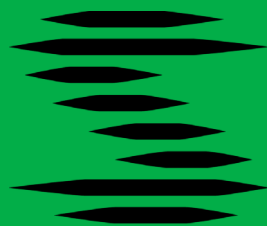




Use of Data Analytics for Secure Operation of the Nordic Power System

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Increased need for real-time data in the national control center

More distributed resources

Needs

- Improve the estimator, models and increase observability
 - Monitor bottlenecks
 - Border connections
 - Stability and security

Enabler

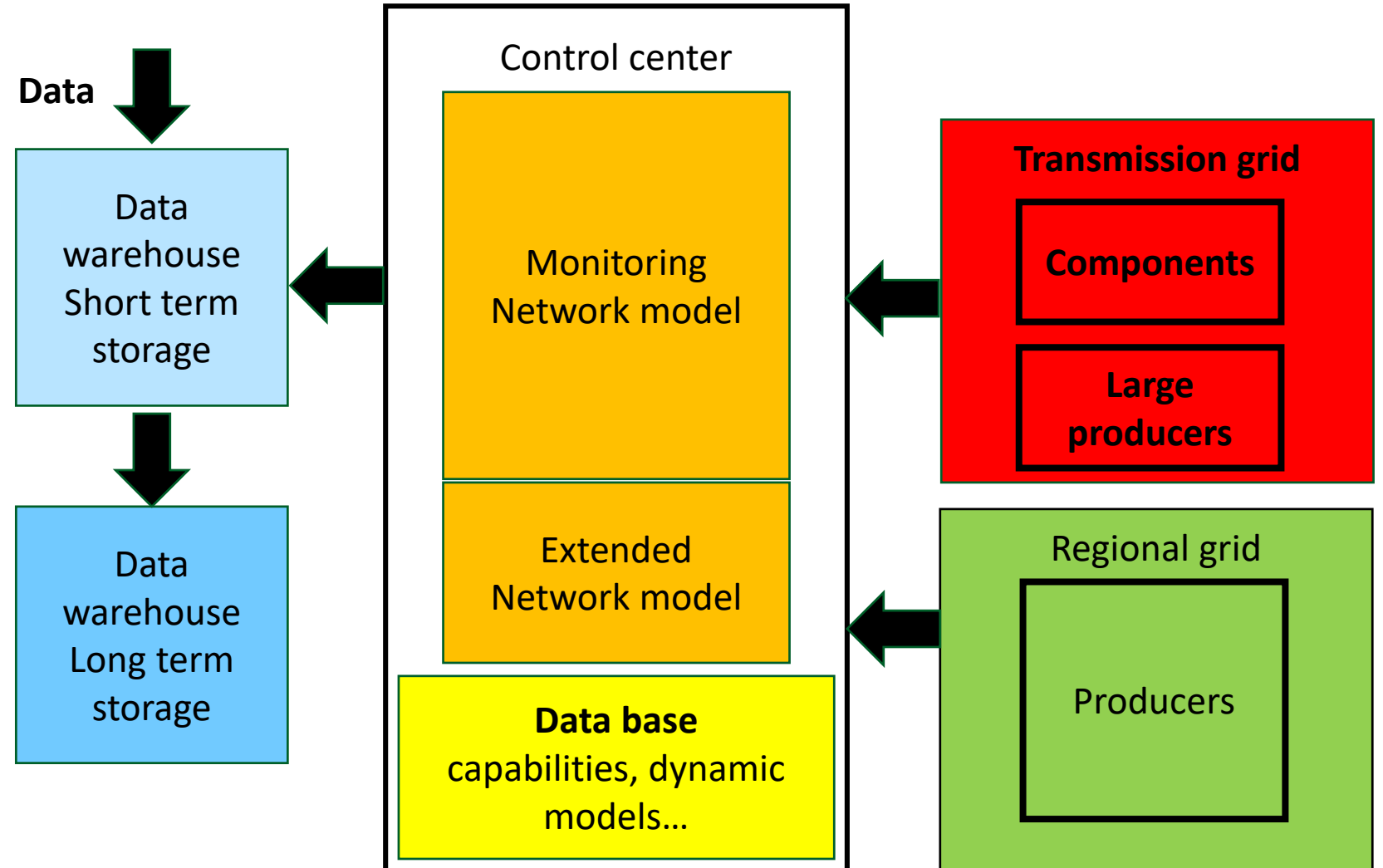
- Grid codes from EU (SO-GL, RfG, DCC)



Real-time data and models in the national control center

Monitor various phenomena by

- SCADA/RTU
- WAMS/PMU
- Power quality meters



Monitoring in the national control center

Data

Model based security assessment

Data driven security assessment

N-1
over
current/thermal
limit assessment

N-1
voltage stability
assessment

...

N-1
frequency
stability
assessment

Imbalance
forecast

...

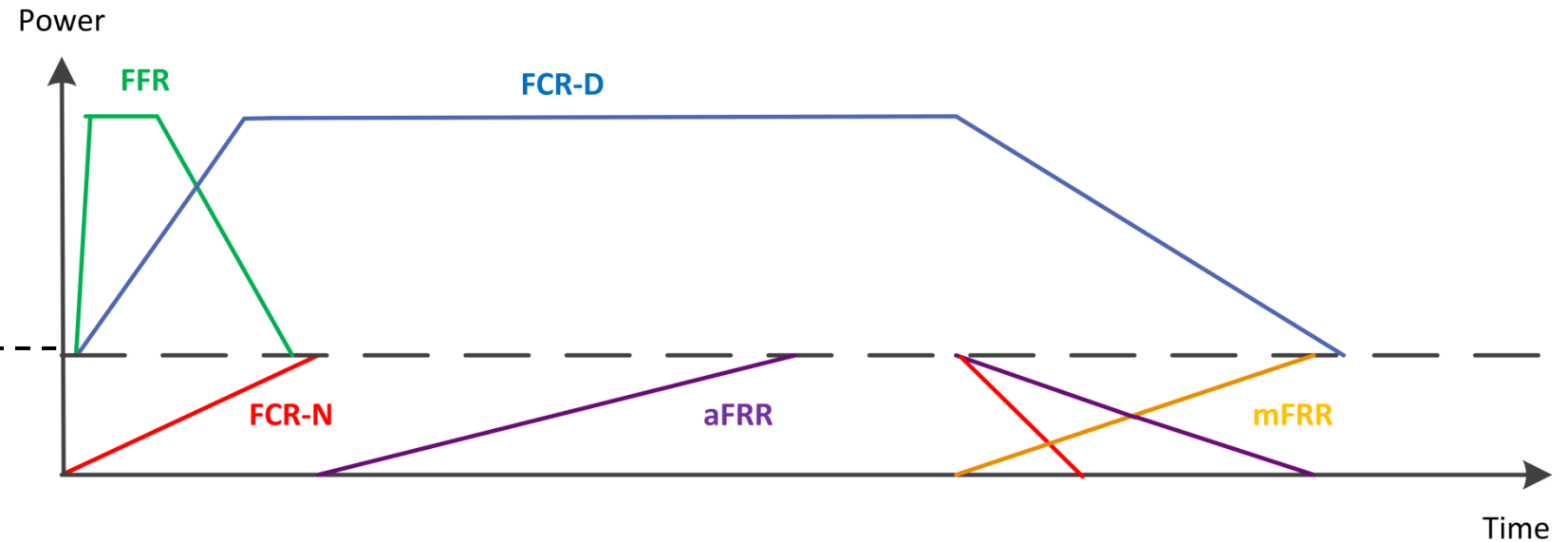
**Challenging to keep
models up to date!**

Balancing

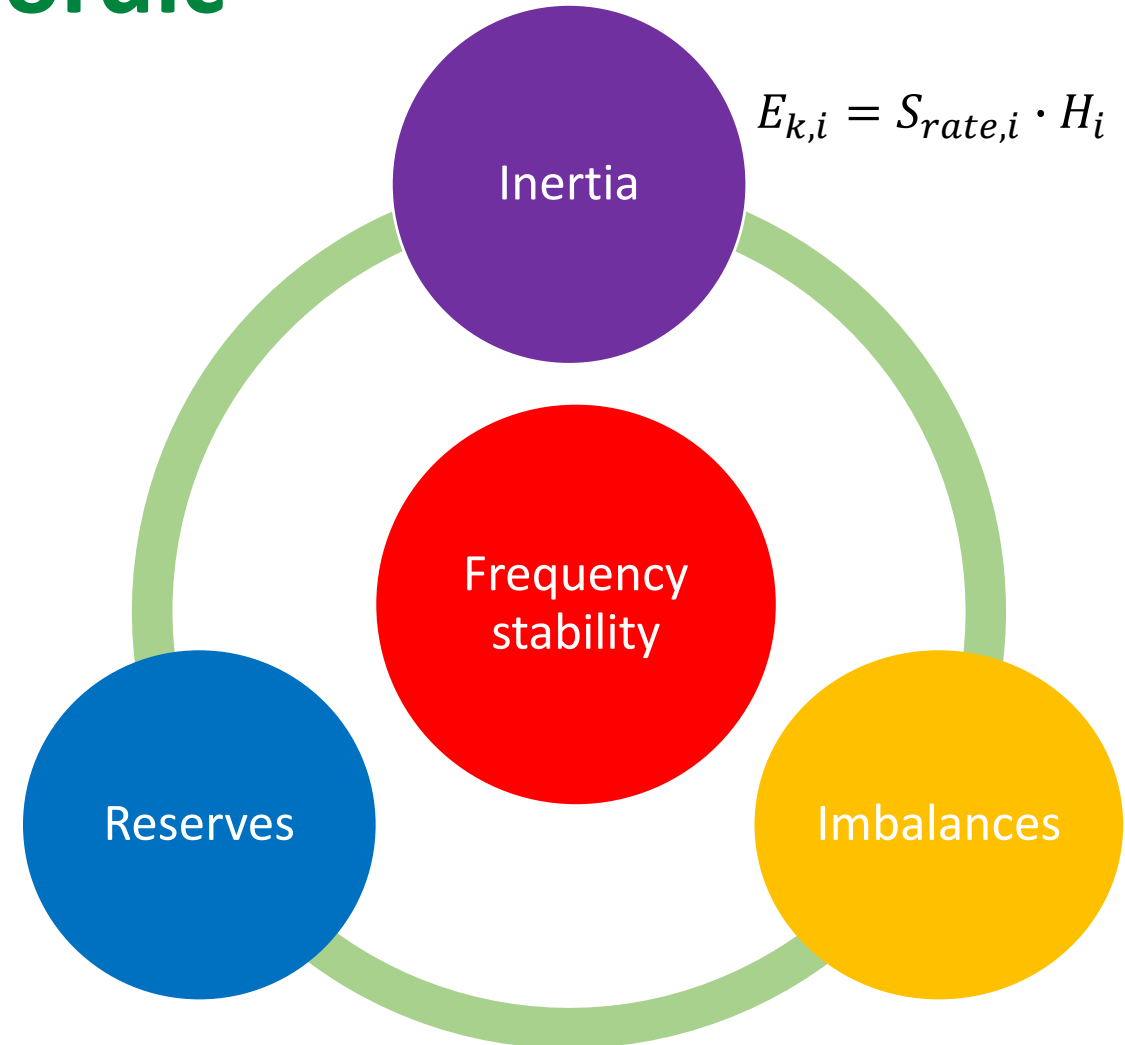
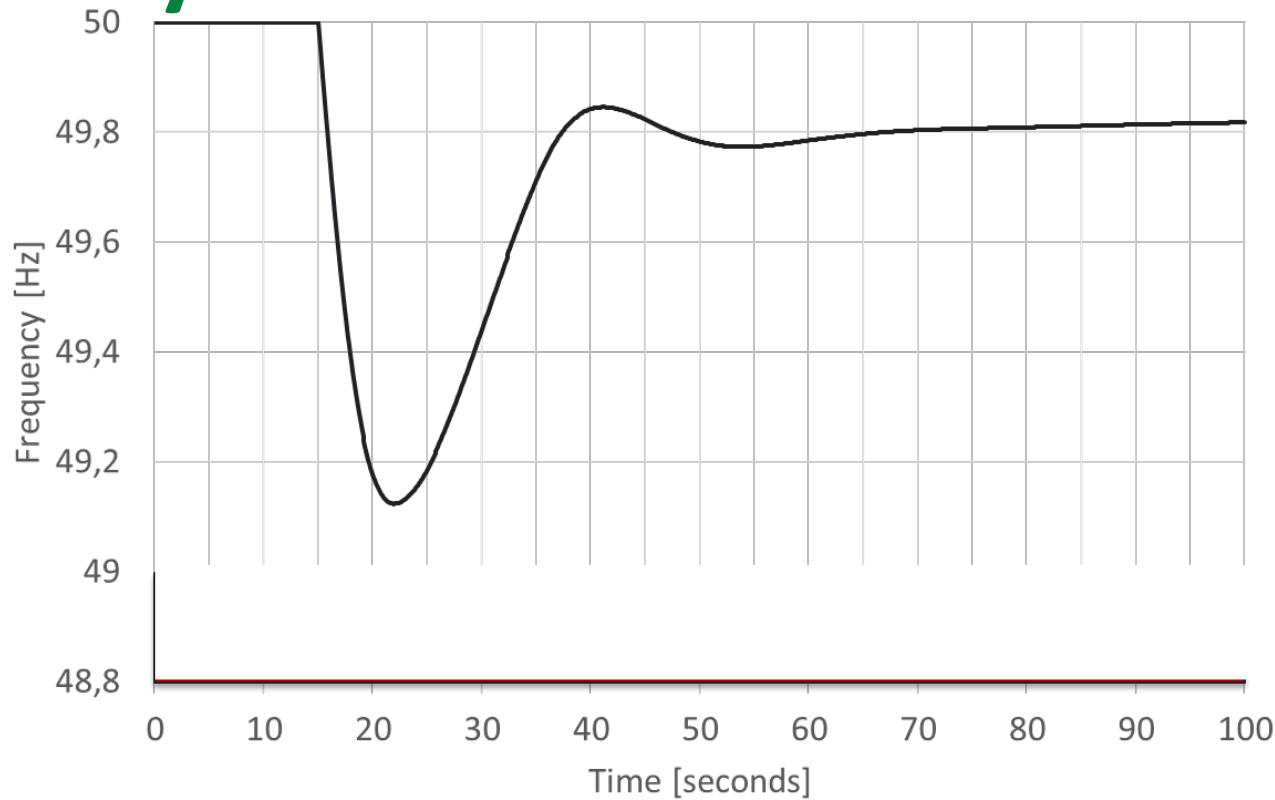
Balancing products in the Nordic power system

1. Transient frequency stability

2. Within the hour balancing

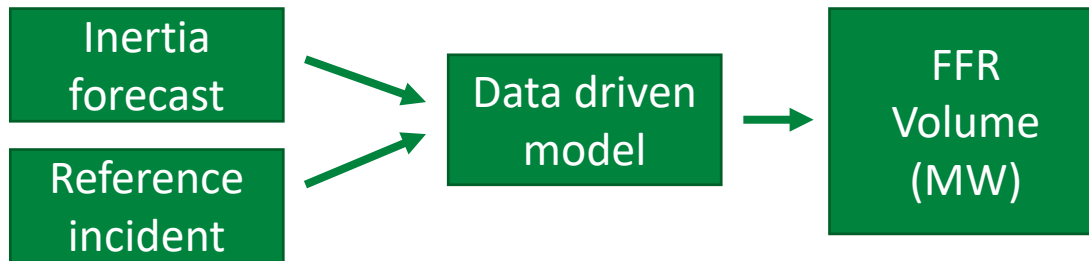
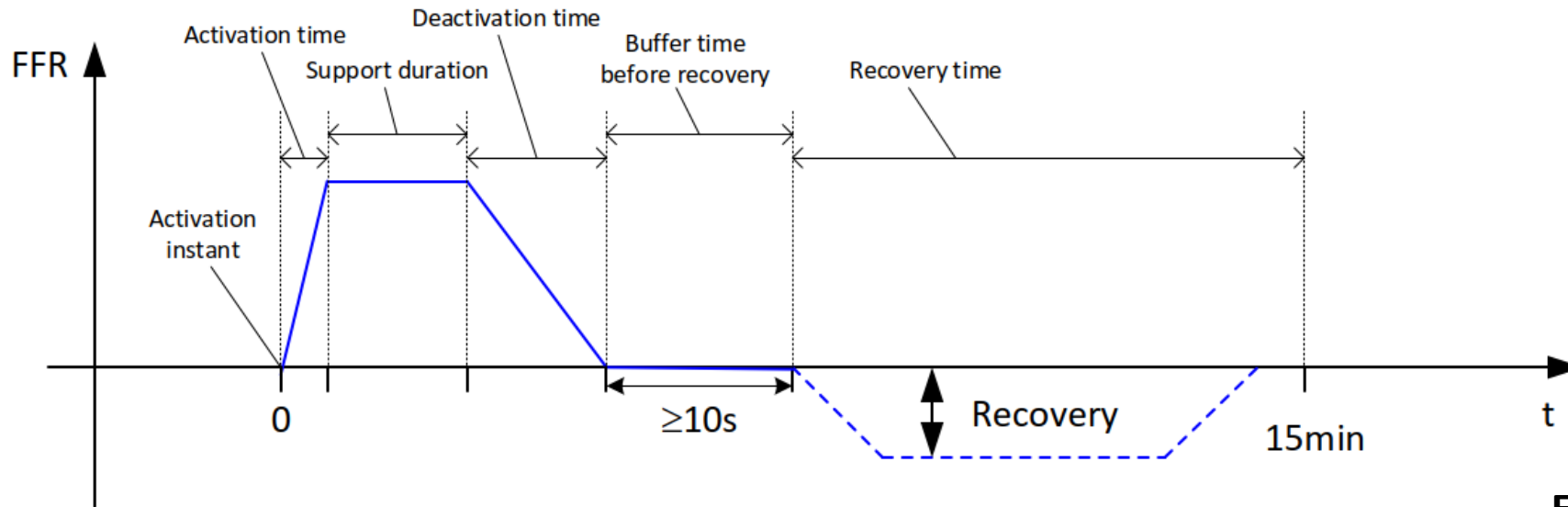


1. Assessment of transient frequency stability in the Nordic system



Ensuring frequency stability

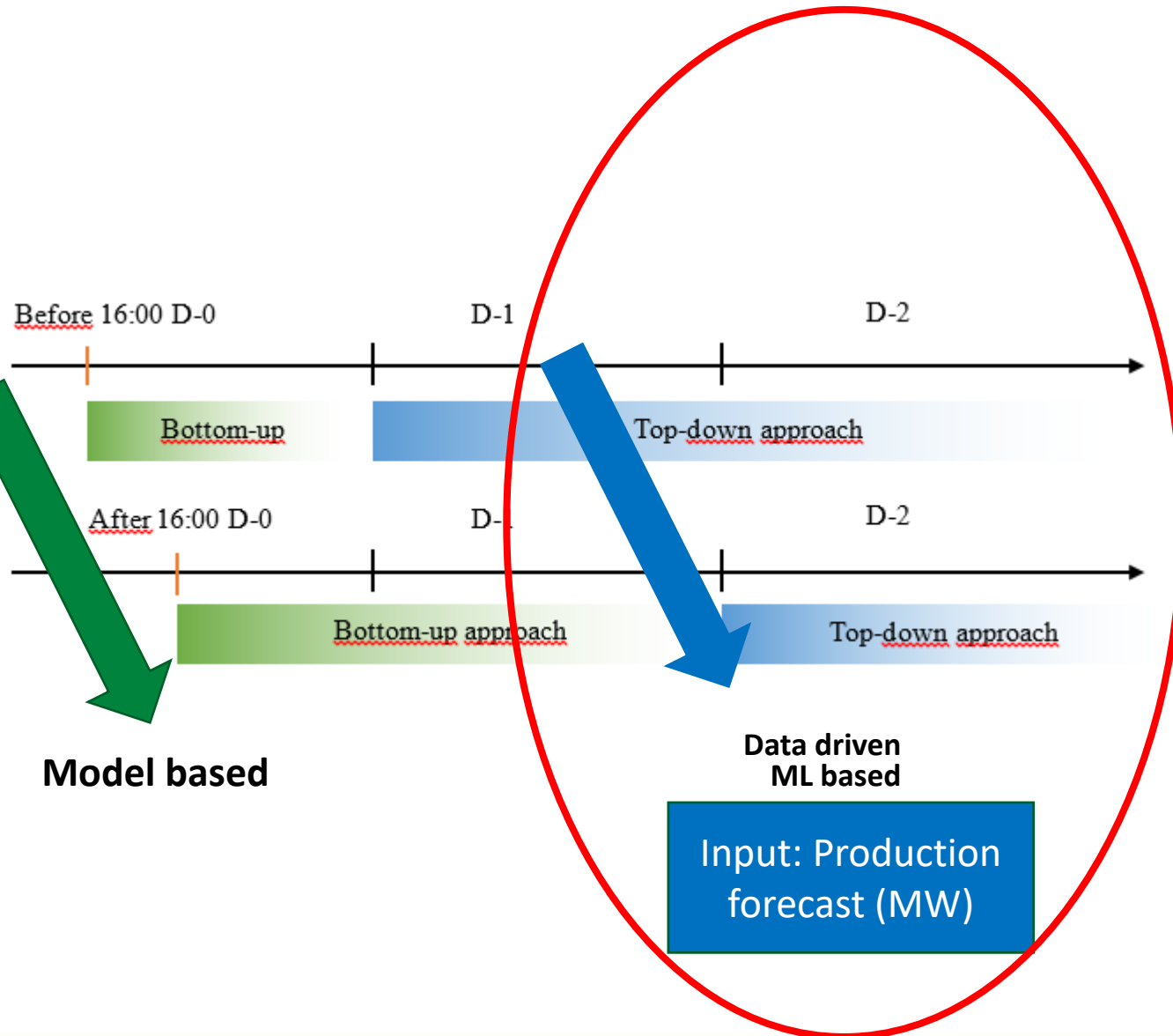
Since 2020 Fast Frequency Reserve (FFR)



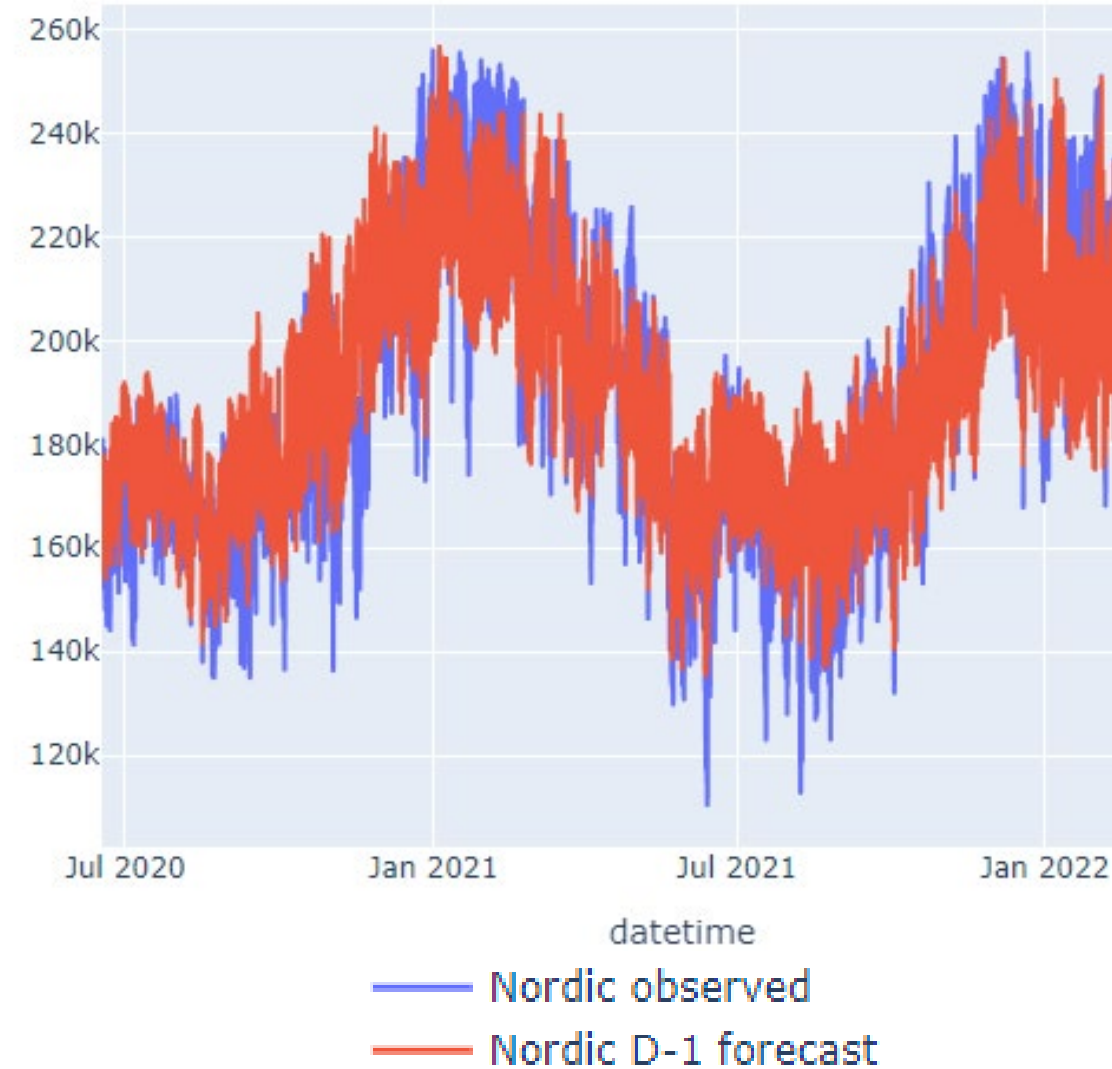
Ensuring frequency stability by procuring FFR

Procurement of FFR twice a week
Volume per hour
 $\Rightarrow D - 1$

Inertia forecast



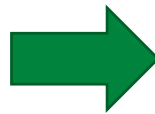
Actual and forecasted inertia



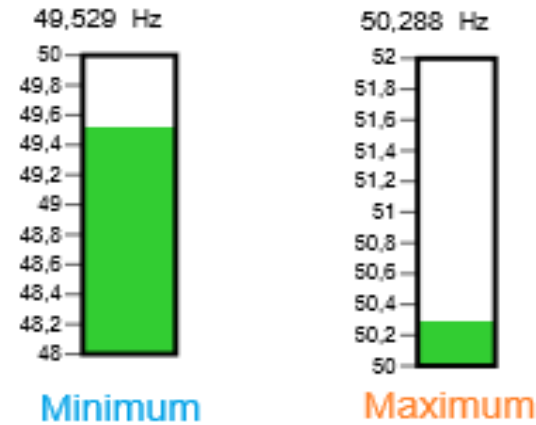
Realtime monitoring of frequency stability

Input data

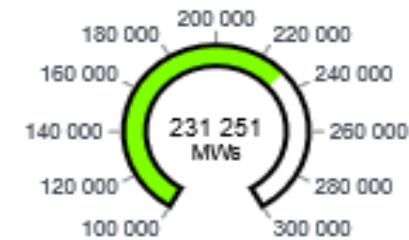
- Inertia
- Largest loss
- Amount FFR



Estimated N-1 frequency

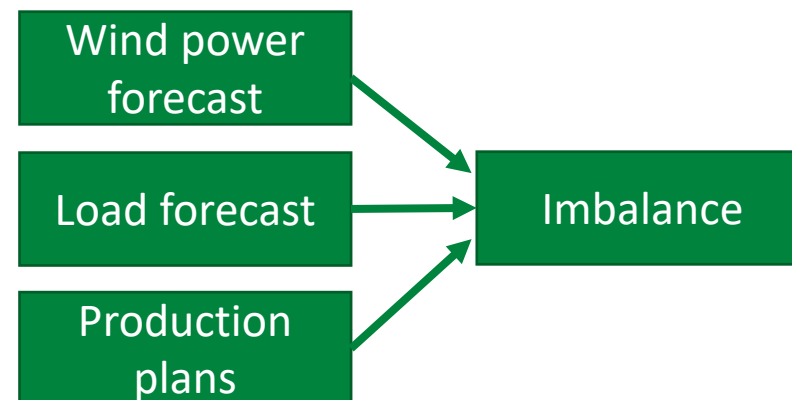


Kinetic energy



2. Balancing within in the hour

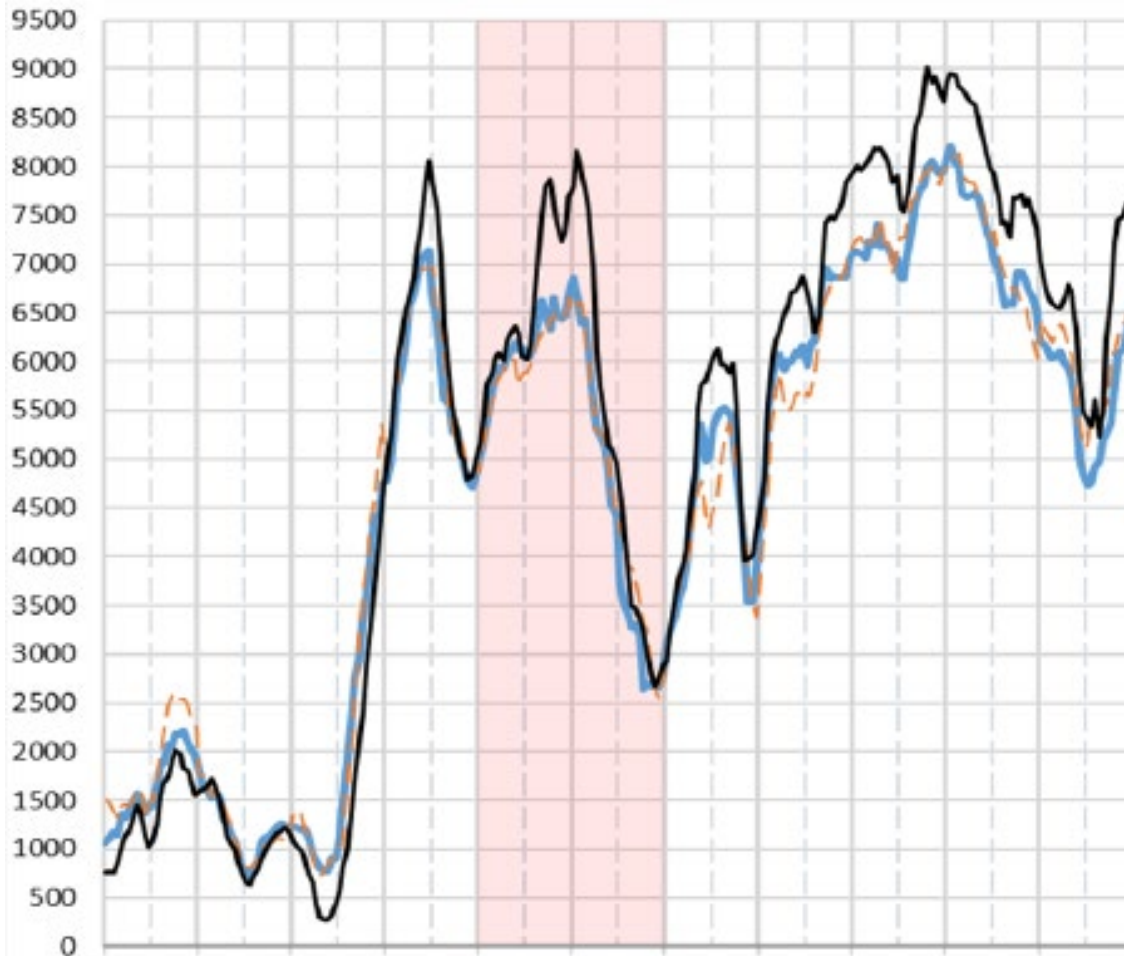
- Automatic reserves
 - Primary (FCR – Frequency Containment Reserve)
 - Secondary (aFRR – automatic Frequency Restoration Reserve)
- Tertiary reserves - Manual activated reserves => automatic activated reserved based on imbalance forecast
- Imbalance forecast



Wind power forecast - Sweden

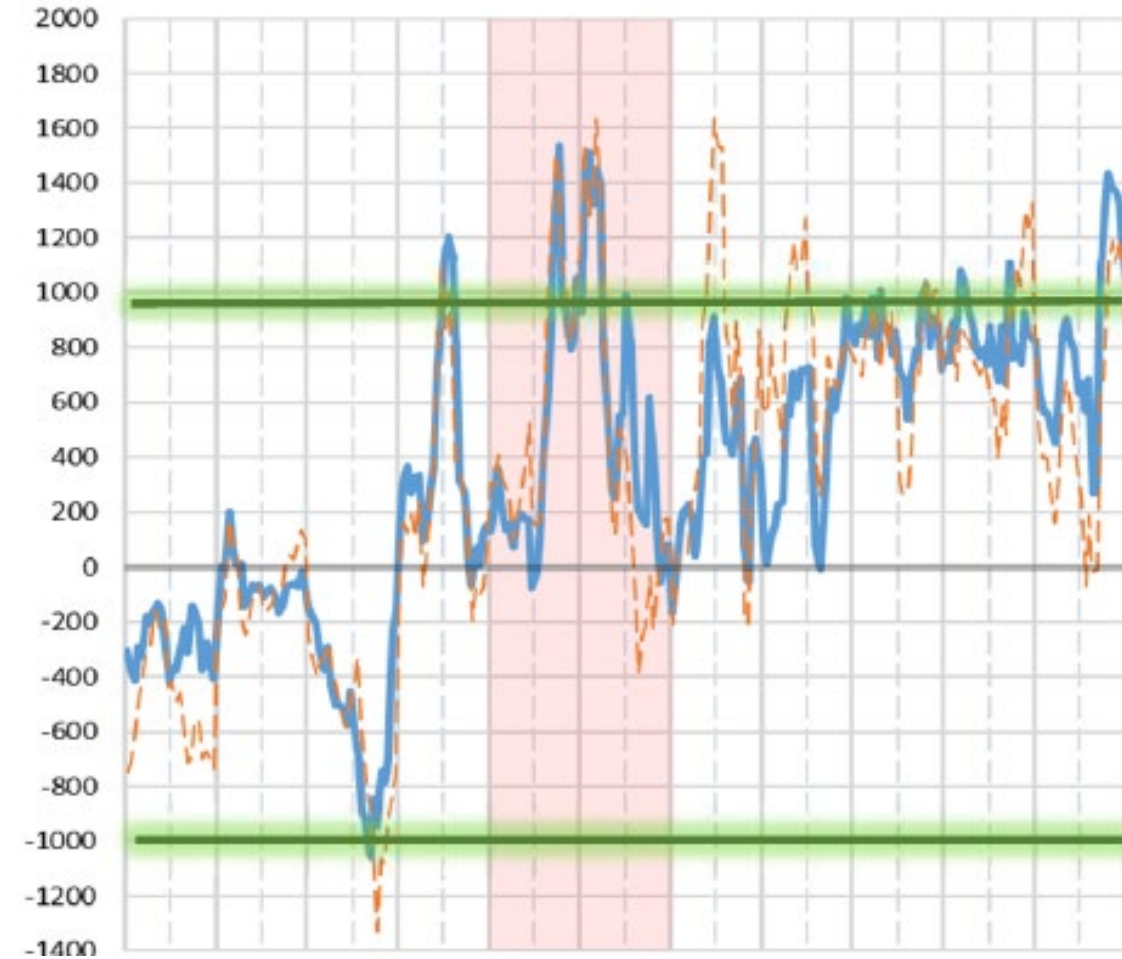
- Day ahead
- Intra day
- Outcome

MW

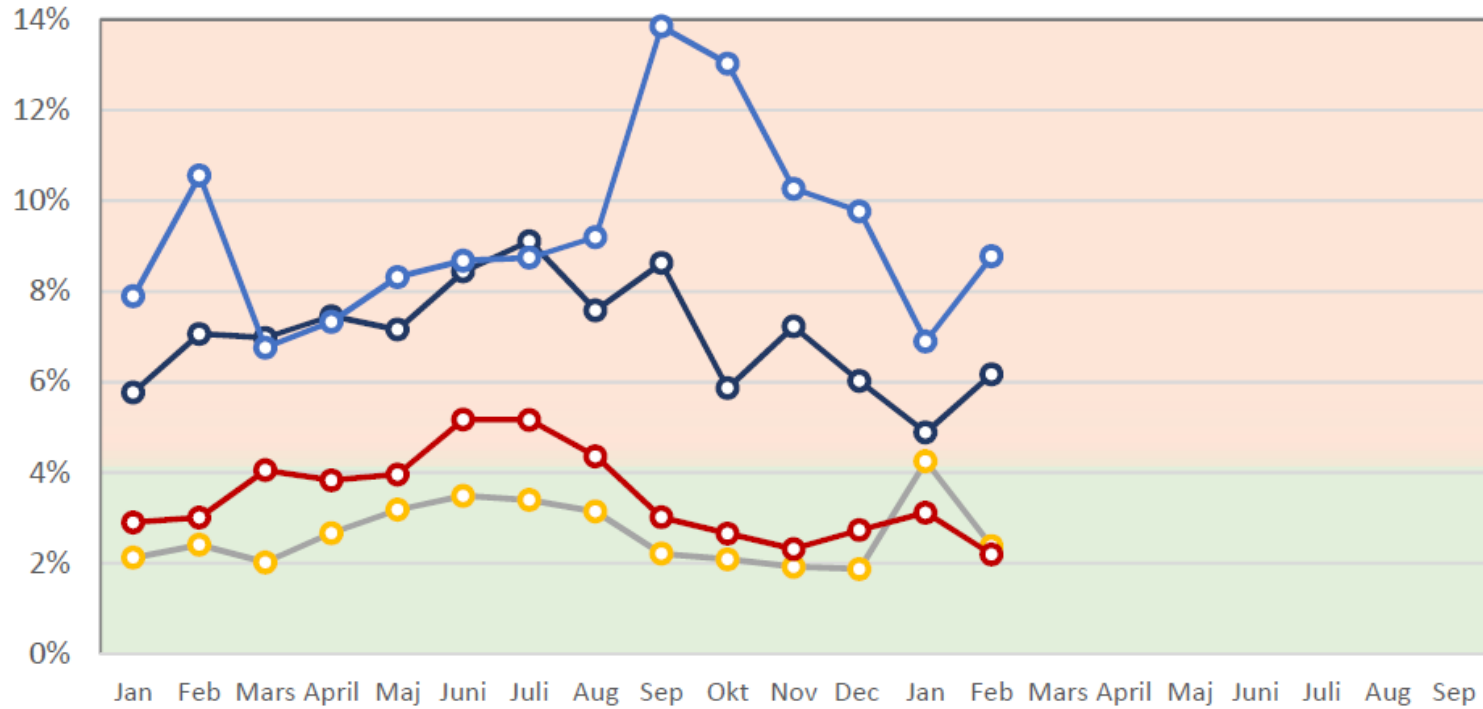


MW

Residues



Average error of loads D-1

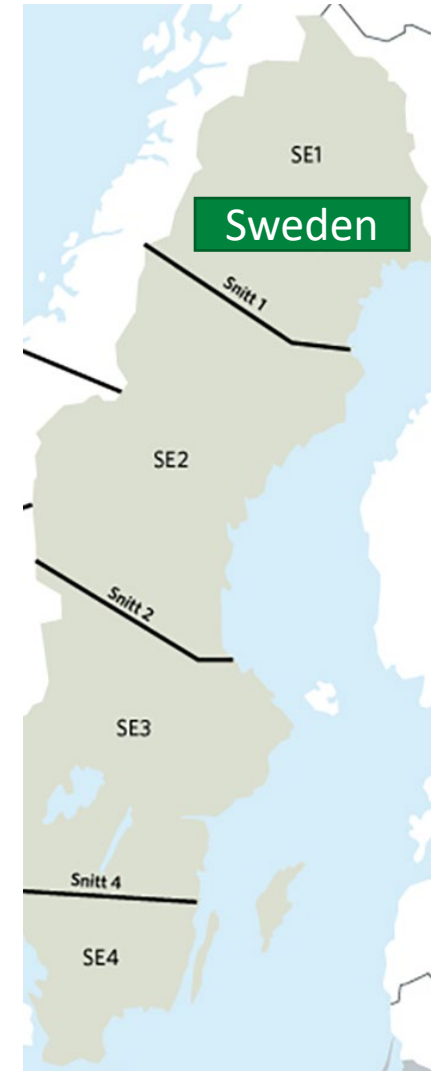


SE1 North

SE2

SE3

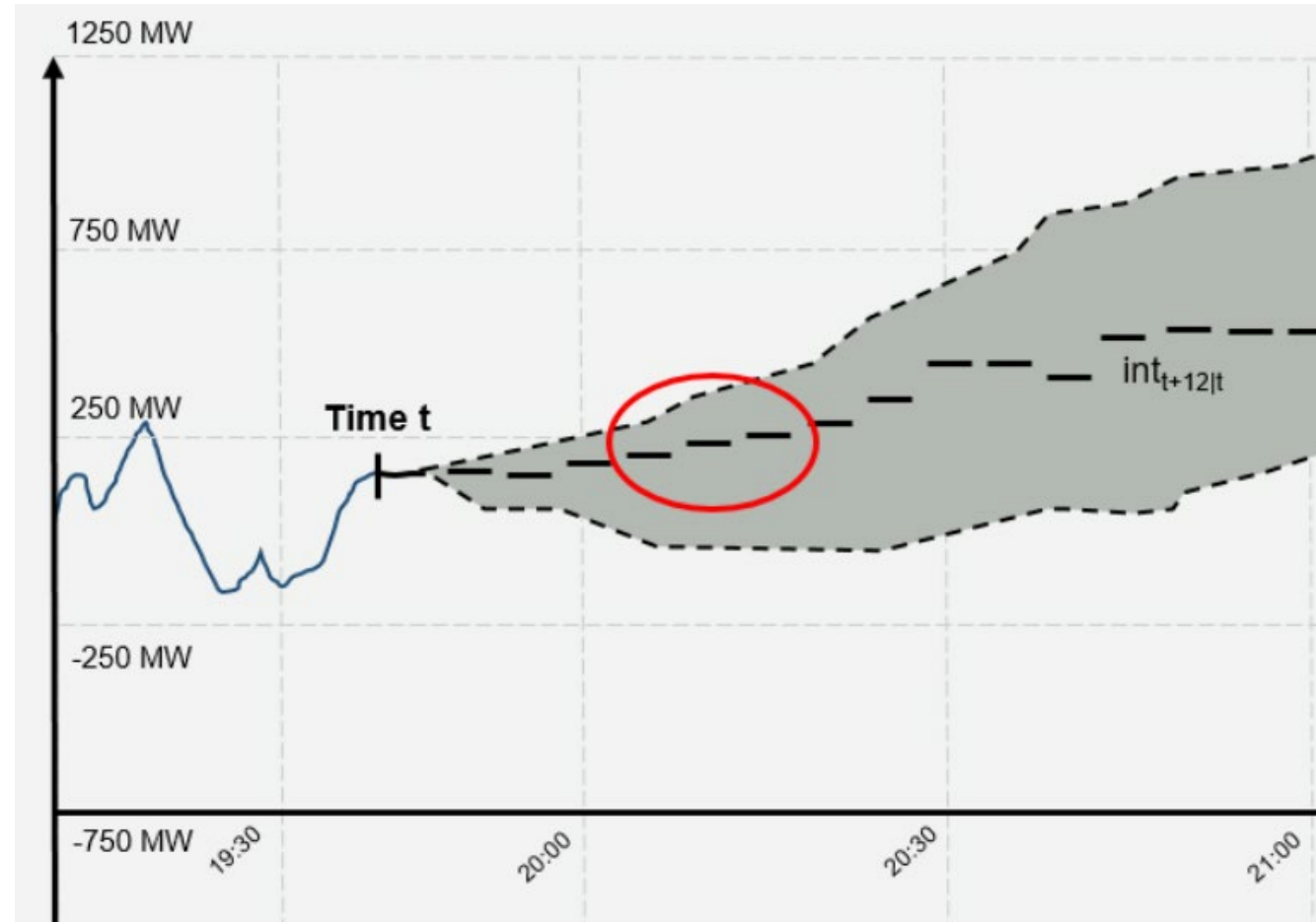
SE4 South



Short term imbalance forecast

Creating forecast models

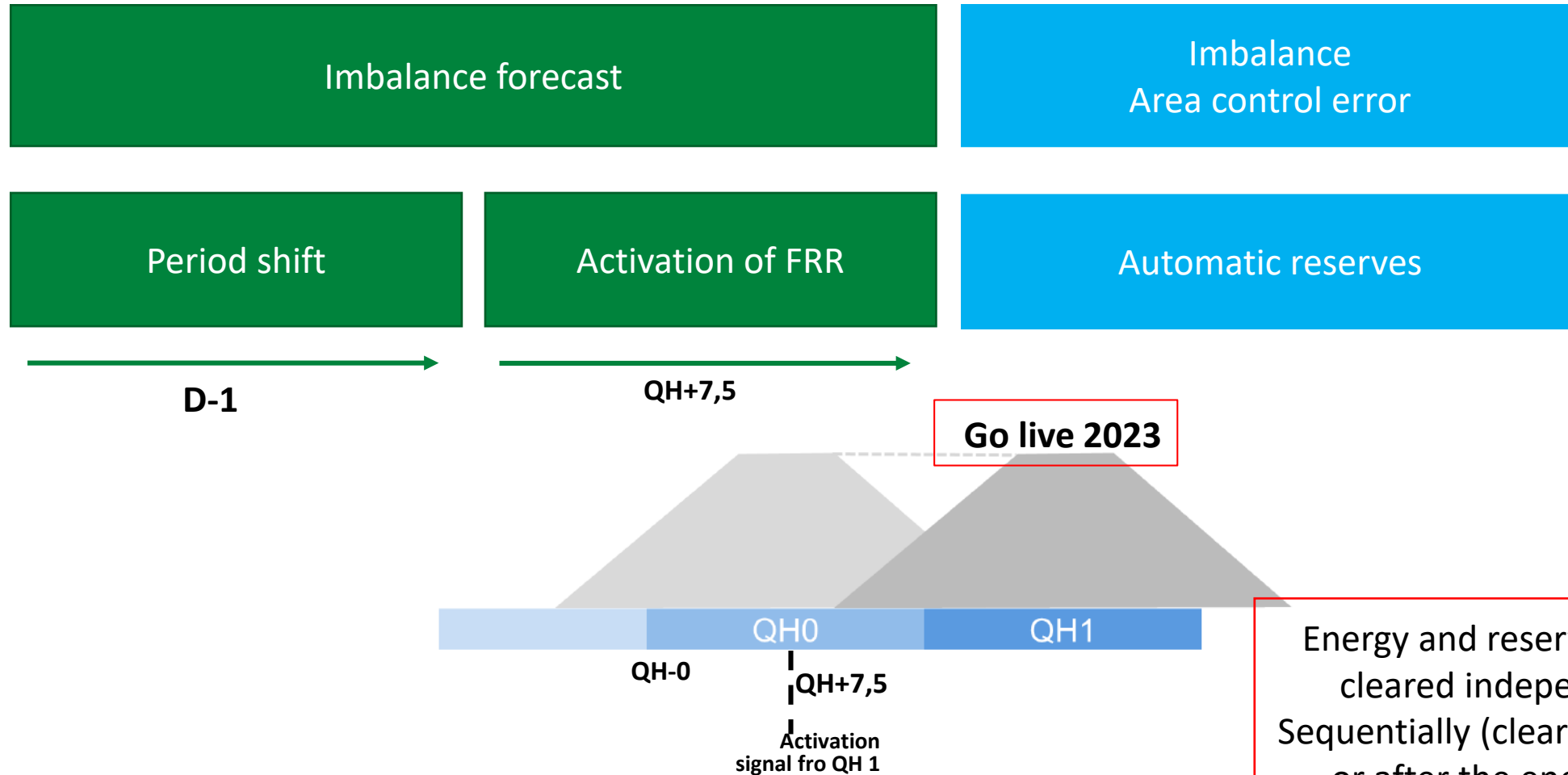
- Machine learning to create imbalance forecast
- Measurements from smaller areas and wind farms
- Learning algorithms



– Forecast over 5 minutes

 Confidence interval

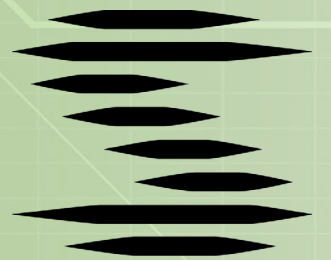
Balancing



Energy and reserve markets are cleared independently and Sequentially (cleared either before or after the energy market.)

Thank you for your attention

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