GLOBAL PST CONSORTIUM

Operation and planning frequency analysis during the arrest period

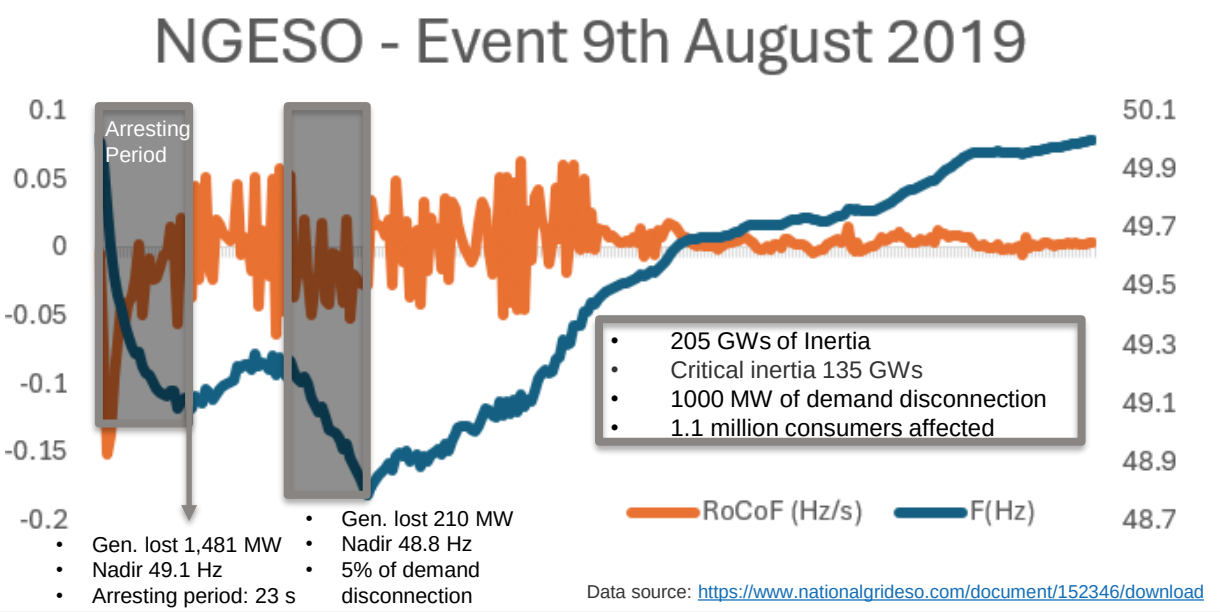
G-PST Future of Inertia Summit

Lina Ramirez -NREL

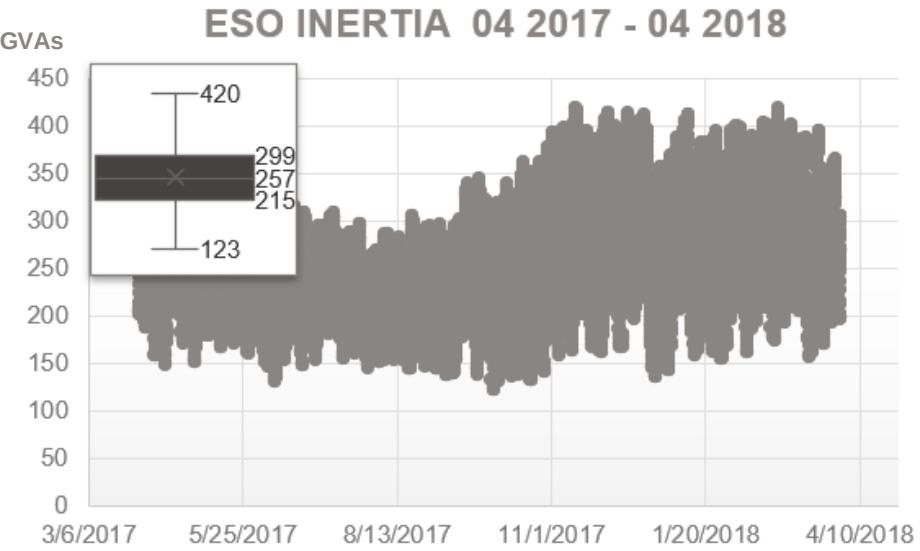
Motivation

Motivation

Does it make sense to talk about inertia in a high IBR integrated system or is it better to talk about the frequency response during arresting period?



- System Operators plan and operate the system to maintain Nadir/Zenit at a safe level during the largest contingency.
- In the past kinetic energy of synchronous generators “inertia’ provided the immediate response to oppose changes in frequency



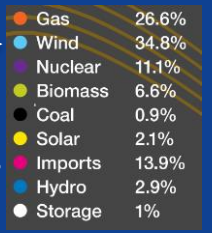
Data source: https://www.nationalgrideso.com/data-portal/system-inertia

Motivation

Is the critical inertia or inertia floor valid in the future?

In February 2024 in NGESO:

- Wind was the largest source of generation (34.8%)
- 51% of electricity from zero carbon sources
- 84% of demand met by zero-carbon sources on 4/02 12:30.
- Inertia floor: 2024 120 GVAs ➔ 2025 102 GVAs



Data source https://www.nationalgrideso.com/electricity-explained/electricity-and-me/great-britains-monthly-electricity-stats

Motivation

Is there a need for new studies and procedures for the reduction of inertia floors and the avoidance of renewable curtailment?

Minimum inertia level reducing from 23 GWs to 17.5 GWs on the island of Ireland for 2030.

“Reducing the minimum inertia requirement should result in a reduction of the minimum number of conventional thermal units on the system which should allow more renewable energy to be used on the system as the energy from these units may be replaced by curtailed energy from renewables.”

Studies are carried out to analyze and understand implications on reducing the inertia floor requirement to 20 GWs. These studies will examine a range of operational scenarios, conditions and contingencies to determine secure operating modes.

Source: ERIGRID https://www.eirgrid.ie/site-files/library/EirGrid/Operational-Policy-Roadmap-2022-to-2023.pdf

Motivation

Is there a need for new studies and procedures for the reduction of inertia floors and the avoidance of renewable curtailment?

"In the high renewable off-peak sensitivity analysis, ERCOT started the case with 55 GW of renewable output. In order to respect various stability limits and the **critical inertia level**, the renewable output was reduced to approximately **50 GW**, which corresponds to an **84%** renewable penetration level."

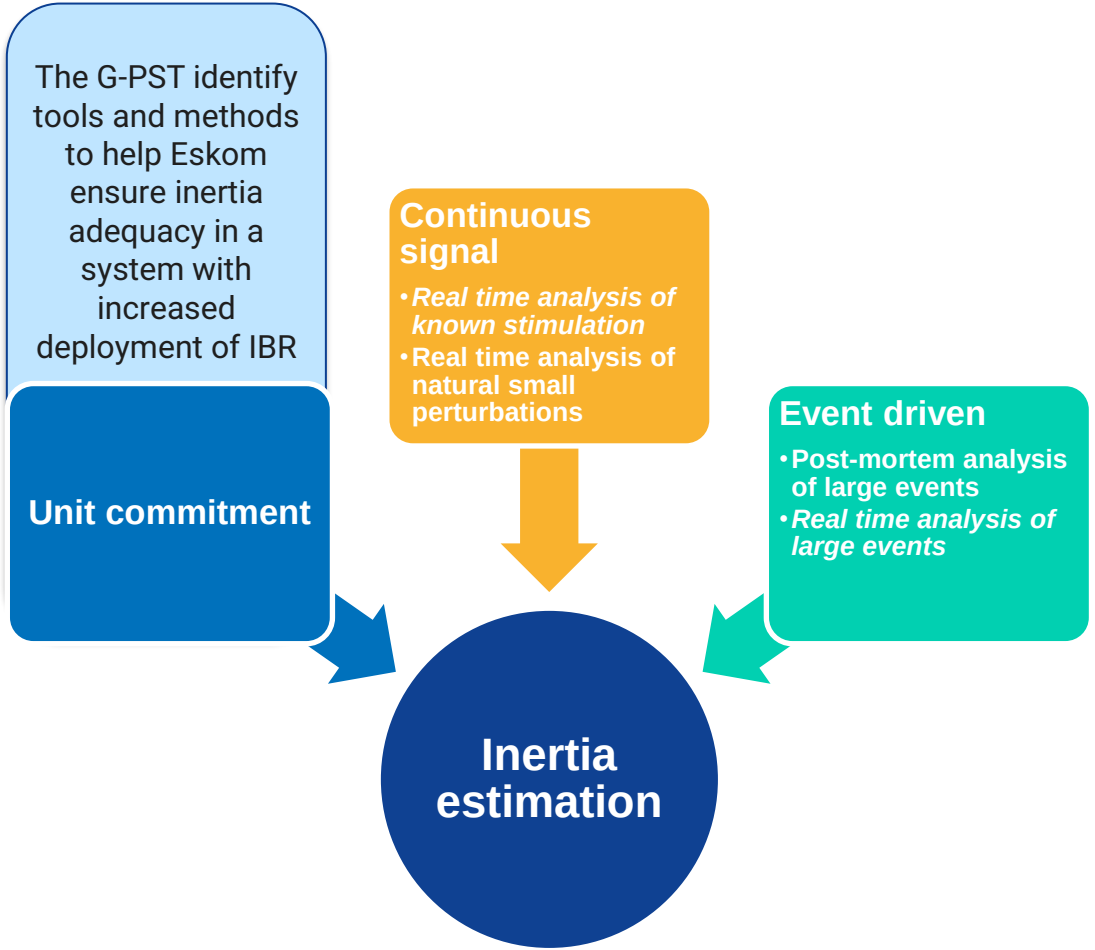
Source: ERCOT System transmission needs for years 2025 through 2029
https://www.ercot.com/files/docs/2023/12/22/2023_Regional_Transmission_Plan_Report_Public.zip

"Operational considerations, such as ramping limitations and maintaining a minimum level of system inertia, would need to be assessed further to ensure reliability under high renewable penetration conditions."

Source: ERCOT 2022 Long-Term System Assessment 10- to 15-year planning horizon
https://www.ercot.com/files/docs/2022/12/22/2022_LTSA_Report.zip

Motivation

- What is the best method for estimating inertia online?
- Is there a need for RoCoF, nadir, near-instantaneous Frequency monitoring?

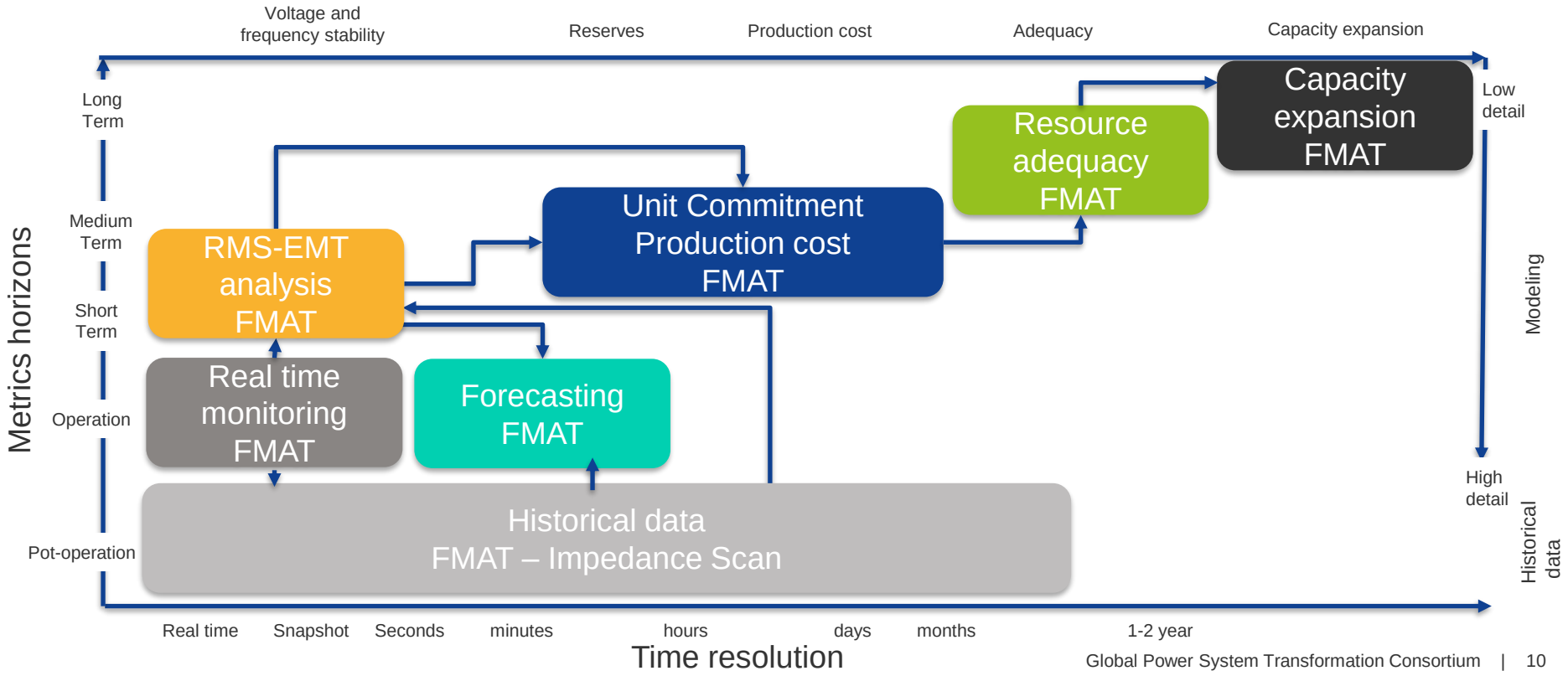


Frequency response evolution during the arresting period

	Power system		Frequency response during the arresting period	
Past		Synchronous Generation (SG)		Inertia
Now		SG + Synchronous Condensers (SC) - Inverter base resources (IBR)		Critical Inertia + Fast Frequency Response (FFR)
Future		100% Renewables: IBR (GFL-GFM) + SC + Clean SG		Near-instantaneous Frequency Response + some inertia

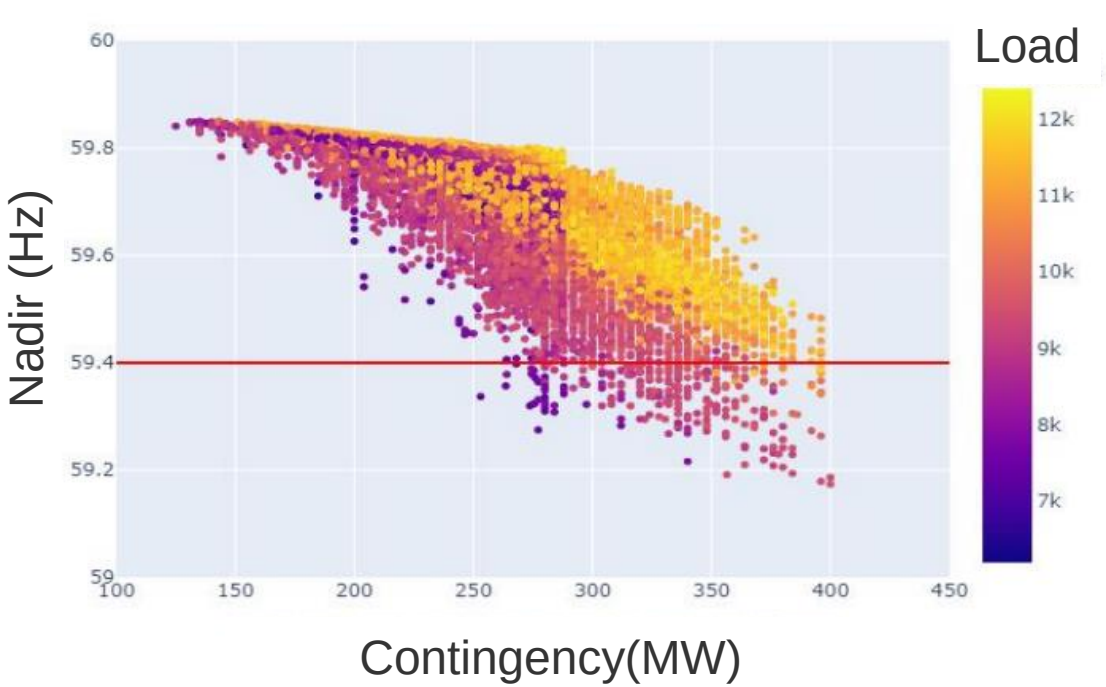
Frequency response evolution during the arresting period

Operating and Planning frequency metrics during arresting time (FMAT)



Planning frequency metrics during arresting time (FMAT)

Nadir/Zenit

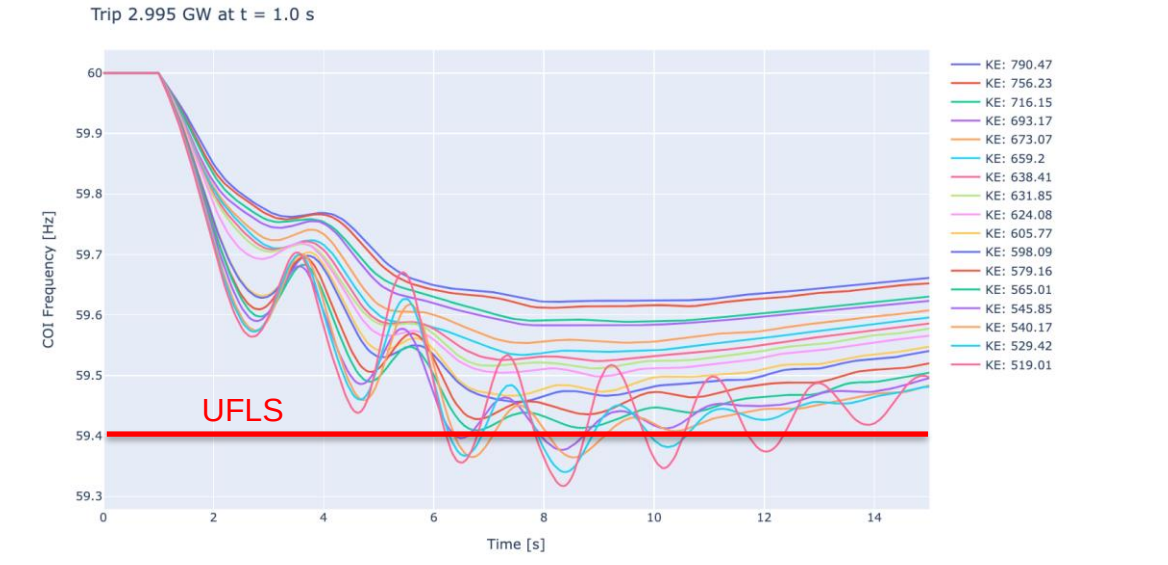


Source: XM https://www.xm.com.co/operaci%C3%B3n/planeaci%C3%B3n/planeaci%C3%B3n-estudios-de-flexibilidad-del-sin/resultados-de-estudios-de-flexibilidad-del-sin

- The nadir is the key metric during the frequency arresting period to prevent load disconnection under the maximum contingency.

Planning frequency metrics during arresting time (FMAT)

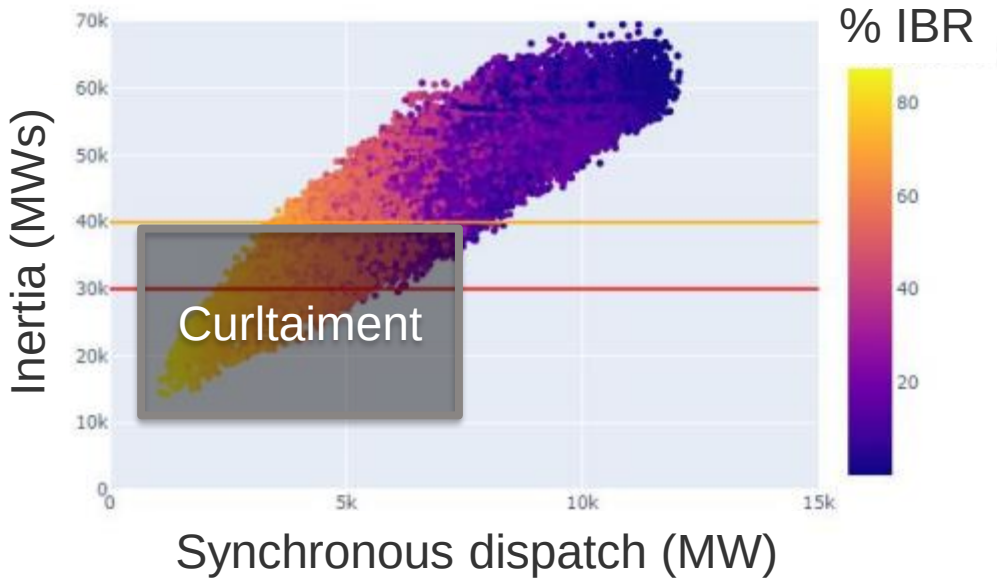
Inertia floor



- The inertia that causes the frequency to fall below the UFLS before the resources can provide sufficient frequency response for maximum generation loss.
- This is currently a periodic study, should it be dynamic? The maximum generation loss could change as well as the frequency response speed of the dispatched resources, requiring a lower inertia floor.

Planning frequency metrics during arresting time (FMAT)

Inertia floor

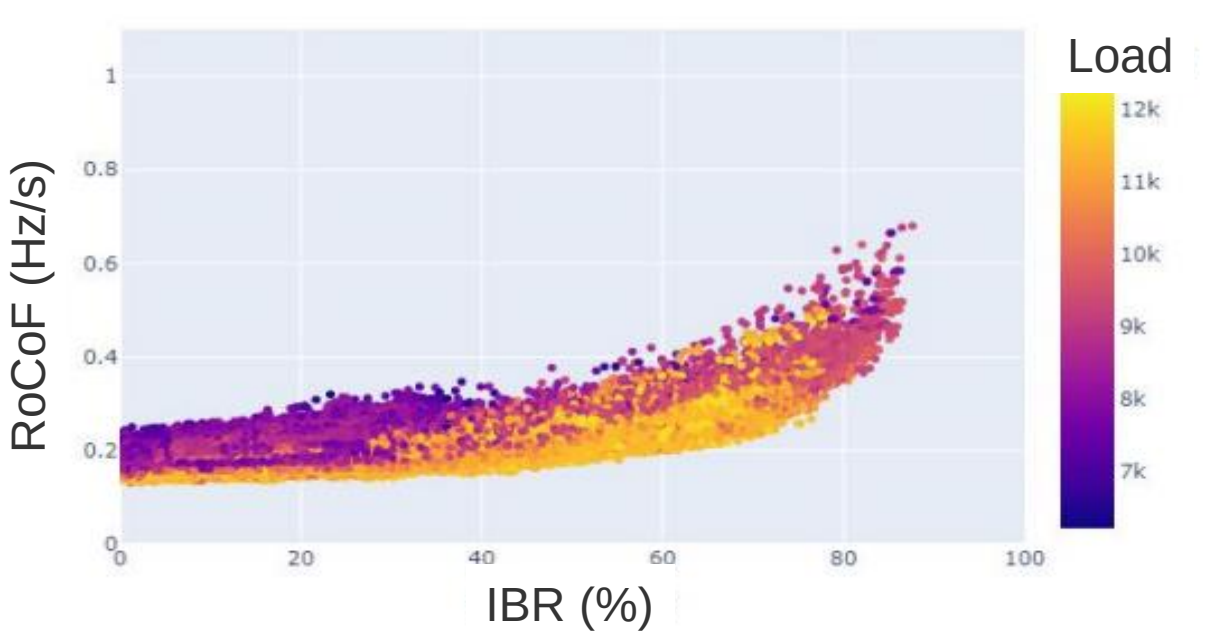


Source: XM https://www.xm.com.co/operaci%C3%B3n/planeaci%C3%B3n/planeaci%C3%B3n-estudios-de-flexibilidad-del-sin/resultados-de-estudios-de-flexibilidad-del-sin

The reduction in the inertia floor requirement should result in a reduction in the number of synchronous thermal units on the system, which should allow more renewable energy to be used on the system.

Planning frequency metrics during arresting time (FMAT)

RoCoF

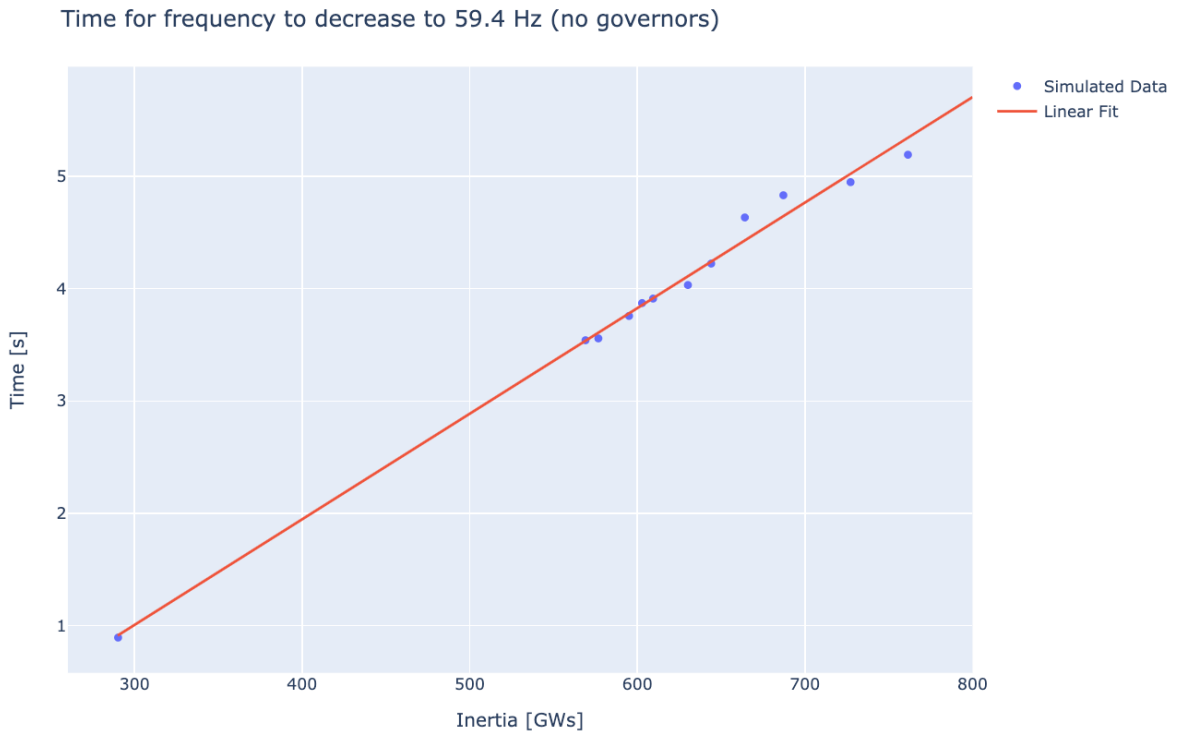


Source: XM https://www.xm.com.co/operaci%C3%B3n/planeaci%C3%B3n/planeaci%C3%B3n-estudios-de-flexibilidad-del-sin/resultados-de-estudios-de-flexibilidad-del-sin

Define critical RoCoF according to the protection setting and dynamic studies to verify it in future scenarios and in real time and ensure resources that guarantee acceptable RoCoF.

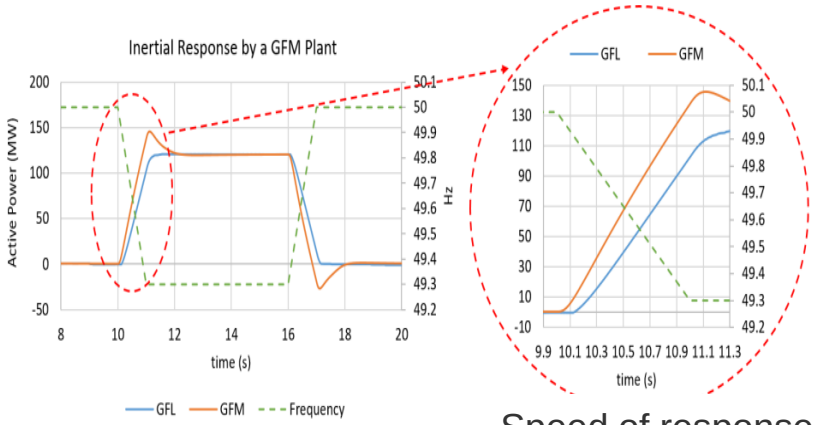
Planning frequency metrics during arresting time (FMAT)

Time to reach nadir



The time it takes to reach the nadir can be used to define and monitor new frequency response resources that can be activated before the frequency reaches the nadir.

Planning frequency metrics during arresting time (FMAT)
Near-instantaneous Frequency Response

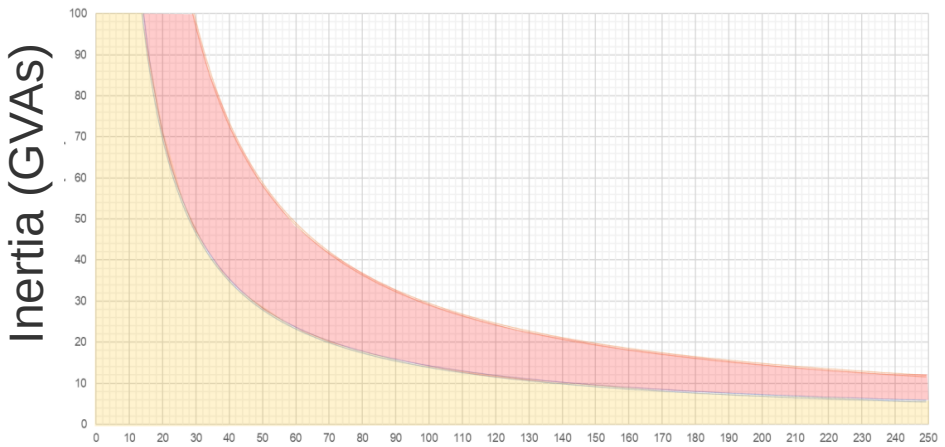


Speed of response

Source: AEMO https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2023/gfm-voluntary-spec.pdf

New frequency requirement of market service clearly defined

- Magnitude of response
- Speed of response
- Delay of response
- Dead band



Frequency speed response (MW/s)

Source: XM https://www.xm.com.co/operaci%C3%B3n/planeaci%C3%B3n/planeaci%C3%B3n-estudios-de-flexibilidad-del-sin/resultados-de-estudios-de-flexibilidad-del-sin

Online Inertia Estimation Methods

Continuous signal

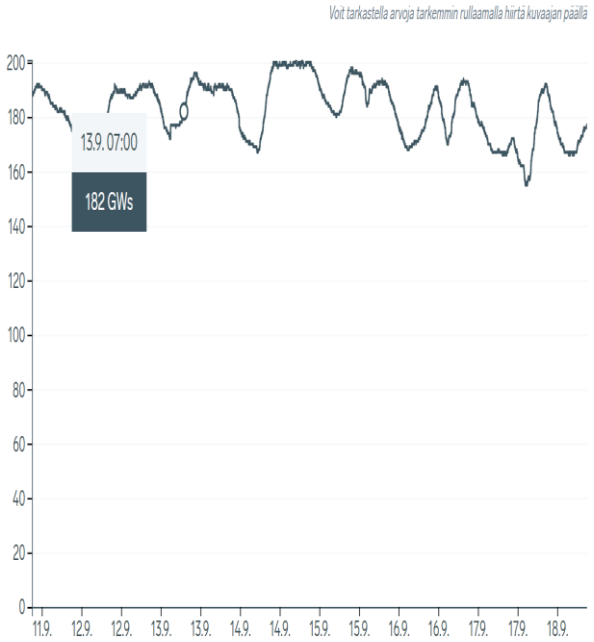
- *Real time analysis of known stimulation*
- Real time analysis of natural small perturbations

Unit commitment

Event driven

- Post-mortem analysis of large events
- *Real time analysis of large events*

Inertia estimation (Area and regional)



Source: Fingrid https://www.fingrid.fi/en/electricity-market-information/InertiaofNordicpowersystem/

Method	Input data	Pros	Cons	SO
Continuous signal: Real time Estimation of known stimulation	• Known stimulation • Frequency measurement	• Demand side inertia can be included • **FFR from IBRs can be included** • Real-time continuous inertia monitoring	• May introduce unwanted disturbances to system operation • Need additional hardware deployment	NGESO, AEMO (Trial), Terna (Pilot on Sardinia), TEPCO (Successful trial on Nii-jima)

Continuous signal

Real time analysis of known stimulation

Real-time inertia estimation based on frequency changes derived from a known stimulus

Source: GPST

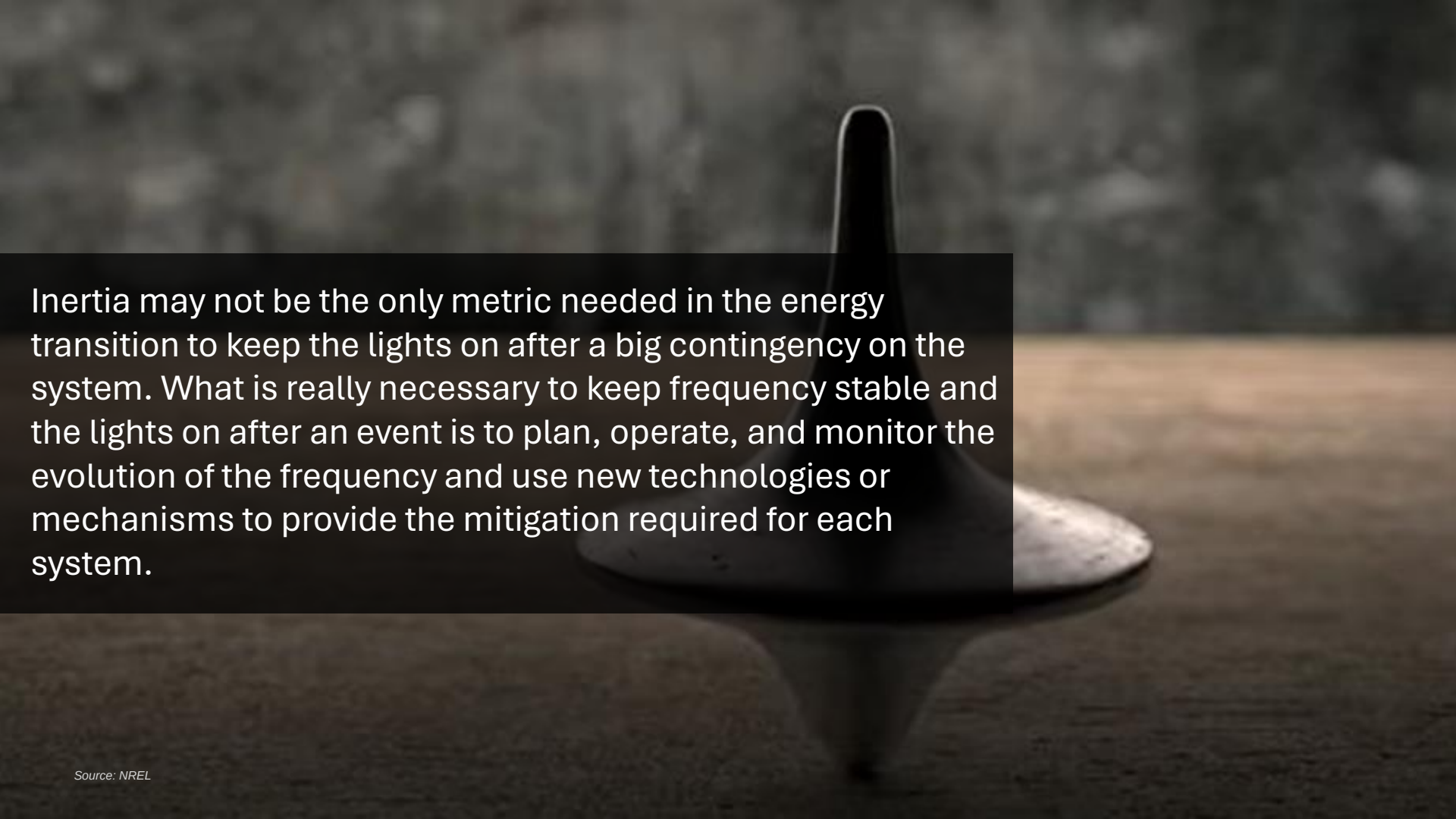
Method	Input data	Pros	Cons	SO
Continuous signal: Real time analysis of natural small perturbations	• Frequency measurement • Active power	• Demand side inertia can be included • **FFR from IBRs can be included** • Real-time continuous inertia monitoring	The relationship between power imbalance and frequency variation cannot be captured	NGESO TEPCO

Continuous signal

Real time analysis of natural small perturbations

Real time inertia estimation based on “ambient” frequency changes

Source: GPST



Inertia may not be the only metric needed in the energy transition to keep the lights on after a big contingency on the system. What is really necessary to keep frequency stable and the lights on after an event is to plan, operate, and monitor the evolution of the frequency and use new technologies or mechanisms to provide the mitigation required for each system.

Source: NREL

Thank you!

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