(SP) <= 0 or/and<br>soe_export_end(SP) <= 0 then TRUE<br>else FALSE |

The following walkthrough demonstrates how the LF Minimum SOE Requirement for a unit contracted to provide 100MW of DRL in EFA 3.

### SP1 calculations

- Minimum SOE requirement at the start of SP1 is equal to REV. REV = 100 MW * 60minutes
  - soe_export_start = 100 MWh
- Given the observed frequency the unit could at most deliver 15MWh of low frequency response while remaining inside the performance bounds.
  - LFE = 15 MWh
- SP1 <= SP4 therefore SOE recovery adjustment is 0.
  - soe_export_adjust_SP4 = 0 MWh
- The minimum SOE requirement at the end SP1 is 85MWh.
  - soe_export_end = soe_export_start + soe_export_adjust_SP4 - LFE

    = 100 MWh + 0 MWh – 15 MWh = 85 MWh
- As current SP is SP1, there is no residual SOE adjustment.
  - soe_export_left_over = 0 MWh
- At this point, the minimum SOE requirement has fallen below REV. The minimum SOE requirement will increase through energy recovery in SP1+4 = SP5. Energy recovery is the minimum between the REV shortfall (15 MWh) and ER (20 MWh), for this example this equals 15 MWh.
  - soe_export_adjust_SP0 = min(15 MWh, 20 MWh) = 15 MWh

### SP2 calculations

- The minimum SOE requirement at the start of SP2 is 85 MWh.
  - soe_export_start = 85 MWh
- Given the observed frequency the unit could at most deliver 12 MWh of low frequency response while remaining inside the performance bounds.
  - LFE = 12 MWh
- SP2 <= SP4 therefore SOE recovery adjustment is 0.
  - soe_export_adjust_SP4 = 0
- The minimum SOE requirement at the end SP2 is 73 MWh.
  - soe_export_end = soe_export_start + soe_export_adjust_SP4 - LFE
  - = 85 MWh + 0 MWh – 12 MWh = 73 MWh
- The residual SOE adjustment is 0 MWh.
  - soe_export_left_over = (15) – (15) = 0 MWh

- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP2+4 = SP6. Energy recovery is the minimum between the REV shortfall and ER – 12 MWh.
  - soe_export_adjust_SP0 = min(12 MWh, 20 MWh) = 12 MWh

## SP3 calculations

- The minimum SOE requirement at the start of SP2 is 73MWh.
  - soe_export_start = 73 MWh
- Given the observed frequency the unit could at most deliver 20MWh of low frequency response while remaining inside the performance bounds.
  - LFE = 20 MWh
- SP3 <= SP4 so SOE recovery adjustment is 0.
  - soe_export_adjust_SP4 = 0
- The minimum SOE requirement at the end SP2 is 53MWh.
  - soe_export_end = soe_export_start+ soe_export_adjust_SP4 - LFE
  - = 73 MWh + 0 MWh – 20 MWh = 53 MWh
- The residual SOE adjustment is 0 MWh.
  - soe_export_left_over = (15+12) – (15+12) = 0 MWh
- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP3+4 = SP7. Energy recovery is the minimum between the REV shortfall and ER, i.e. 20 MWh.
  - soe_export_adjust_SP0 = min(20 MWh, 20 MWh) = 20 MWh

## SP4 calculations

- The minimum SOE requirement at the start of SP4 is 53MWh.
  - soe_export_start = 53 MWh
- Given the observed frequency the unit could at most deliver 40MWh of low frequency response while remaining inside the performance bounds. The minimum SOE requirement falls by 40MWh.
  - LFE = 40 MWh
- SP4 <= SP4 so SOE recovery adjustment is 0.
  - soe_export_adjust_SP4 = 0
- The minimum SOE requirement at the end SP4 is 13MWh.
  - soe_export_end = soe_export_start + soe_export_adjust_SP4 - LFE
  - = 53 MWh – 40 MWh = 13 MWh
- The residual SOE adjustment is 0 MWh.

  - soe_export_left_over = (15+12+20) – (15+12+20) = 0 MWh

- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP4+4 = SP8. Energy recovery is the minimum between the REV shortfall and ER, i.e. 20 MWh.
  - soe_export_adjust_SP0 = min(40 MWh, 20 MWh) = 20 MWh

### SP5 calculations

- The minimum SOE requirement at the start of SP5 is 13MWh.
  - soe_export_start = 13 MWh
- Given the observed frequency the unit could at most deliver 30MWh of low frequency response while remaining inside the performance bounds.
  - LFE = 30 MWh
- There is a SOE recovery adjustment from SP1 of 15 MWh.
  - soe_export_adjust_SP4 = 15 MWh
- The minimum SOE requirement at the end SP5 is -2 MWh[1].
  - soe_export_end = soe_export_start + soe_export_adjust_SP4 - LFE

    = 13 MWh + 15 MWh – 30 MWh = -2 MWh
- The residual SOE adjustment is 20 MWh.
  - soe_export_left_over = (15+12+20+40) – (15+12+20+20) = 20 MWh
- The minimum SOE requirement remains below REV. However, there are no SPs remaining in the EFA available for SOE adjustment. (SP5+4 would be SP9).
  - soe_export_adjust_SP0 = min((30 + 20) MWh, 20 MWh) = min(50 MWh, 20MWh) = 20 MWh

### SP6 calculations

- The minimum SOE requirement at the start of SP6 is -2 MWh.
  - soe_export_start = -2 MWh
- Given the observed frequency the unit could at most deliver 4 MWh of low frequency response while remaining inside the performance bounds.
  - LFE = 4 MWh
- There is a SOE recovery adjustment from SP2 of 12 MWh.
  - soe_export_adjust_SP4 = 12 MWh

[1] If a unit's SOE falls to 0 MWh it should notify the ENCC of unavailability and declare unavailability in the performance monitoring files. If the Minimum SOE Requirement is at or below 0 then it will be deemed as allowed unavailability.

- The minimum SOE requirement at the end SP6 is 6 MWh.
  - soe_export_end = soe_export_start + soe_export_adjust_SP4 - LFE

    = -2 MWh + 12 MWh – 4 MWh = 6 MWh
- The residual SOE adjustment is 30 MWh.
  - soe_export_left_over = (15+12+20+40+30) – (15+12+20+20+20) = 30 MWh
- The minimum SOE requirement remains below REV. However, there are no SPs remaining in the EFA available for SOE adjustment. (SP6+4 would be SP10).
  - soe_export_adjust_SP0 = min((30 + 30) MWh, 20 MWh) = min(60 MWh, 20MWh) = 20 MWh

### SP7 calculations

- The minimum SOE requirement at the start of SP7 is 6 MWh.
  - soe_export_start = 6 MWh
- Given the observed frequency the unit could at most deliver 5 MWh of low frequency response while remaining inside the performance bounds.
  - LFE = 5 MWh
- There is a SOE recovery adjustment from SP3 of 20 MWh.
  - soe_export_adjust_SP4 = 20 MWh
- The minimum SOE requirement at the end SP7 is 21 MWh.
  - soe_export_end = soe_export_start + soe_export_adjust_SP4 - LFE

    = 6 MWh + 20 MWh – 5 MWh = 21 MWh
- The residual SOE adjustment is 14 MWh.
  - soe_export_left_over = (15+12+20+40+30+4) – (15+12+20+20+20+20) = 14 MWh
- The minimum SOE requirement remains below REV. However, there are no SPs remaining in the EFA available for SOE adjustment. (SP7+4 would be SP11).
  - soe_export_adjust_SP0 = min((5 + 14) MWh, 20 MWh) = min(19 MWh, 20MWh) = 19 MWh

### SP8 calculations

- The minimum SOE requirement at the start of SP8 is 21 MWh.
  - soe_export_start = 21 MWh
- Given the observed frequency the unit could at most deliver 1 MWh of low frequency response while remaining inside the performance bounds.
  - LFE = 1 MWh
- There is a SOE recovery adjustment from SP4 of 20 MWh.
  - soe_export_adjust_SP4 = 20 MWh

- The minimum SOE requirement at the end SP8 is 40 MWh.
  - soe_export_end = soe_export_start + soe_export_adjust_SP4 - LFE
    = 21 MWh + 20 MWh – 1 MWh = 40 MWh
- The residual SOE adjustment is 0 MWh.
  - soe_export_left_over = (15+12+20+40+30+4+5) – (15+12+20+20+20+20+19) = 0 MWh
- The minimum SOE requirement remains below REV. However, there are no SPs remaining in the EFA available for SOE adjustment. (SP8+4 would be SP12).
  - soe_export_adjust_SP0 = min(1 MWh, 20 MWh) = 1 MWh

## Table Format Summary

Table 6 summarises the worked example shown in previous sections.

*Table 6: LF worked example summary*

| LF | Select Service Type | | DR | | | |
|---|---|---|---|---|---|---|
| | **Contracted Quantity (MW)** | | 100 | [MW] | | |
| | **REV** | | 100 | [MWh] | | |
| | **ER** | | 20 | [MWh] | | |

| SP | LFE | start | end | SP0 | SP4 | left_over | Allowed Unavailability |
|---|---|---|---|---|---|---|---|
| **1** | 15 | **100** | 85 | 15 | 0 | 0 | FALSE |
| **2** | 12 | **85** | 73 | 12 | 0 | 0 | FALSE |
| **3** | 20 | **73** | 53 | 20 | 0 | 0 | FALSE |
| **4** | 40 | **53** | 13 | 20 | 0 | 0 | FALSE |
| **5** | 30 | **13** | -2 | 20 | 15 | 20 | TRUE |
| **6** | 4 | **-2** | 6 | 20 | 12 | 30 | TRUE |
| **7** | 5 | **6** | 21 | 19 | 20 | 14 | FALSE |
| **8** | 1 | **21** | 40 | 1 | 20 | 0 | FALSE |

The most important column is the 'start' column, as at the start of each settlement period, the first SOE value reported by the unit in its performance monitoring data will be compared again the value in the 'start' column. If the SOE value reported by the unit is below the unit from the table, then the unit fails SOE management.

## Diagram Format Summary

A visual representation of the energy flows used for the minimum soe requirement calculation is shown in Figure 3. It shows the volumes by which the requirement decreases and increases in each settlement period.

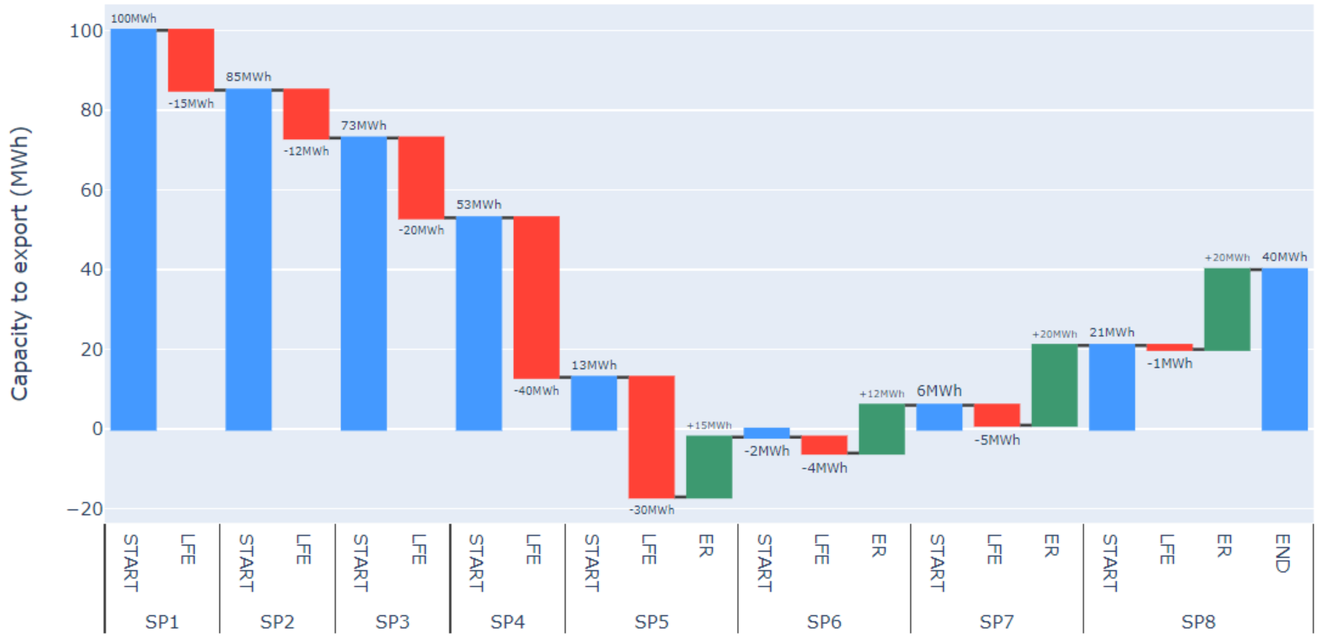


*Figure 3: Waterfall illustration of LF worked example*

## Algorithm High Frequency

Table below shows the parameters used to calculate the minimum SOE requirement for High Frequency response contracts. The minimum SOE requirement value that is compared against the reported SOE level at the start of each settlement period comes from the *soe_import_start* parameter.

*Table 7: High Frequency response SOE monitoring parameters*

| Parameter | Description | Function of SP |
|---|---|---|
| HFE | Total theoretical high frequency response energy delivery over SP | HFE = the energy delivered by the $LB_{HF}$ during the SP |
| soe_import_start | Minimum SoE Requirement at the start of the SP | If SP is SP 1 of EFA then<br>soe_import_start = REV<br>else<br>soe_import_start = soe_import_end(SP-1) |
| soe_import_end | Minimum SoE requirement at the end of the SP | soe_import_end(SP) = soe_import_start(SP) + soe_import_adjust_SP4(SP) – HFE(SP) |
| soe_import_adjust_SP0 | SoE adjustment needed given current SP delivery | soe_import_adjust_SP0(SP) = min(HFE(SP)+soe_import_left, ER) |
| soe_import_adjust_SP4 | SoE adjustment implemented for current SP. (Passed on from SP-4). | If SP is SP<= 4 of EFA then:<br>soe_import_adjust_SP4 = 0<br>else:<br>soe_import_adjust_SP4 = soe_import_adjust_SP0(SP-4) |
| soe_import_left_over | Residual SoE adjustment by allowing for the minimum Energy Recovery requirement | If SP is SP 1 of EFA:<br>soe_import_left_over(SP) = 0<br>else:<br>soe_import_left_over(SP)= SUM(HFE(SP1 to SP-1)) -SUM(soe_import_adjust_SP0(SP1 to SP-1)) |
| soe_import_flag | Indicates whether unavailability caused by SOE depletion due to delivery is allowed | If soe_import_start(SP) <= 0 or<br>soe_import_end(SP) <= 0 then TRUE<br>else FALSE |

The following walkthrough demonstrates how the HF Minimum SOE Requirement for a unit would be calculated given that the unit is contracted to provide 40MW of DCH.

### SP1 calculations

- The minimum SOE requirement at the start of SP1 is REV. REV = 40 MW * 15 minutes
  - soe_import_start = 10 MWh
- Given the observed frequency the unit could at most deliver 0MWh of low frequency response while remaining inside the performance bounds.
  - HFE = 0 MWh
- SP1 <= SP4 so SOE recovery adjustment is 0.
- The minimum SOE requirement at the end SP1 is 10 MWh.
  - soe_import_end = soe_import_start + soe_import_adjust_SP4 - HFE

    = 10 MWh + 0 MWh – 0 MWh = 0 MWh
- As it is the first SP, there is no residual SOE adjustment to be made.
- The minimum SOE requirement has not fallen below REV. There is no energy recovery needed in SP1+4.
  - soe_import_adjust_SP0 = min(0 MWh, 2 MWh) = 0 MWh

### SP2 calculations

- The minimum SOE requirement at the start of SP2 is 10 MWh.
  - soe_import_start = 10 MWh
- Given the observed frequency the unit could at most deliver 1 MWh of high frequency response while remaining inside the performance bounds.
  - HFE = 1 MWh
- SP2 <= SP4 so SOE recovery adjustment is 0.
- The minimum SOE requirement at the end SP2 is 9 MWh.
  - soe_import_end = soe_import_start + soe_import_adjust_SP4 - HFE

    = 10 MWh + 0 MWh – 1 MWh = 9 MWh
- The residual SOE adjustment is 0 MWh
  - soe_import_left_over = (0) – (0) = 0 MWh
- The minimum SOE requirement falls below REV. The minimum SOE requirement will increase through energy recovery in SP2+4 = SP6. Energy recovery is the minimum between the REV shortfall and ER, i.e. 1 MWh.
  - soe_import_adjust_SP0 = min((1 +0) MWh, 2 MWh) = 1 MWh

### SP3 calculations

- The minimum SOE requirement at the start of SP2 is 9 MWh.
  - soe_import_start = 9 MWh
- Given the observed frequency the unit could at most deliver 2 MWh of low frequency response while remaining inside the performance bounds.
  - HFE = 2 MWh
- SP3 <= SP4 so SOE recovery adjustment is 0.
- The minimum SOE requirement at the end SP2 is 1MWh.
  - soe_import_end = soe_import_start + soe_import_adjust_SP4 - HFE

    = 9 MWh + 0 MWh – 8 MWh = 1 MWh
- The residual SOE adjustment is 0 MWh.
  - soe_import_left_over = (0+1) – (0+1) = 0 MWh
- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP3+4 = SP7. Energy recovery is the minimum between the REV shortfall and ER, i.e. 1.
  - soe_import_adjust_SP0 = min((8+0) MWh, 2 MWh) = 2 MWh

### SP4 calculations

- The minimum SOE requirement at the start of SP4 is 1 MWh.
  - soe_import_start = 1 MWh
- Given the observed frequency the unit could at most deliver 2 MWh of low frequency response while remaining inside the performance bounds.
  - HFE = 2 MWh
- SP4 <= SP4 so SOE recovery adjustment is 0.
- The minimum SOE requirement at the end SP4 is -1 MWh.
  - soe_import_end = soe_import_start + soe_import_adjust_SP4 - HFE

    = 1 MWh + 0 MWh – 2 MWh = -1 MWh
- The residual SOE adjustment is 6 MWh
  - soe_import_left_over = (0+1+8) – (0+1+2) = 6 MWh
- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP4+4 = SP8. Energy recovery is the minimum between the REV shortfall and ER - 1.
  - soe_import_adjust_SP0 = min((2+6) MWh, 2 MWh) = 2 MWh

### SP5 calculations

- The minimum SOE requirement at the start of SP5 is -1 MWh.
  - soe_import_start = -1 MWh

- Given the observed frequency the unit could at most deliver 0 MWh of low frequency response while remaining inside the performance bounds.
  - HFE = 0 MWh
- There is no SOE recovery adjustment from SP1.
  - soe_import_adjust_SP4 = 0 MWh
- The minimum SOE requirement at the end SP5 is -1 MWh.
  - soe_import_end = soe_import_start+ soe_import_adjust_SP4 - HFE

    = -1 MWh + 0 MWh – 0 MWh = -1 MWh
- The residual SOE adjustment is 6 MWh
  - soe_import_left_over = (0+1+8+2) – (0+1+2+2) = 6 MWh
- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP5+4 = SP9. Energy recovery is the minimum between the REV shortfall and ER, i.e. 2 MWh.
  - soe_import_adjust_SP0 = min((2+6) MWh, 2 MWh) = 2 MWh

### SP6 calculations

- The minimum SOE requirement at the start of SP6 is -1 MWh.
  - soe_import_start = -1 MWh
- Given the observed frequency the unit could at most deliver 0 MWh of low frequency response while remaining inside the performance bounds.
  - HFE = 0 MWh
- There is a SOE recovery adjustment from SP2 of 1 MWh.
  - soe_import_adjust_SP4 = 1 MWh
- The minimum SOE requirement at the end SP6 is 0 MWh.
  - soe_import_end = soe_import_start + soe_import_adjust_SP4 - HFE =

    = -1 MWh + 1 MWh– 0 MWh = 0 MWh
- The residual SOE adjustment is 4 MWh
  - soe_import_left_over = (0+1+8+2+0) – (0+1+2+2+2) = 4 MWh
- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP+4 = SP7. Energy recovery is the minimum between the REV shortfall and ER, i.e. 2 MWh.
  - soe_import_adjust_SP0 = min((2+4) MWh, 2 MWh) = 2 MWh

### SP7 calculations

- The minimum SOE requirement at the start of SP7 is 0 MWh.
  - soe_import_start = 0 MWh

- Given the observed frequency the unit could at most deliver 0 MWh of low frequency response while remaining inside the performance bounds.
  - HFE = 0 MWh
- There is a SOE recovery adjustment from SP3 of 2 MWh.
  - soe_import_adjust_SP4 = 2 MWh
- The minimum SOE requirement at the end SP4 is 2 MWh.
  - soe_import_end = soe_import_start + soe_import_adjust_SP4 - HFE =
  - = 0 MWh + 2 MWh– 0 MWh = 2 MWh
- The residual SOE adjustment is 2 MWh
  - soe_import_left_over = (0+1+8+2+0+0) – (0+1+2+2+2+2) = 2 MWh
- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP7+4 = SP11. Energy recovery is the minimum between the REV shortfall and ER, i.e. 2 MWh.
  - soe_import_adjust_SP0 = min((2+2) MWh, 2 MWh) = 2 MWh

### SP8 calculations

- The minimum SOE requirement at the start of SP8 is 2 MWh.
  - soe_import_start = 2 MWh
- Given the observed frequency the unit could at most deliver 0 MWh of low frequency response while remaining inside the performance bounds.
  - HFE = 0 MWh
- There is a SOE recovery adjustment from SP3 of 2 MWh.
  - soe_import_adjust_SP4 = 2 MWh
- The minimum SOE requirement at the end SP4 is 2 MWh.
  - soe_import_end = soe_import_start + soe_import_adjust_SP4 - HFE =
  - = 0 MWh + 2 MWh– 0 MWh = 2 MWh
- The residual SOE adjustment is 2 MWh
  - soe_import_left_over = (0+1+8+2+0+0+0) – (0+1+2+2+2+2+2) = 0 MWh
- The minimum SOE requirement remains below REV. The minimum SOE requirement will increase through energy recovery in SP8+4 = SP12. Energy recovery is the minimum between the REV shortfall and ER, i.e. 0 MWh.
  - soe_import_adjust_SP0 = min((0+0) MWh, 2 MWh) = 0 MWh

## Table Format Summary

Table 8 summarises the worked example shown in previous sections.

*Table 8: HF worked example summary*

| HF | Select Service Type | | | DC | | | |
|---|---|---|---|---|---|---|---|
| | Contracted Quantity (MW) | | | 40 | [MW] | | |
| | REV | | | 10 | [MWh] | | |
| | ER | | | 2 | [MWh] | | |
| **SP** | **HFE** | **Start** | **end** | **SP0** | **SP4** | **left_over** | **Allowed Unavailability** |
| **1** | 0 | **10** | 10 | 0 | 0 | 0 | FALSE |
| **2** | 1 | **10** | 9 | 1 | 0 | 0 | FALSE |
| **3** | 8 | **9** | 1 | 2 | 0 | 0 | FALSE |
| **4** | 2 | **1** | -1 | 2 | 0 | 6 | TRUE |
| **5** | 0 | **-1** | -1 | 2 | 0 | 6 | TRUE |
| **6** | 0 | **-1** | 0 | 2 | 1 | 4 | TRUE |
| **7** | 0 | **0** | 2 | 2 | 2 | 2 | TRUE |
| **8** | 0 | **2** | 4 | 0 | 2 | 0 | FALSE |

The most important column is the 'start' column, as at the start of each settlement period, the first SOE value reported by the unit in its performance monitoring data will be compared again the value in the 'start' column. If the SOE value reported by the unit is below the unit from the table, then the unit fails SOE management.

## Diagram Format Summary

A visual representation of the energy flows used for the minimum soe requirement calculation is shown in Figure 4. It shows the volumes by which the requirement decreases and increases in each settlement period.

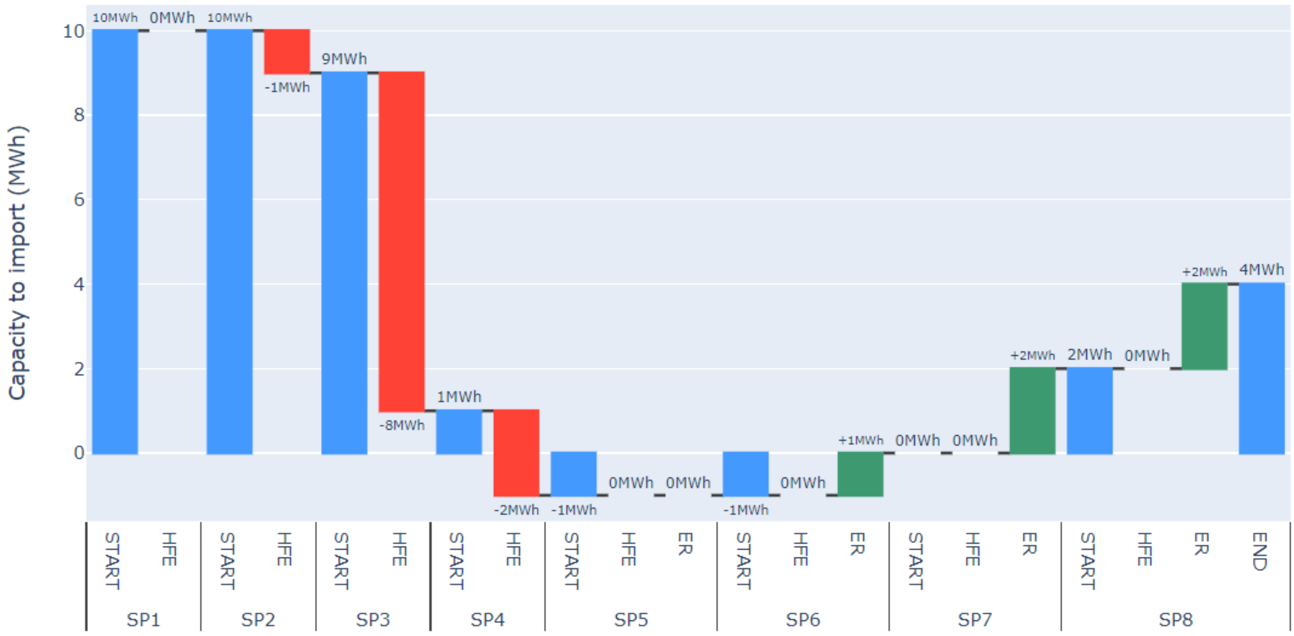


*Figure 4: Waterfall illustration of HF worked example*

## Consecutive contracts

The DC/DM/DR contracts are awarded separately in advance for each EFA block, hence the SOE monitoring should consider each EFA block independently. For the situation where providers have contracts for consecutive EFA blocks (with same or different **Contracted quantity**), the SOE minimum requirement refreshes at the beginning of the next EFA block with the requirement calculated from the corresponding **Contracted quantity**. Providers should use the last Settlement Periods (SPs) before entering the new EFA block to adjust their SOE at the start of the new EFA block.

Example: A provider has 4MW DRL contract in EFA1 and 5MW DRL contract in EFA2.

- At the beginning of EFA 1, the lower boundary of SOE the unit should hold is the REV, i.e. 4MW * 1h = 4MWh.
- During EFA1 manage the SOE with SOE rules.
- Before entering EFA 2, use the last SPs to prepare the SOE that can meet the REV for EFA 2
- At the beginning of EFA 2, the lower boundary of SOE the unit should hold is the REV, i.e. 5MW * 1h = 5MWh.