Public

Webinar:

Pre-fault Frequency Control Modelling

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Frequency Risk and Modelling (FRM) Market Requirements

12 March 2025

NESO
National Energy System Operator

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Agenda

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- **Context**
- **Introduction to pre-fault frequency control**
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  2. Pre-fault frequency response services
- **Pre-fault frequency control modelling**
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  3. Reversed system imbalance calculation
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- **Recommendation**
- **Future Steps**
- **Q&A**
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Context

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- Recently NESO has increased Dynamic Regulation (DR) & Dynamic Moderation (DM) requirements:

	Prior to 3 Feb 2025	From 3 Feb 2025
DR	330 MW DR-Low / High	480 MW DR-Low / High
DM	170 MW DM-Low 200 MW DM-High	300 MW DM-Low /High

- We communicated the changes on 5th February 2025 OTF and via NESO Ancillary Services Important Industry Notifications page.
- The increase helps NESO managing volatile system frequency observed in recent months whilst we are undertaking analysis to understand the root causes and introduce future mitigations.
- **This webinar aims to explain:**
  - Modelling approach we used to decide the new DR volume, and
  - Future plans to quantify DM requirement.

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Introduction to Pre-fault Frequency Control

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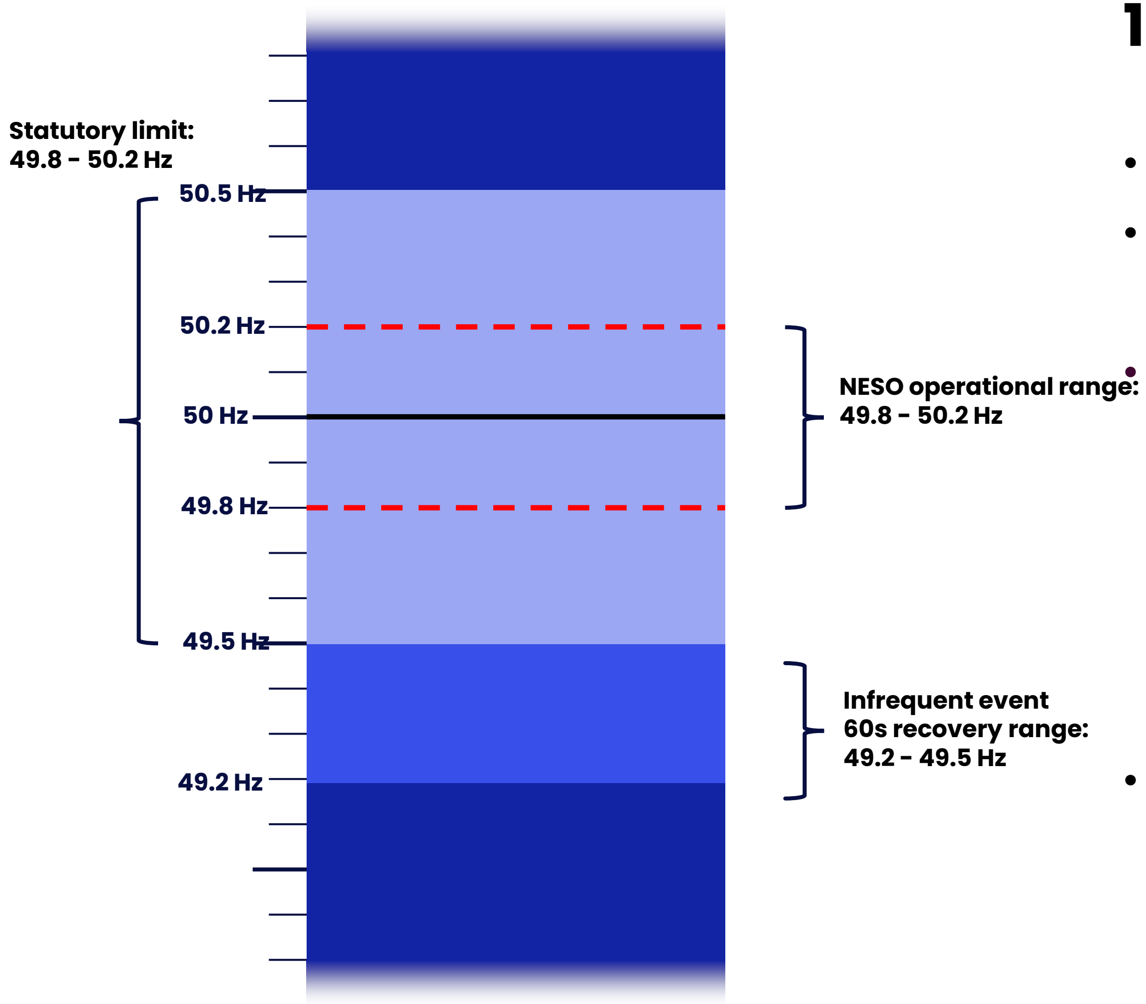

1. Operation Standards

- Frequency Statutory limit in **SQSS**: 49.5 – 50.5 Hz.
- NESO introduces an operational standard: 49.8 – 50.2 Hz.

- **Frequency Risk and Control Report (FRCR)** defines detailed requirements under *Unacceptable Frequency Conditions*, where a transient frequency deviations outside the limits of 49.5 and 50.5 Hz. Frequency can reach to 49.2 Hz and must return to 49.5 Hz within 60 seconds. Consultation of FRCR 2025 is open until 31st March.

- **Purpose of pre-fault frequency control:**
  - To help stabilise frequency deviations caused by system natural imbalance.
  - To work together with post-fault response services to contain frequency deviation.

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Introduction to Pre-fault Frequency Control

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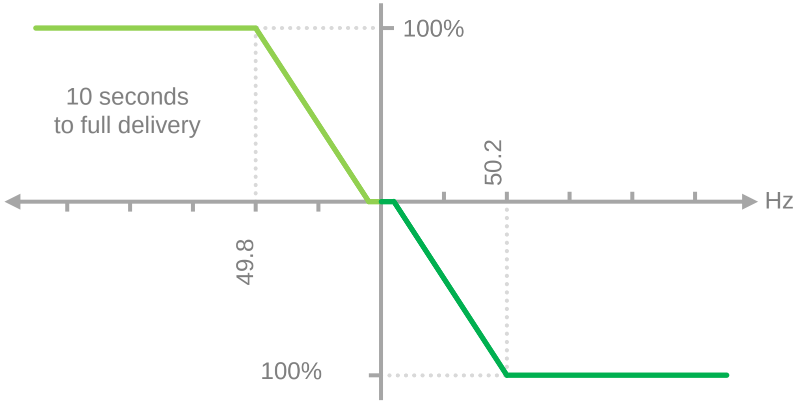
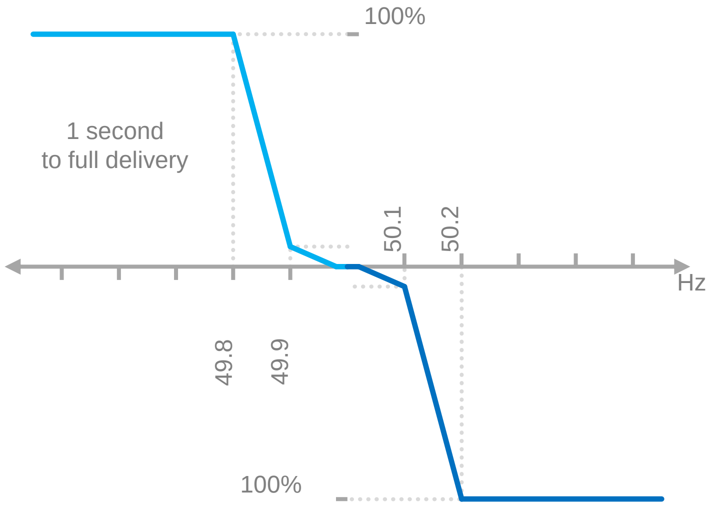
Day-ahead auction

Dynamic Regulation	Dynamic Moderation
	
Assist in keeping frequency near to 50Hz during normal conditions	Assist in keeping frequency within 0.2Hz, especially during more volatile conditions

Dynamic Regulation (DR) & Dynamic Moderation (DM) are cost-effective hence the primary products for pre-fault control.

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Introduction to Pre-fault Frequency Control

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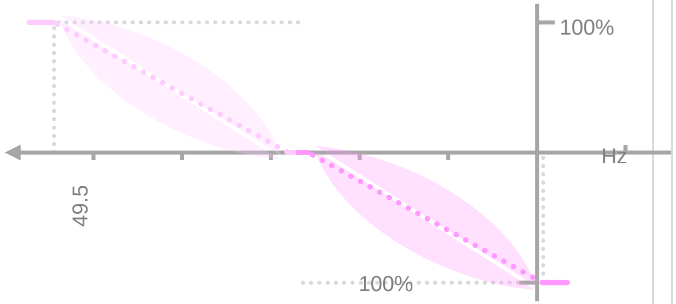
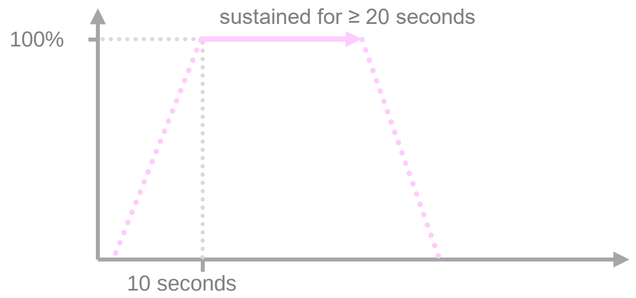
Real-time instruction

Mandatory Frequency Response



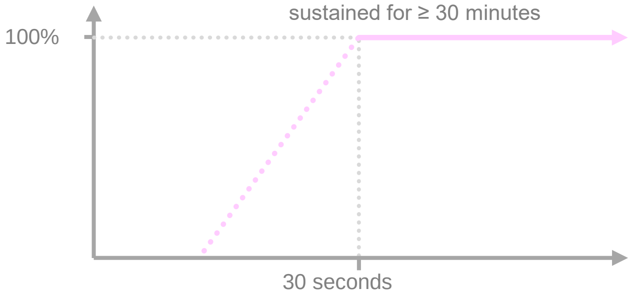
"Frequency Sensitive Mode"
under Grid Code

Primary



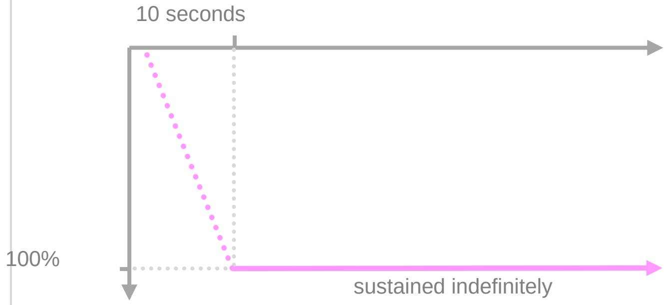
Low frequency response

Secondary



Low frequency response

High



High frequency response

- Mandatory Frequency Response (MFR) is an automatic change in active power output in response to a frequency change.
- MFR requires reform to be compliant with energy regulations and better meet the needs of future system and optimise as part of wider suite of services. Find out recent webinar record from our website.

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Pre-fault Frequency Control Modelling

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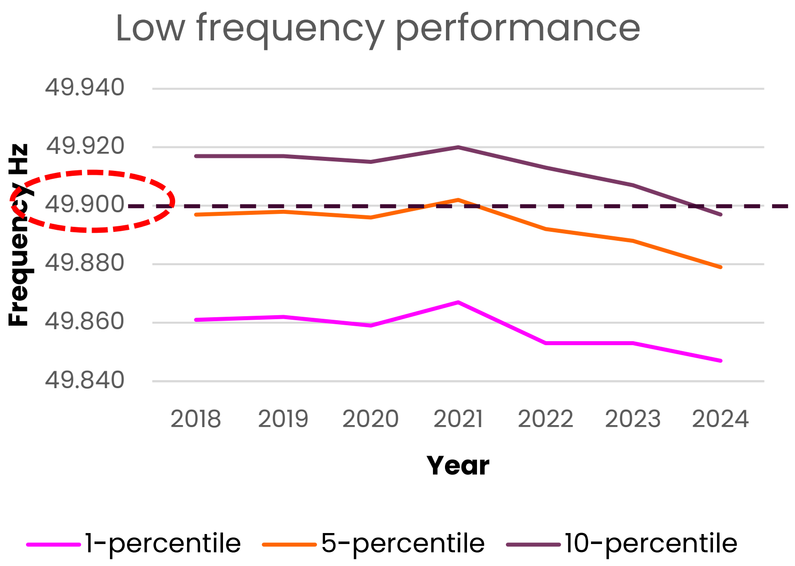
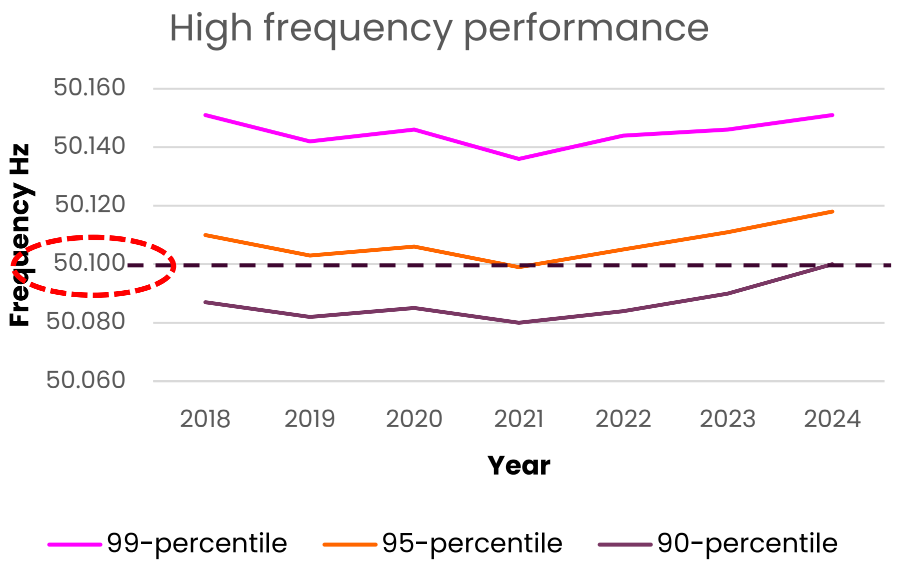
1. Historic Frequency Performance Review





From 2018 to 2020, **5%** frequency deviated out of 49.9 Hz, vs.
In 2024, **10%** frequency deviated out of 49.9 Hz

From 2019 to 2021, **95%** frequency deviated within 50.1 Hz, vs.
In 2024, **90%** frequency deviated within 50.1 Hz, meaning **10%** was out of 0.1 Hz deviation

- A declining frequency performance trend is observed over the past 7 years.
- This could be driven by the fast-changing system conditions including less synchronising elements, more use of natural resources, and consumer behaviour.
- We aim to improve pre-fault frequency performance by using new response services, and to facilitate post-fault security.
- Meanwhile, in post-fault service, i.e. DC requirement setting, we assume pre-fault excursion of +/- 0.15 Hz.

2018-2023 data are from ENTSO-e Load Frequency Control Annual Report;
2024 data is published on NESO webpage - NESO frequency data

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2. High-level modelling approach

Step 1 Statistic view of frequency performance

↓

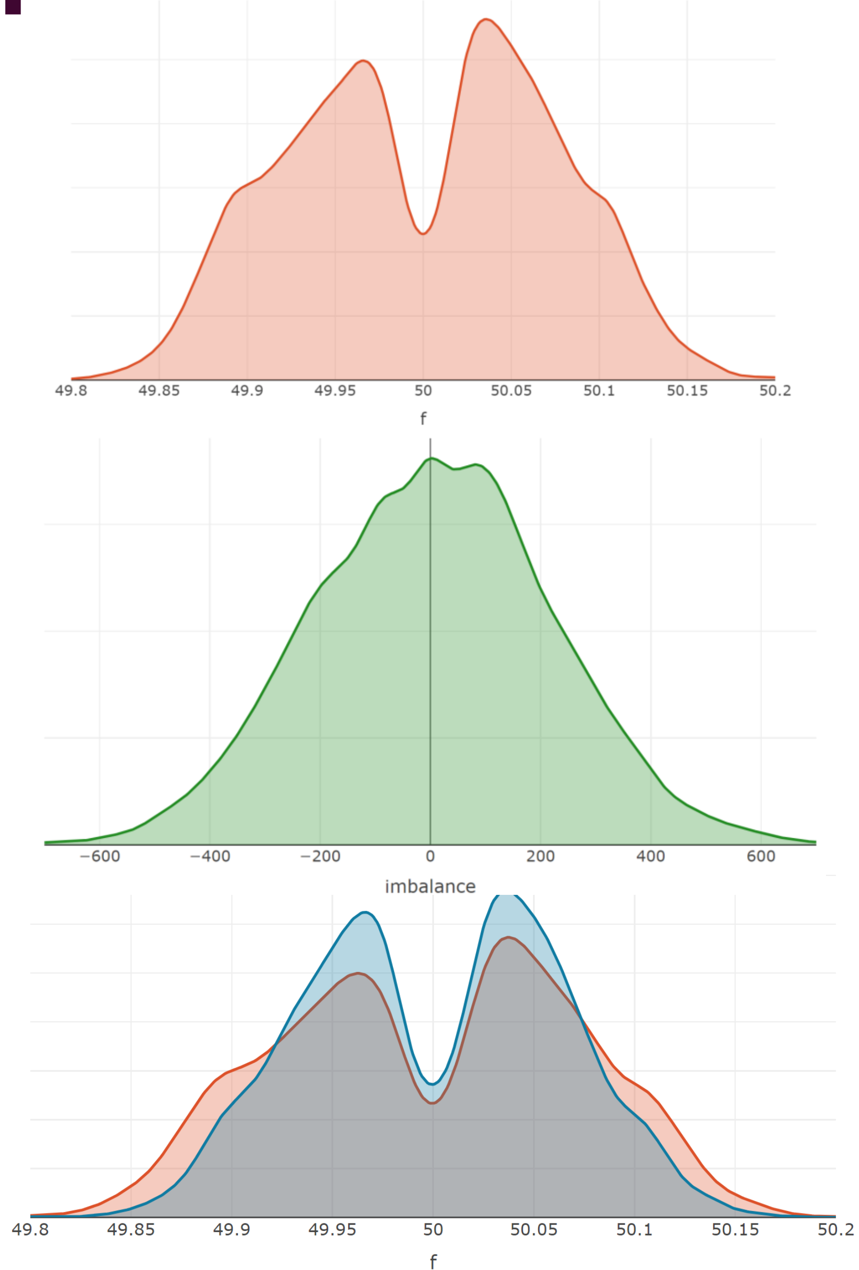
Step 2 Reverse frequency deviation to system imbalance

↓

Step 3 Calculate additional DR volume

↓

Step 4 Test effectiveness of new DR volume



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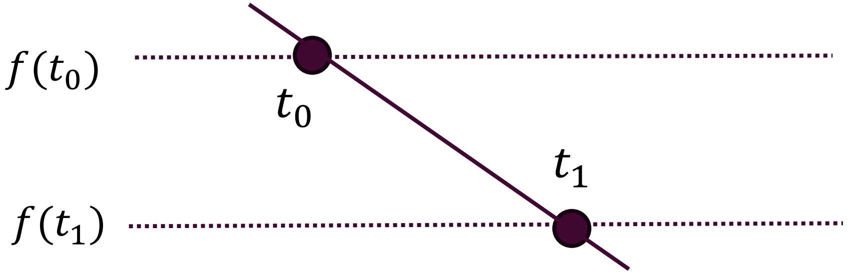
3. Reversed system imbalance calculation



- System imbalance (Imb_{total}) is composed of **Stable imbalance (Imb_{stable})** and **RoCoF imbalance (Imb_{RoCoF})**.

Stable imbalance (Imb_{stable}): imbalance which is offset by response.

At $t_0, G_0 = D_0$

At $t_1, G_1 = D_1$

$$G_0 + LF_{response} + Imb_G = D_0 - \Delta D + Imb_D$$

Use Imb_{stable} to replace $Imb_G - Imb_D$

$$Imb_{stable} = -G_0 - LF_{response} + D_0 - \Delta D$$

$$= -LF_{response} + \Delta D$$

Where, ΔD is the response provided by demand change, i.e. 2.5% /Hz as an empirical number.

RoCoF imbalance (Imb_{RoCoF}): imbalance when frequency is moving.

$$within\ \Delta t, RoCoF = \frac{f(t_1 + \Delta t) - f(t_1)}{(t_1 + \Delta t) - t_1}$$

$$= \frac{Imb_{RoCoF}}{2 \times Inertia} \times f_{nominal}$$

$$Imb_{RoCoF} = \frac{2}{f_{nominal}} \times inertia \times \frac{f(t_1 + \Delta t) - f(t_1)}{(t_1 + \Delta t) - t_1}$$

Where, $f_{nominal} = 50\ \mathrm{Hz}$.

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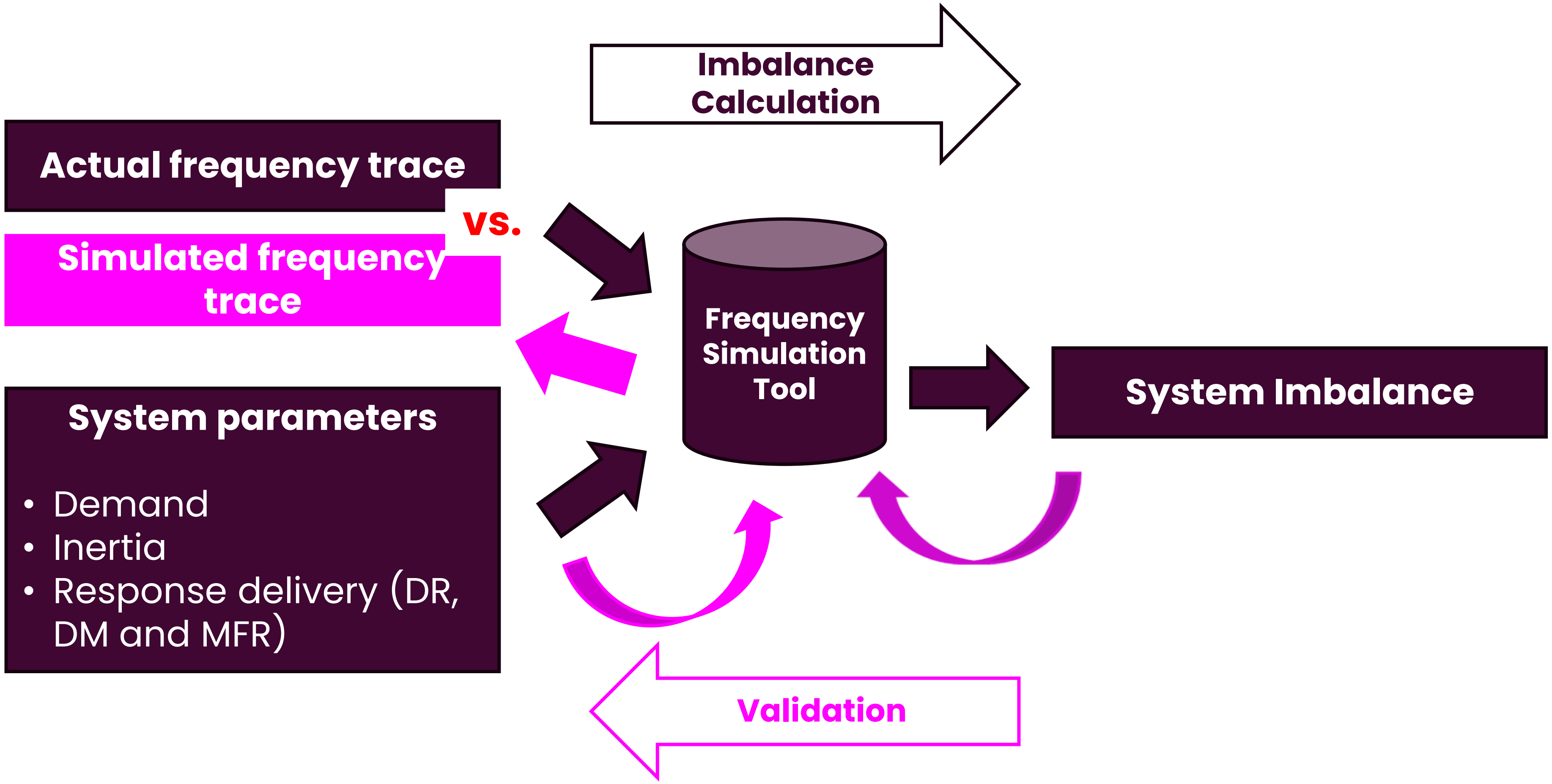
3. Reversed system imbalance calculation

- System imbalance (Imb_{total}) = Stable imbalance (Imb_{stable}) + RoCoF imbalance (Imb_{RoCoF})
- NESO in-house tool is used for calculation.



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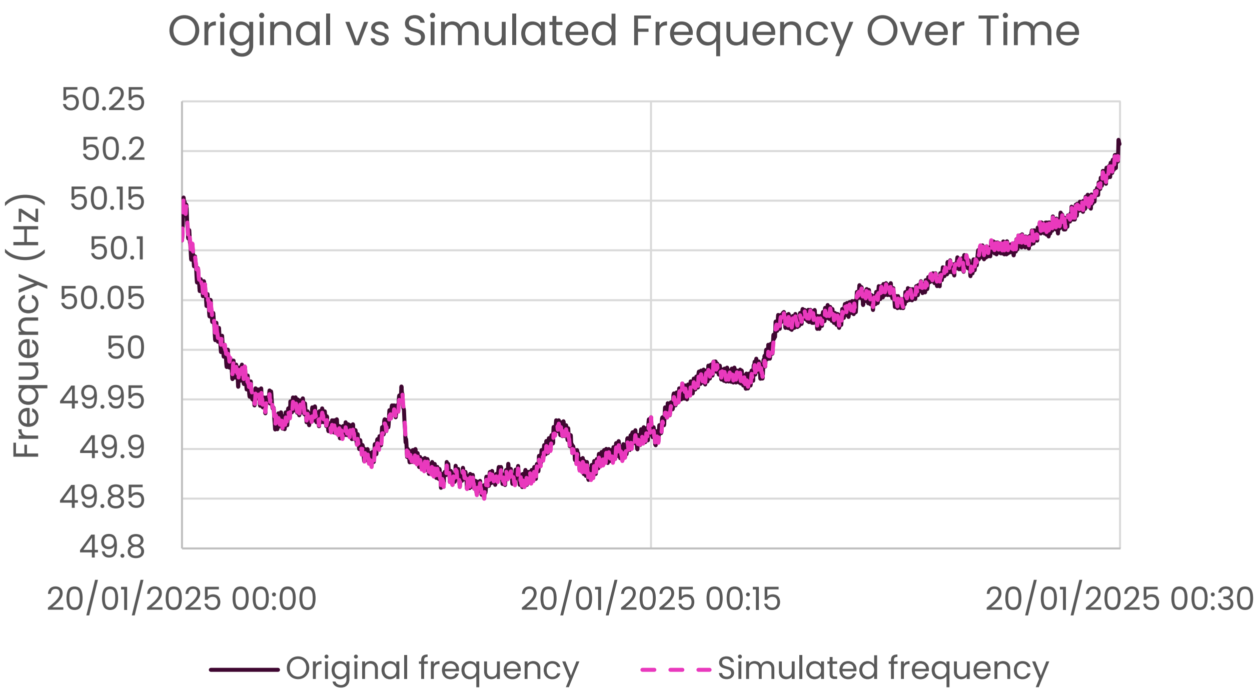
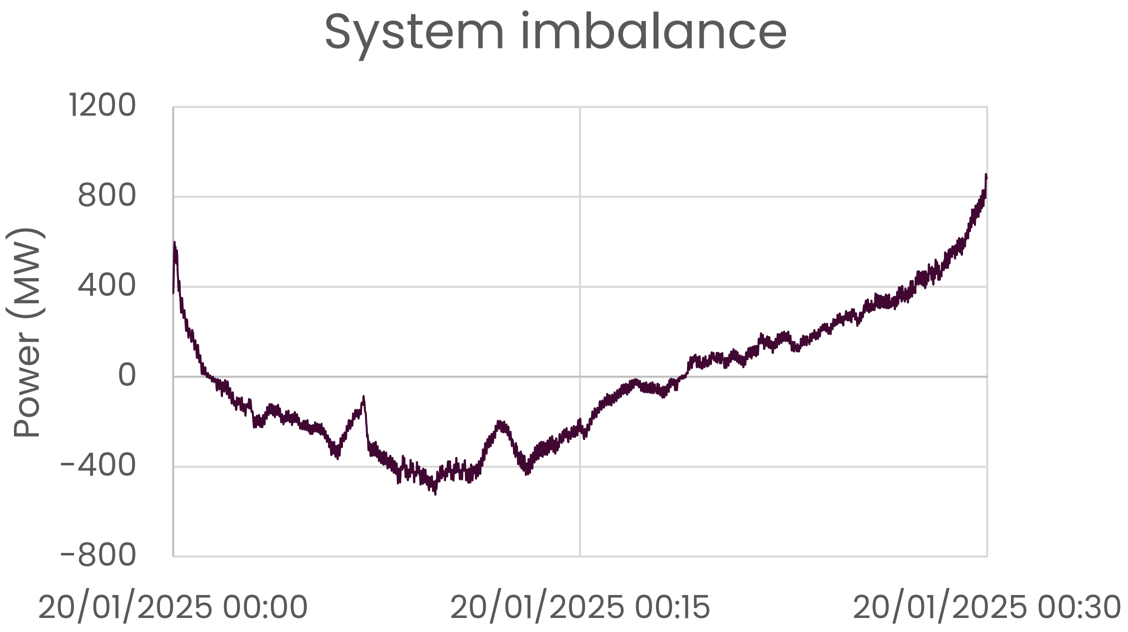
3. Reversed system imbalance calculation





- Example of system imbalance calculation and validation for Settlement Period 1 (SP1), 00:00-00:30hrs, 20 January 2025.

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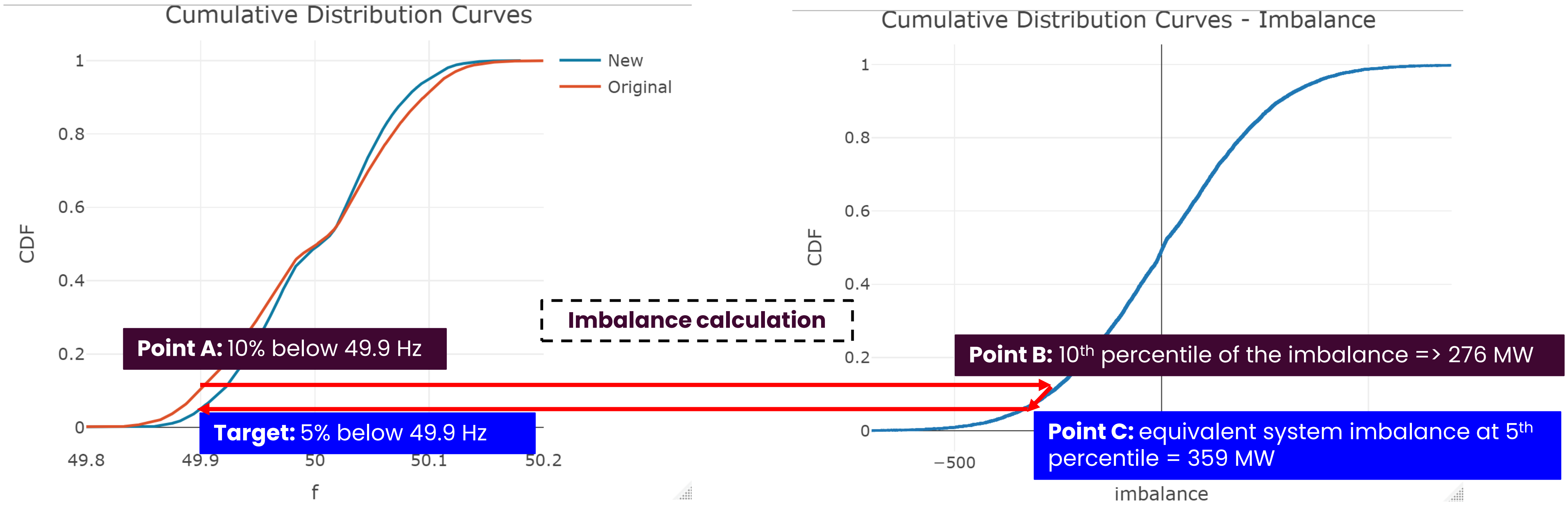
4. Quantify DR requirement

For example – July 2024

Frequency distribution	Imbalance distribution



- Additional imbalance between B and C is 359 – 276 = 83 MW.
- DR-L delivers 0-100% response between 50 and 49.8 Hz, e.g. at 49.9 Hz, DR-L delivery = 50% x capacity.
- To contain additional imbalance of 83 MW, **additional DR–L volume = 83 / 50% = 166 MW**.

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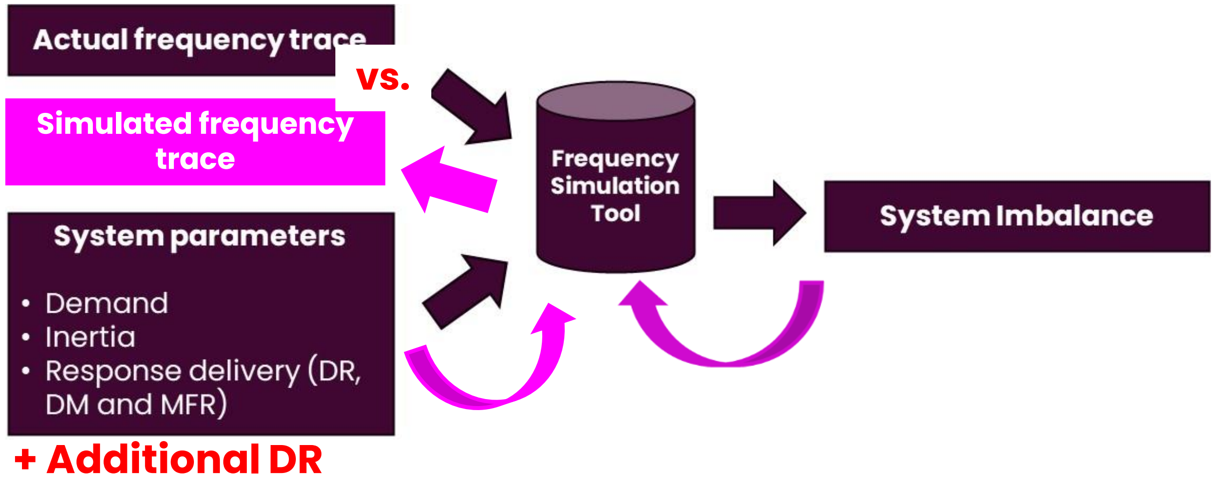
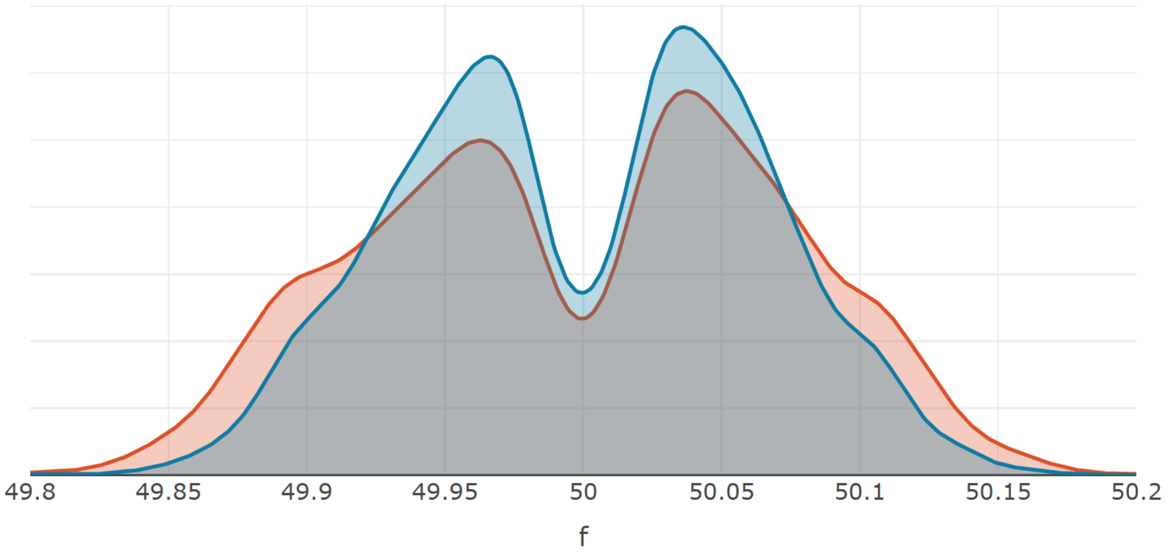
5. Test updated DR volume

- Additional DR-H is quantified based on the same approach. Additional DR-H = 140 MW
- Effectiveness of additional 160 MW DR-L and 140 MWDR-H is tested in the frequency simulation tool based on July 2024 data.





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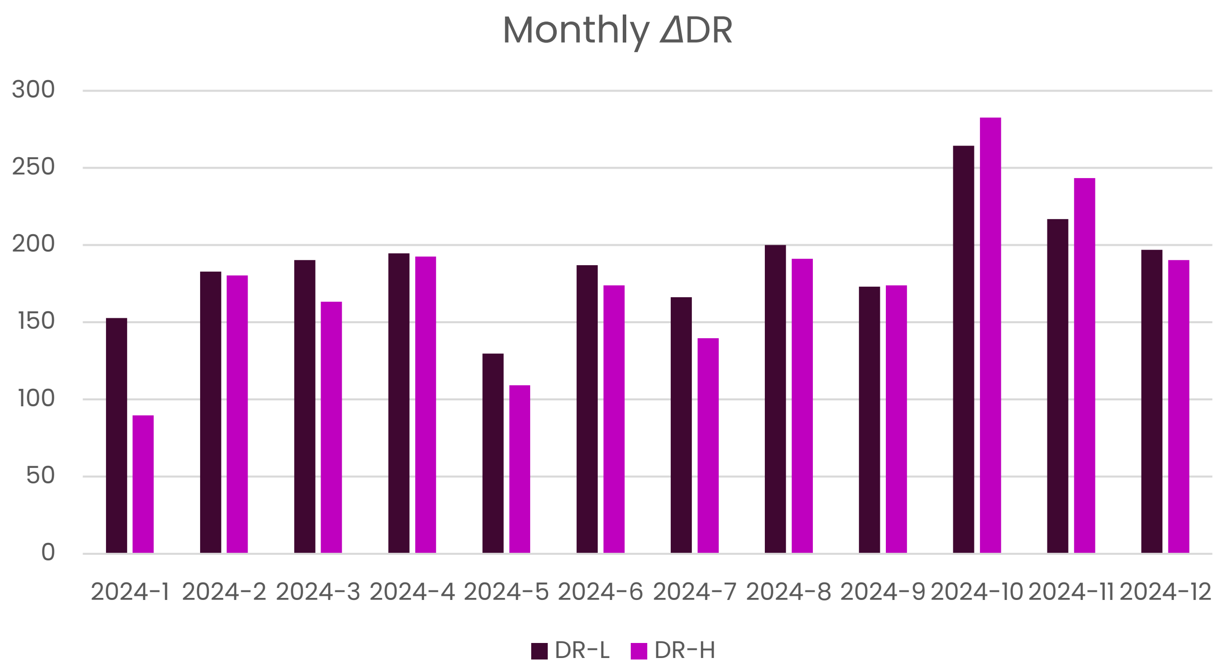
6. Proposed DR volume

- This modelling approach is applied to monthly frequency data from January to December 2024, to update DR-L and DR-H requirement.
- Proposed additional DR (ΔDR-L and ΔDR-H volumes) based on monthly average are:

ΔDR-L	ΔDR-H
183	172



Other Consideration: DR Cap

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- Some response services may lead to frequency oscillatory scenarios.
- The oscillation could be caused by a slow response service, e.g. DR, that measures frequency and delivers response after the fast services deliver, which could overcorrect the frequency and cause oscillations.
- NESO conducted analysis in PowerFactory considering GB transmission topology. The analysis was also verified in frequency simulation tool.
- According to PowerFactory analysis, key parameters leading to system oscillations could be:
  - **Response speed**
  - **Response service distribution**
  - **Response service location vs. origin of imbalance**
  - **Response service locational volumes**
  - **System conditions**
- DR performance monitoring data indicates, in many cases DR service is fast with response delay much less than 2 seconds, especially when DR is stacking with DC or/and DM.

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Other Consideration: DR Cap

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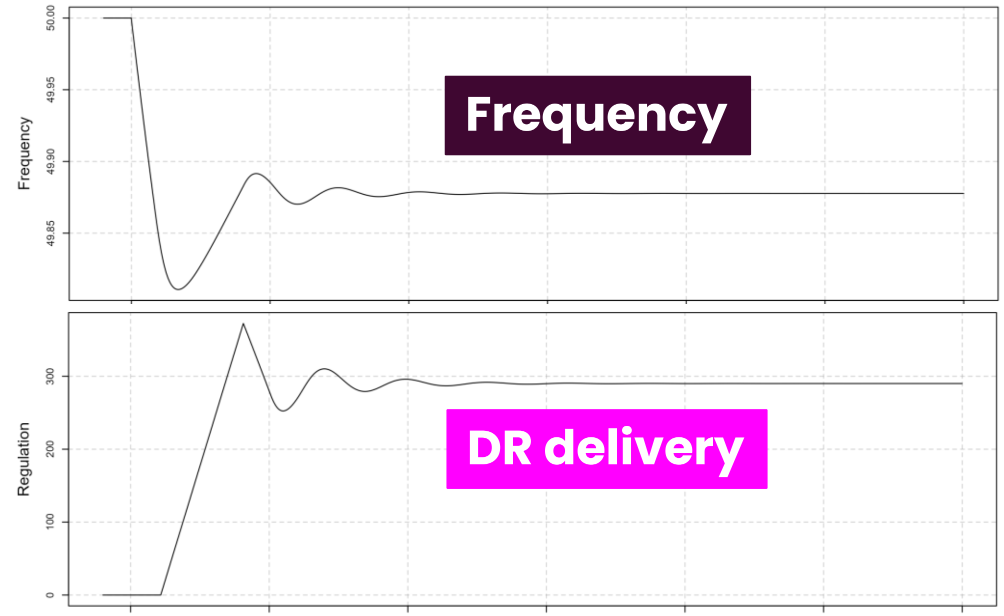
- Applying a cap volume on DR service presents a mitigation to the oscillation.
- Historic DR cap was 350 MW.
- Analysis concluded 500 MW DR would not cause any oscillations even under the worst scenario, i.e. all DR are slow service with 2-seconds delayed response.
- With DR > 500 MW, slowly-damped power swings could be observed.
- **Therefore, NESO has adopted 500 MW as new DR cap.**
- Further analysis will be performed following system condition changes and tool development.

Example	
Demand	14 GW
Inertia	120 GVA.s
Imbalance	400 MW
DR-L (2 s delay, 8 s ramping rate)	500 MW



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Recommendations

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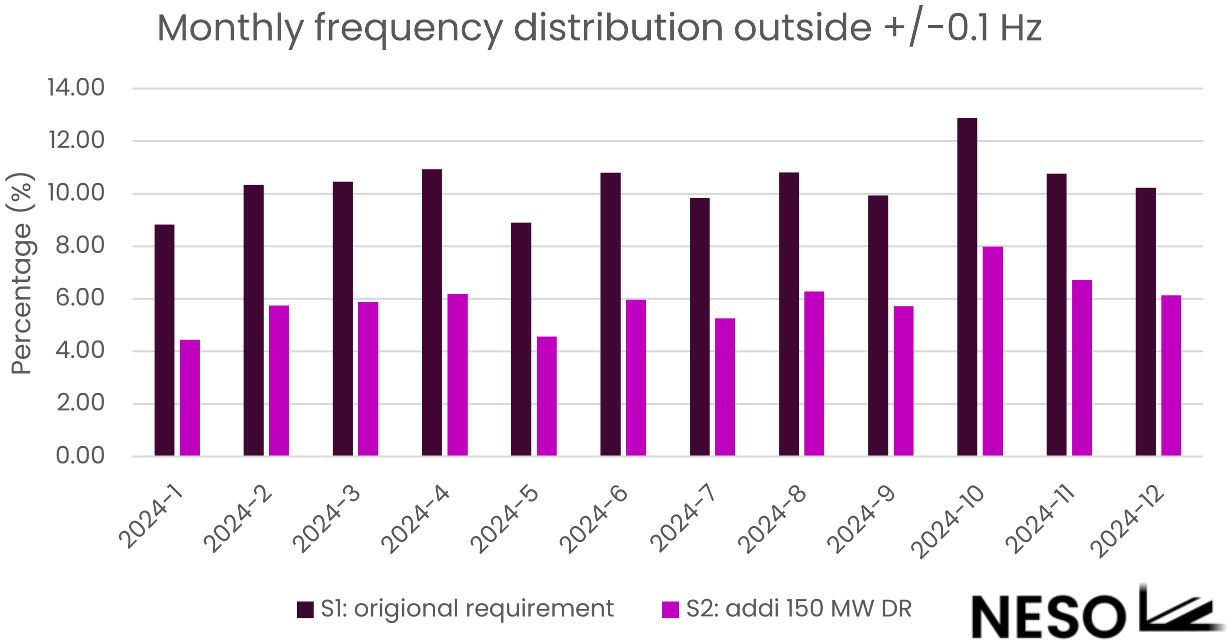
- Considering proposed additional DR and DR cap, the recommended new DR-L and DR-H volumes are:

	DR-L	DR-H
Previous DR	330	330
Proposed ΔDR	183	172
DR cap	150	150
New DR volume	480	480

- To further improve pre-fault frequency performance, we recommended DM to increase

	DM-L	DM-H
Previous DM	170	200
New DM volume	300	300

- With additional 150 MW DR-L and DR-H, simulated frequency distribution out of +/-0.1 Hz deviation is improved:
- **The average percentage of instances where frequency deviation exceeding +/-0.1 Hz drops from 10.39% to 5.90%.**



Future Steps

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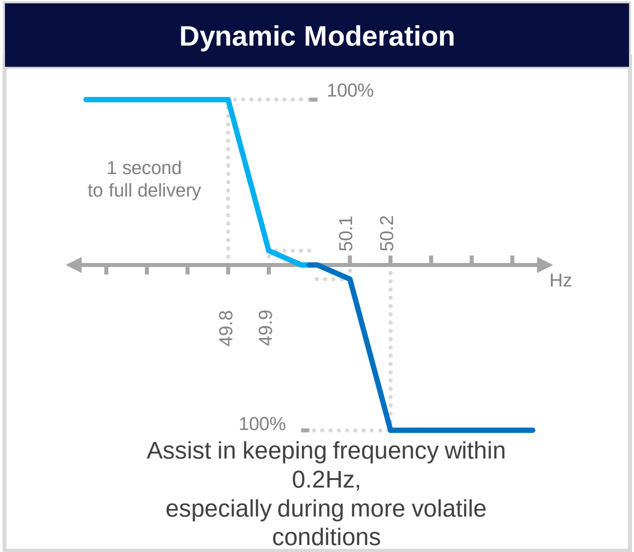
- **Dynamic Regulation**
  - We will continuously monitor the frequency performance and apply the methodology to adjust DR requirements.
  - Further analysis will be carried out to adjust DR cap.
- **Dynamic Moderation**
  - Clarify DM modelling and adjust requirement to facilitate MFR service reform.
  - **Option A:** apply the same modelling approach to adjust DM volume aiming to improve frequency performance within +/-0.15 Hz deviations.
  - **Option B:** develop a dynamic DM profile to tackle system uncertainties and volatility, e.g. caused by wind or market-signal driven behaviour.



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