

Public

**Webinar:**

# **Pre-fault Frequency Control Modelling**

Slido code #FRM

## **Frequency Risk and Modelling (FRM) Market Requirements**

**12 March 2025**



# Housekeeping

Slido code #FRM

- You have been joined in listen only mode with your camera turned off.
- To ask your questions live please go to Slido **event code #FRM**. Ask your questions as early as possible. Slido page remains open until this webinar closes:
- Please provide your full name and organisation. Questions from unidentified parties will not be answered.
- Questions will be answered in the upvoted order whenever possible. We endeavour to answer as many as possible during the session. We may need to take some questions away.
- **Out of scope questions will not be managed in this webinars** and will be forwarded to the appropriate NESO team for response.
- Webinar slides are available on [NESO website](#). Recording will be published after the webinar. A full Q&A document will be published by Friday 28 March.
- Please contact [box.FRM@nationalenergyso.com](mailto:box.FRM@nationalenergyso.com) for feedbacks and other comments.

# Agenda

Slido code #FRM

- **Context**
- **Introduction to pre-fault frequency control**
  1. Operation standards
  2. Pre-fault frequency response services
- **Pre-fault frequency control modelling**
  1. Historical performance
  2. High-level modelling approach
  3. Reversed system imbalance calculation
  4. Quantify DR requirement
  5. Test updated DR volume
  6. Proposed DR volume
- **Other consideration: DR cap**
- **Recommendation**
- **Future Steps**
- **Q&A**
- **Further Information and Close**

# Context

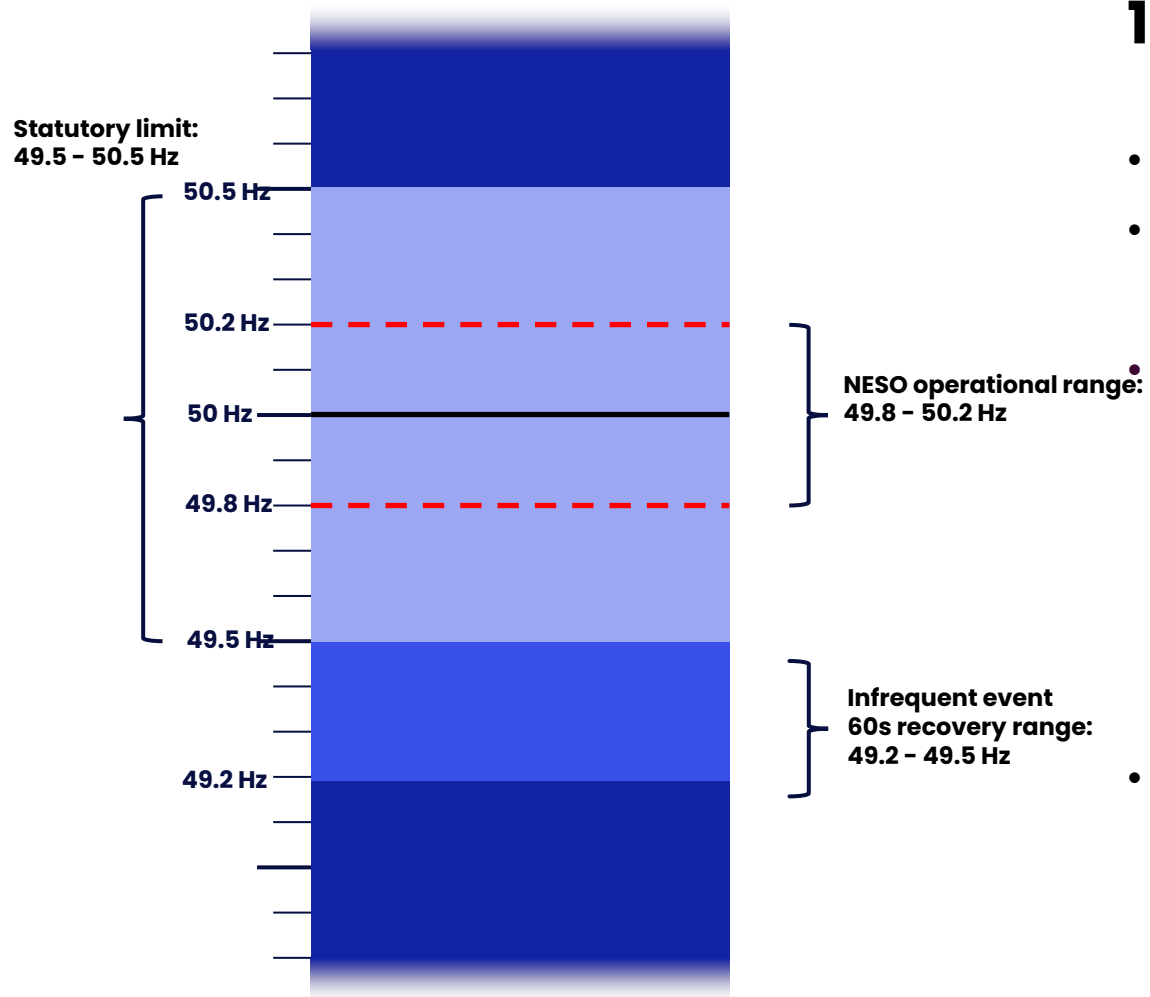
- Recently NESO has increased Dynamic Regulation (DR) & Dynamic Moderation (DM) requirements:

	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 [5<sup>th</sup> 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.

# Introduction to Pre-fault Frequency Control

Slido code #FRM



## 1. Operation Standards

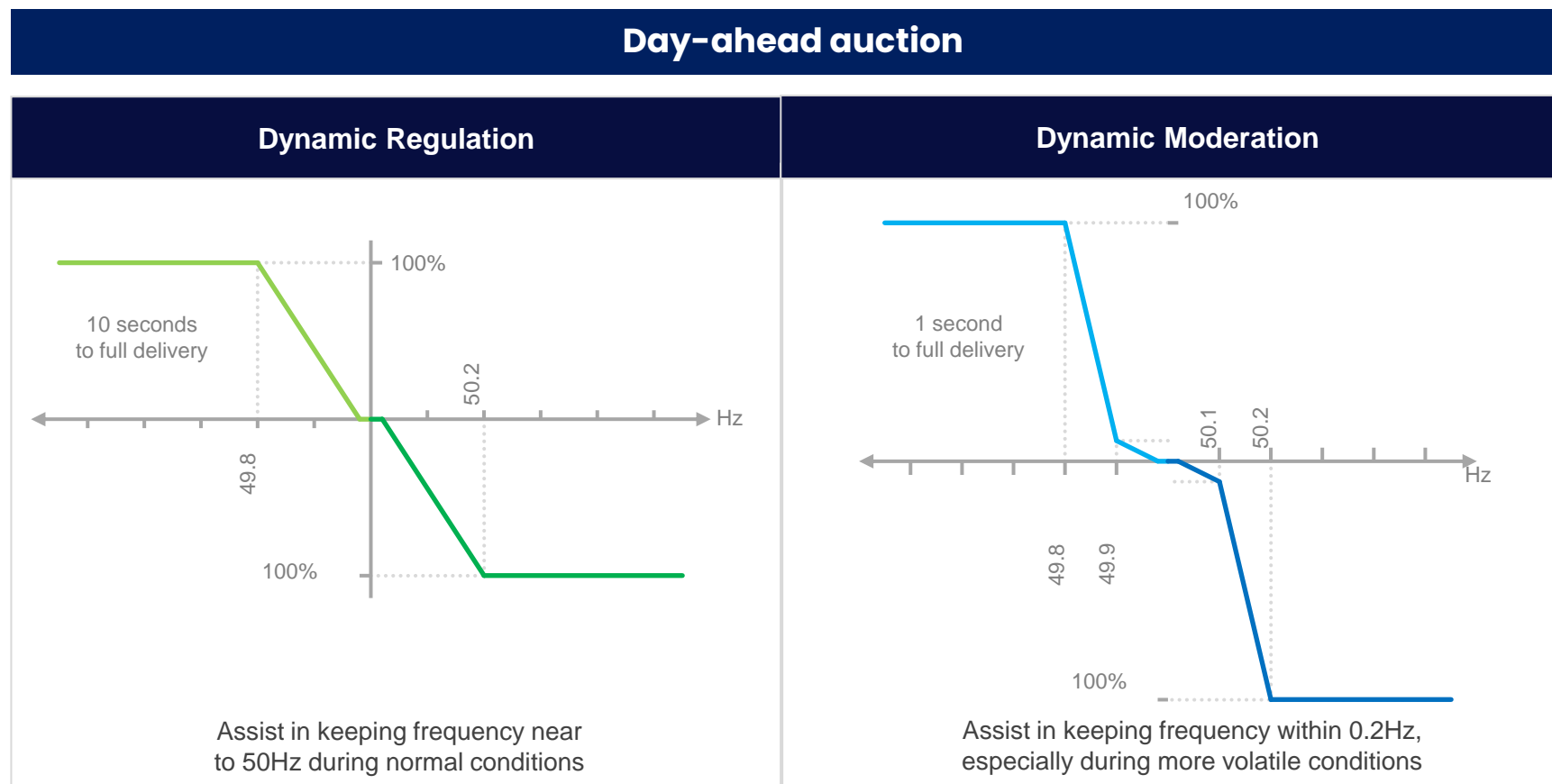
- Frequency Statutory limit in **SQSS**: 49.5 – 50.5 Hz.
- NESO introduces an operational standard: 49.8 – 50.2 Hz.

**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 31<sup>st</sup> 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.

# Introduction to Pre-fault Frequency Control

Slido code #FRM



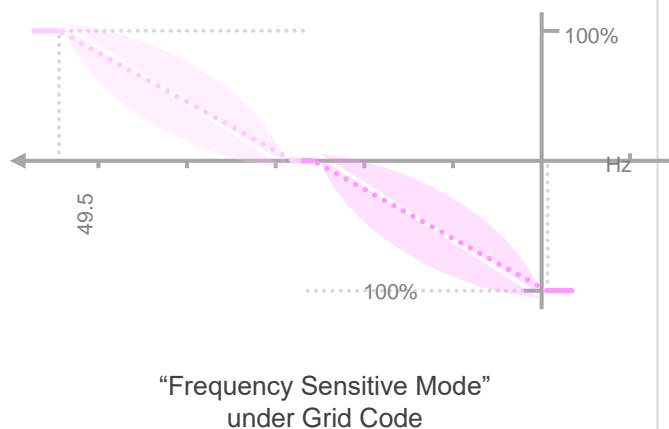
Dynamic Regulation (DR) & Dynamic Moderation (DM) are cost-effective hence the primary products for pre-fault control.

# Introduction to Pre-fault Frequency Control

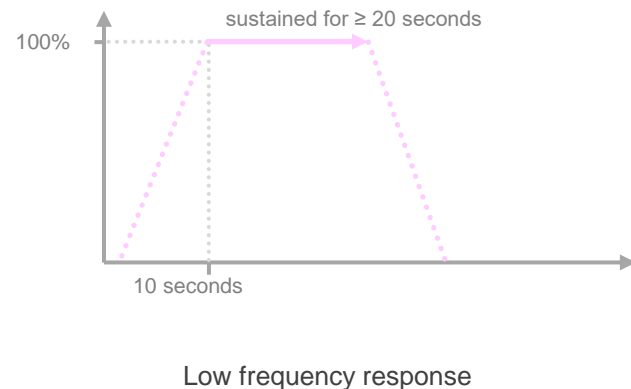
Slido code #FRM

Real-time instruction

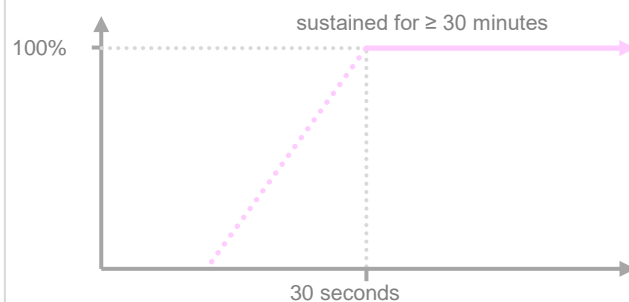
## Mandatory Frequency Response



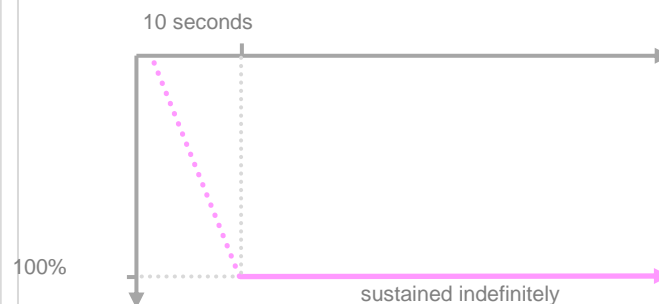
## Primary



## Secondary



## High

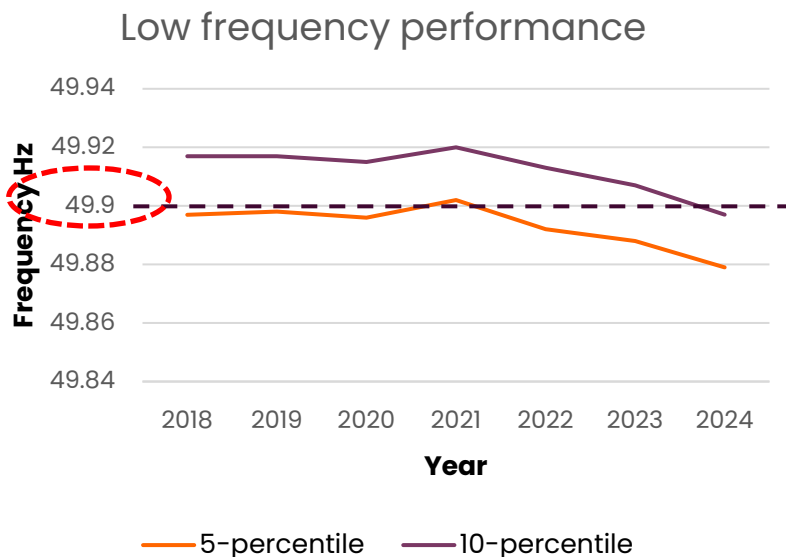


- Mandatory Frequency Response (MFR) is an automatic change in active power output in response to a frequency change.
- MFR requires reform to be compliant with energy regulations and better meet the needs of future system and optimise as part of wider suite of services. Find out recent webinar record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

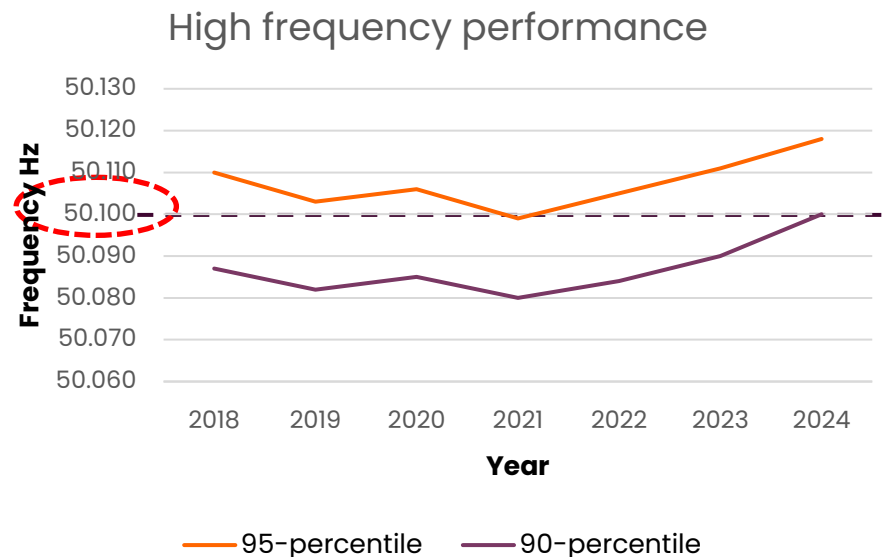
# Pre-fault Frequency Control Modelling

Slido code #FRM

## 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 trend in frequency performance over the past 7 years has been observed.
- 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  $\pm 0.15$  Hz.

2018–2023 data are from [ENTSO-e Load Frequency Control Annual Report](#);  
2024 data is published on NESO webpage - [NESO frequency data](#)



# Pre-fault Frequency Control Modelling

Slido code #FRM

## 2. High-level modelling approach

**Step 1**

Statistic view of frequency performance

**Step 2**

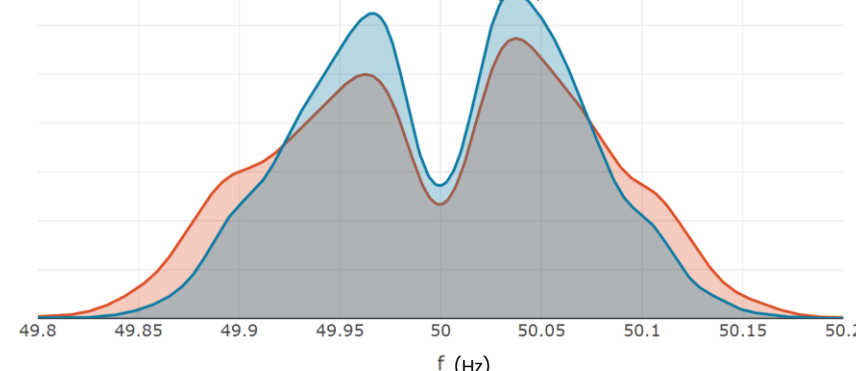
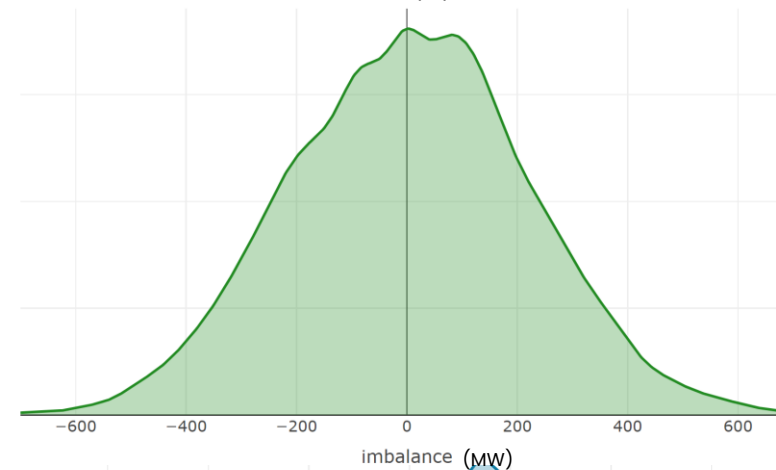
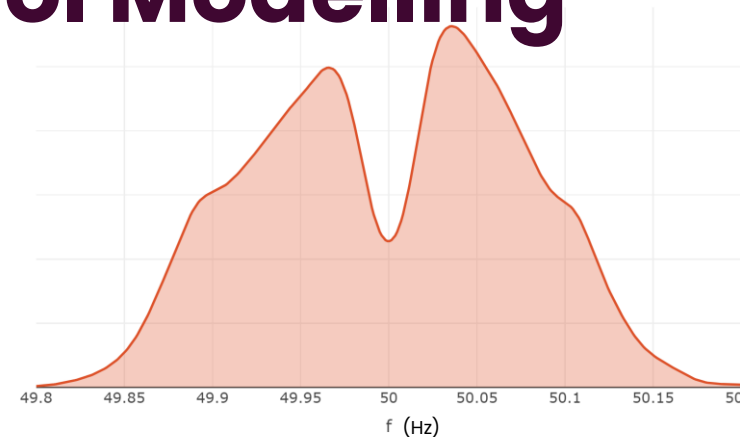
Reverse frequency deviation to system imbalance

**Step 3**

Calculate additional DR volume

**Step 4**

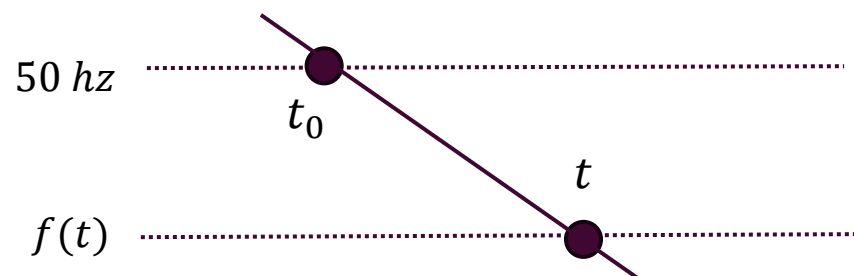
Test effectiveness of new DR volume



# Pre-fault Frequency Control Modelling

Slido code #FRM

## 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.

$$\text{At } 50 \text{ Hz, } G_{50} = D_{50}$$

$$\text{At } t, G_t = D_t$$

Re-write



$$G_{50} + LF_{response} + Imb_G = D_{50} - \Delta D + Imb_D$$

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

$$\begin{aligned} Imb_{stable} &= -G_{50} - LF_{response} + D_{50} - \Delta D \\ &= -LF_{response} + \Delta D \end{aligned}$$

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

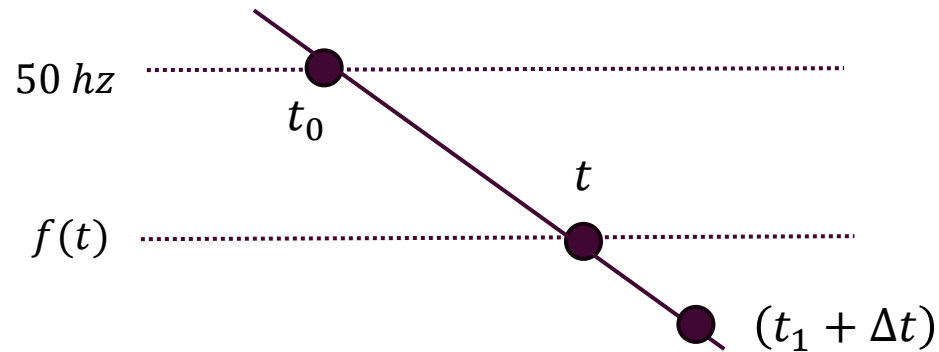
- $Imb_G$  and  $Imb_D$  refer to the total changes in generation and demand respectively
- $\Delta D$  is the demand response which can be calculated as:

$$\Delta D = 2.5\% * (f(t) - 50) * D_t$$

# Pre-fault Frequency Control Modelling

Slido code #FRM

## 3. Reversed system imbalance calculation



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

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

Based on the Swing Equation:

$$\frac{df}{dt} = Imbalance \times \frac{f_n}{2 \times inertia}$$

For RoCoF imbalance at  $t$ ,  $\frac{df}{dt} = \frac{f(t_1 + \Delta t) - f(t_1)}{(t_1 + \Delta t) - t_1} = \frac{Imb_{RoCoF}}{2 \times Inertia} \times f_{nominal}$

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

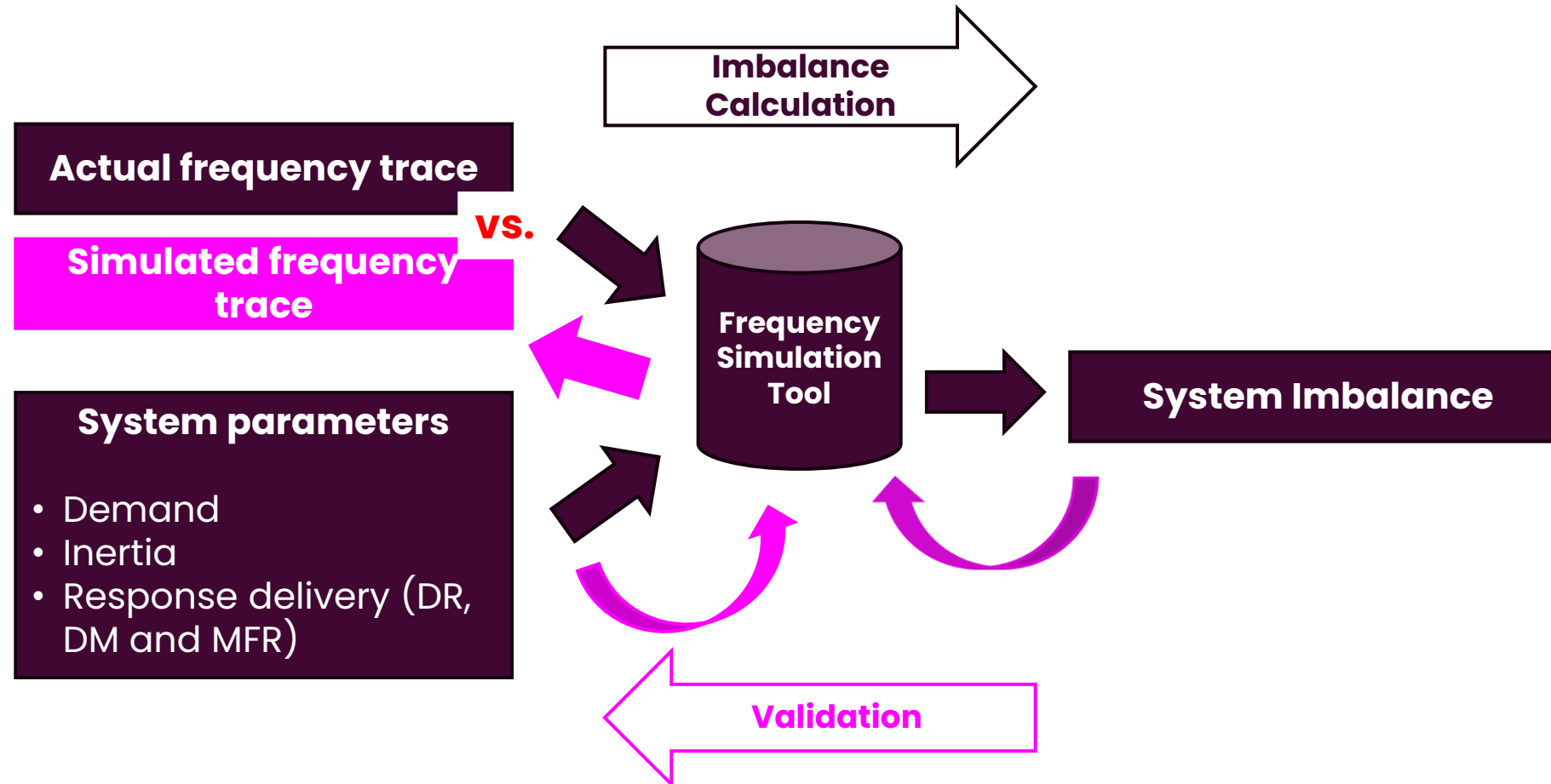
Where,  $f_{nominal} = 50 \text{ Hz}$ .

# Pre-fault Frequency Control Modelling

Slido code #FRM

## 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.



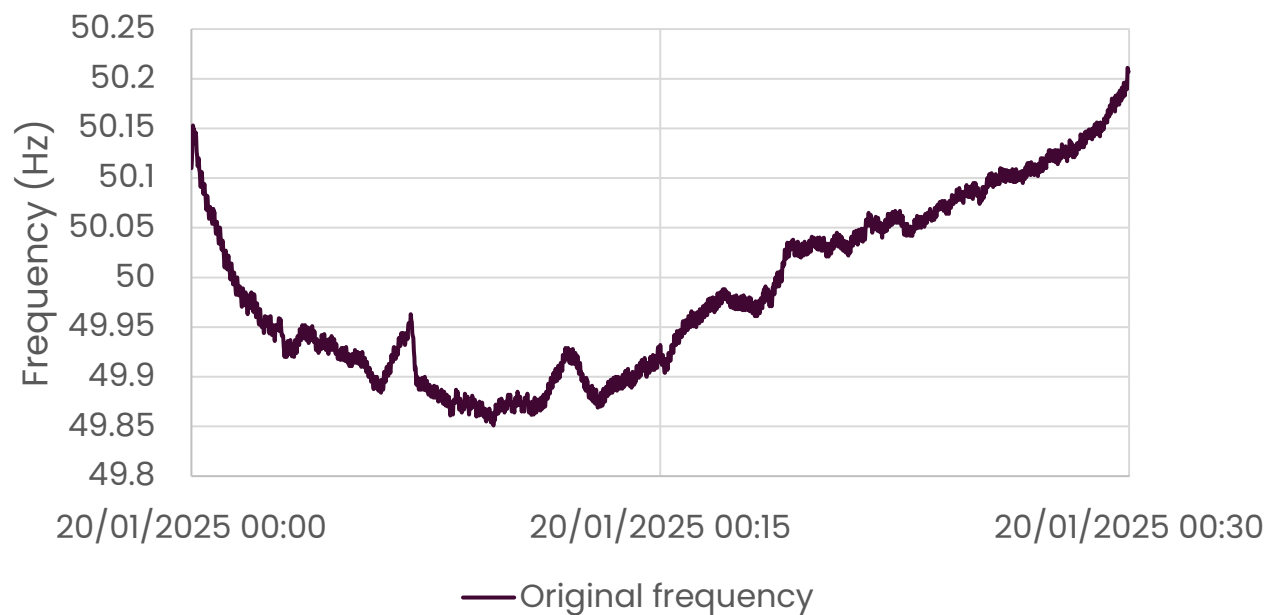


# Pre-fault Frequency Control Modelling

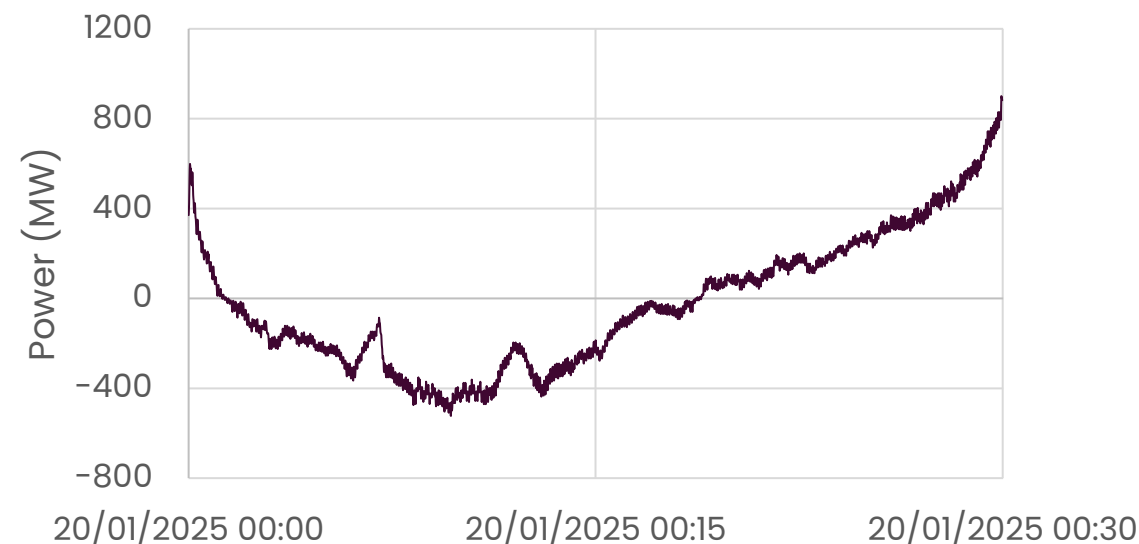
Slido code #FRM

## 3. Reversed system imbalance calculation

Original vs Simulated Frequency Over Time



System imbalance



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

# Pre-fault Frequency Control Modelling

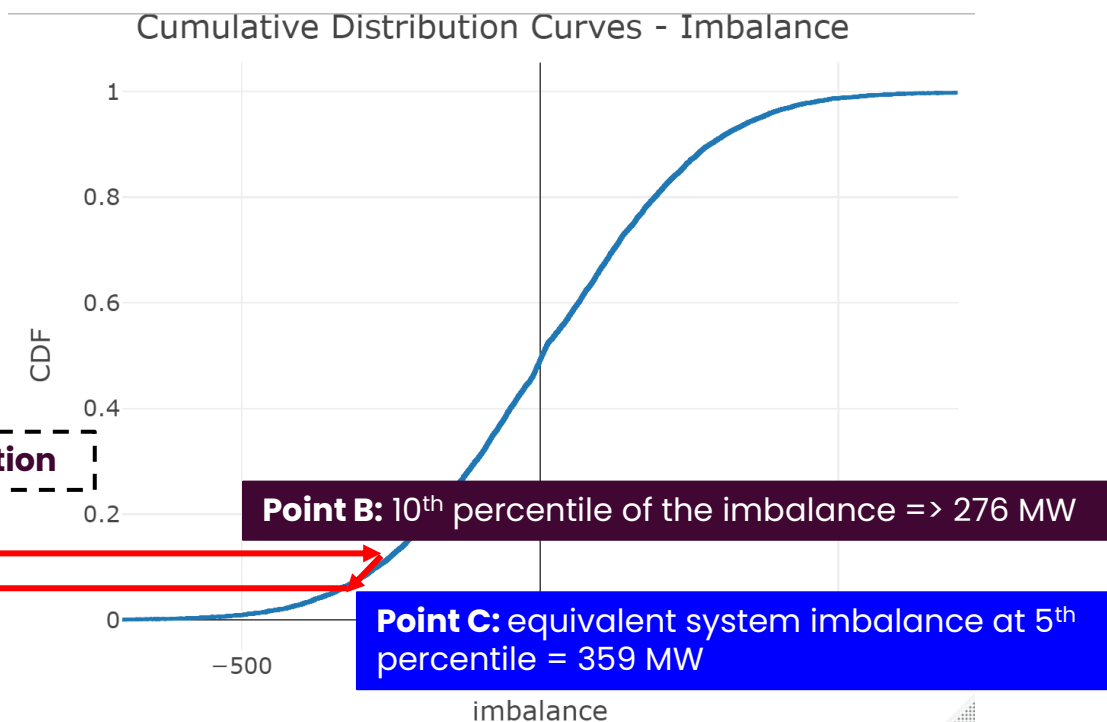
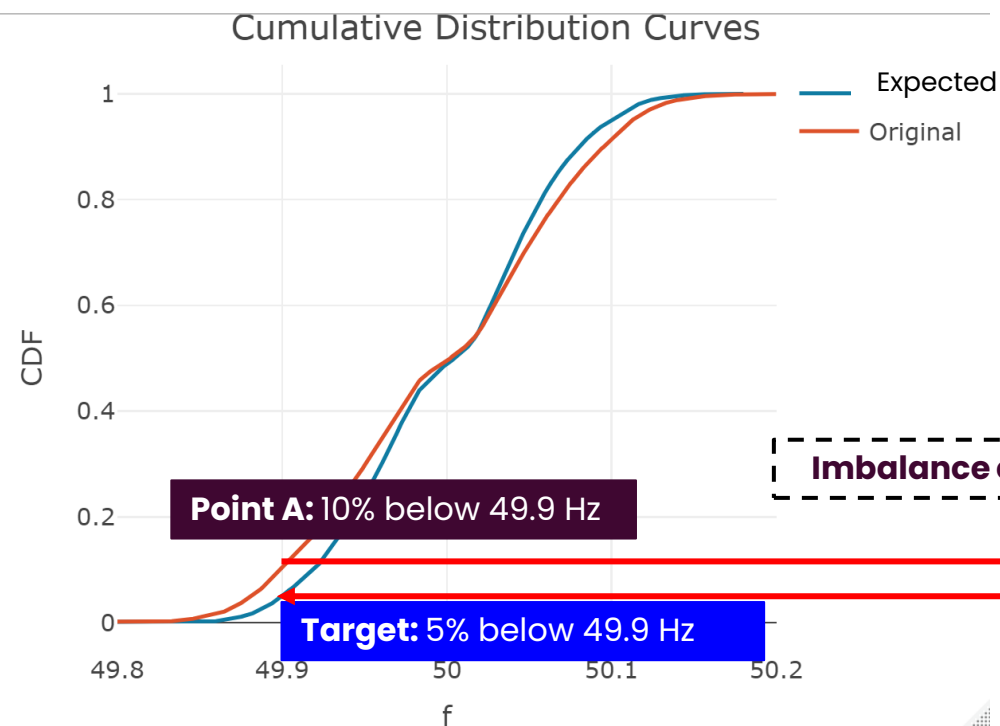
Slido code #FRM

## 4. Quantify DR requirement

For example – July 2024

### Frequency distribution

### Imbalance distribution



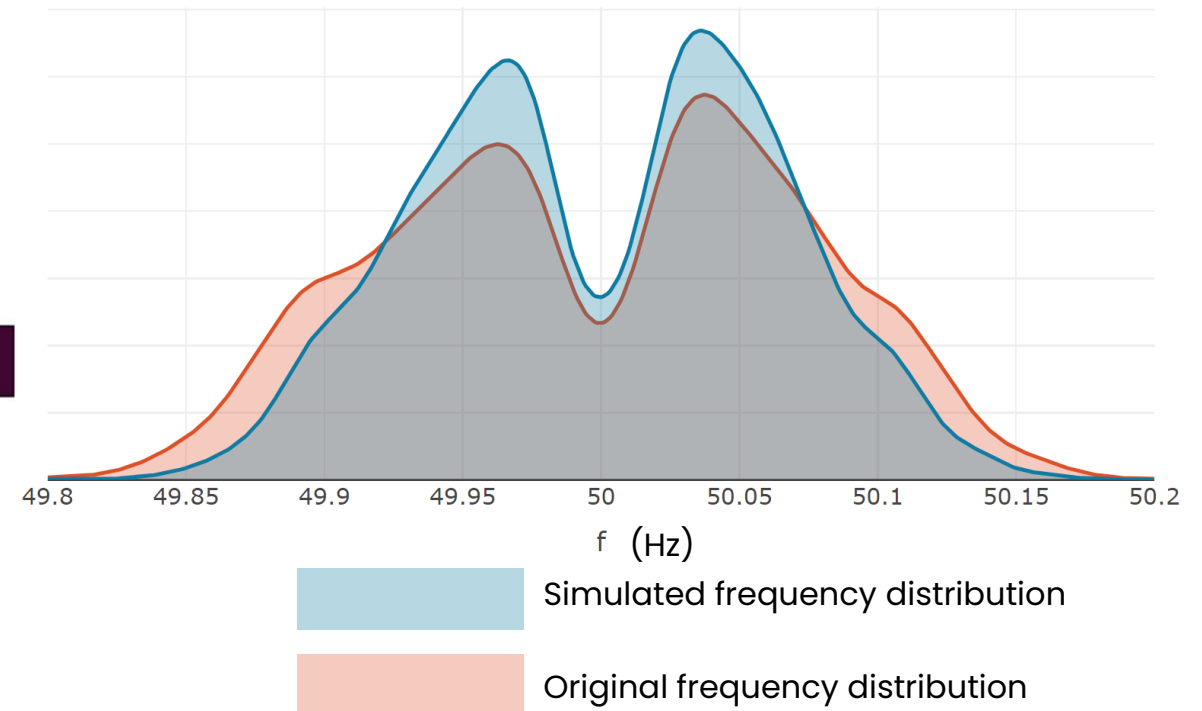
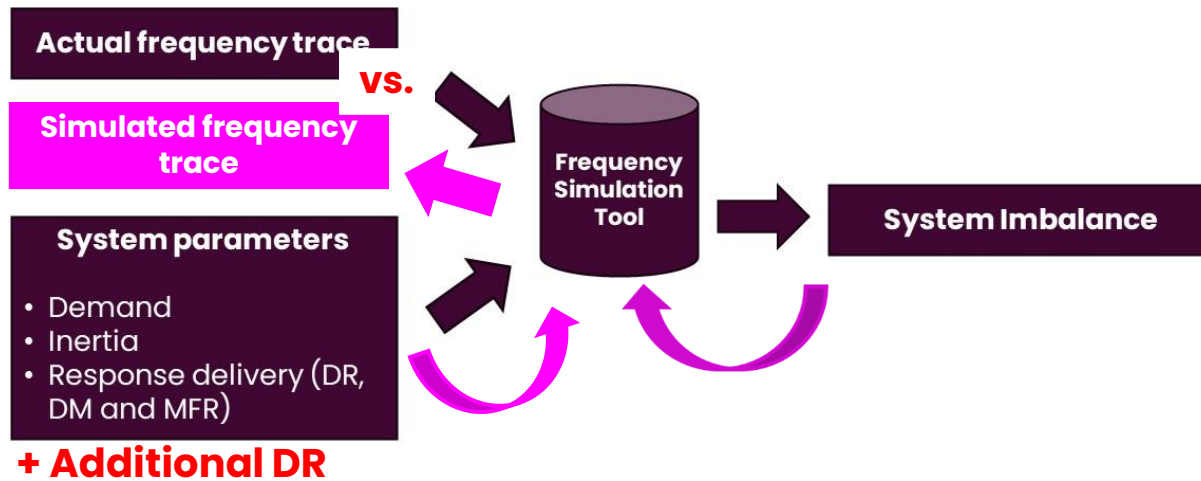
- Additional imbalance between B and C is  $359 - 276 = 83$  MW.
- DR-L delivers 0-100% response between 50 and 49.8 Hz, e.g. at 49.9 Hz, DR-L delivery = 50% x capacity.
- To contain additional imbalance of 83 MW, **additional DR-L volume =  $83 / 50\% = 166$  MW.**

# Pre-fault Frequency Control Modelling

Slido code #FRM

## 5. Test updated DR volume

- Additional DR-H is quantified based on the same approach. Additional DR-H = 140 MW
- Effectiveness of additional 166 MW DR-L and 140 MW DR-H is tested in the frequency simulation tool based on July 2024 data.



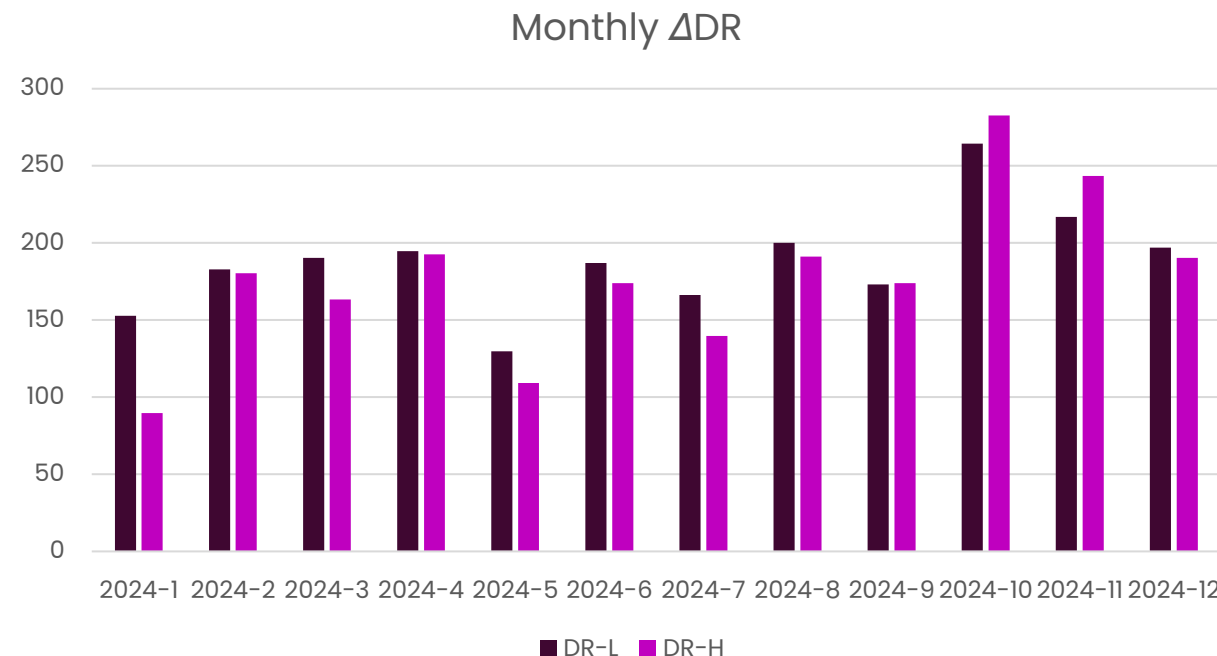
# Pre-fault Frequency Control Modelling

Slido code #FRM

## 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 ( $\Delta\text{DR-L}$  and  $\Delta\text{DR-H}$  volumes) based on monthly average are:

$\Delta\text{DR-L}$	$\Delta\text{DR-H}$
183	172





# Other Consideration: DR Cap

Slido code #FRM

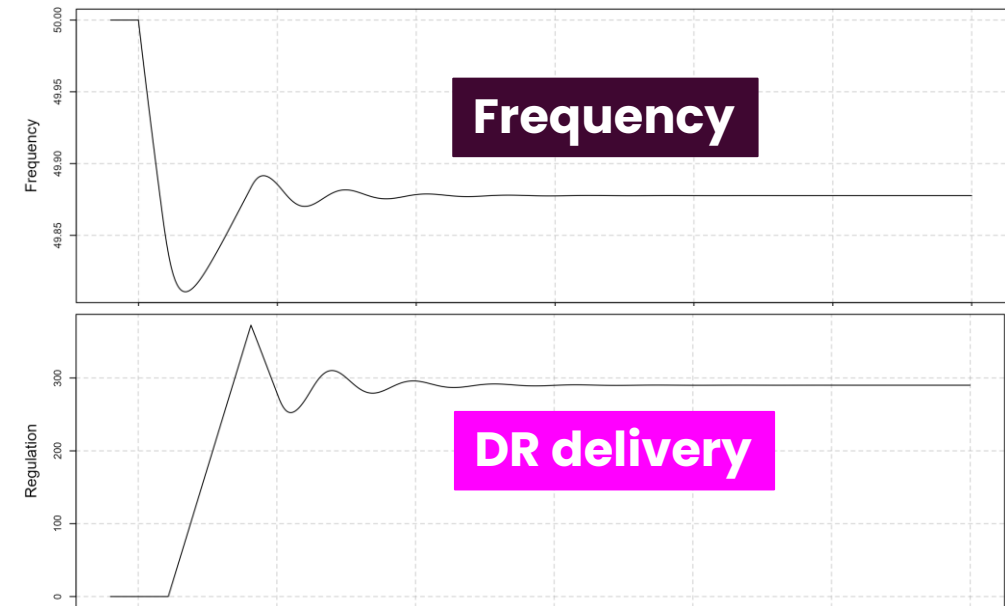
- Some response services may lead to frequency oscillatory scenarios.
- The oscillation could be caused by a slow response service, e.g. DR, that measures frequency and delivers response after the fast services deliver, which could overcorrect the frequency and cause oscillations.
- NESO conducted analysis 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.

# Other Consideration: DR Cap

Slido code #FRM

- 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



# Recommendations

Slido code #FRM

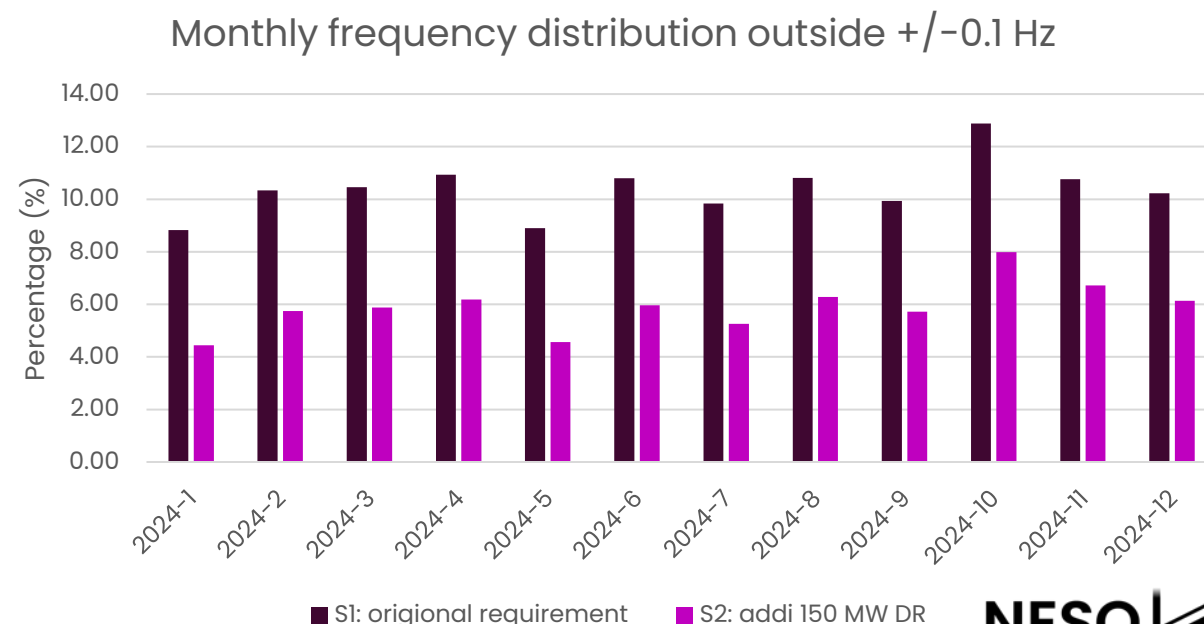
- Considering proposed additional DR and DR cap, the recommended new DR-L and DR-H volumes are:

	DR-L	DR-H
<b>Previous DR</b>	330	330
<b>Proposed <math>\Delta</math>DR</b>	183	172
<b>After DR cap</b>	150	150
<b>New DR volume</b>	480	480

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

	DM-L	DM-H
<b>Previous DM</b>	170	200
<b>New DM volume</b>	300	300

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



# Future Steps

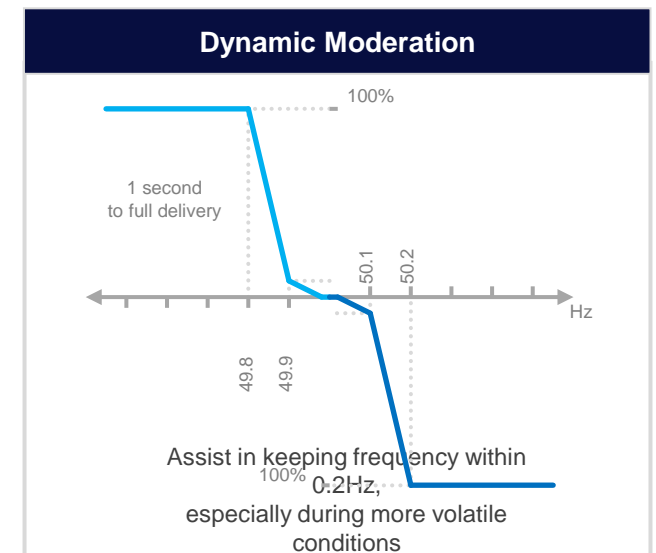
Slido code #FRM

- **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  $\pm 0.15$  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.





slido



Join at [slido.com](https://slido.com)  
**#FRM**

 Start presenting to display the joining instructions on this slide.

slido



## Audience Q&A

① Start presenting to display the audience questions on this slide.

# Thank you for attending

- Webinar slides are available on [NESO website](#). Recording will be published after the webinar. A full Q&A document will be published by Friday 28 March.
- Please contact [box.FRM@nationalenergyso.com](mailto:box.FRM@nationalenergyso.com) for feedbacks and other questions.