CASE STUDY

Dynamic Dimensioning with the Nordic TSOs: Principles and Methodologies

Working Together: Developing Probabilistic Models with Nordic TSOs for Multi-Area Reserves Dimensioning

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Context

In power system operations, the high-voltage System Operator (TSO) is responsible for *maintaining the balance* between injections and off-take in its control area.

Operating reserves represent capacity that can be activated upward or downward when the TSO requests to restore the system balance.

Inadequate reserve capacity increases the risk of resorting to emergency measures, such as demand shedding or the curtailment of generation, which should be avoided (up to a certain reliability level, typically with a minimum of 99% as per Art. 157 of the SOGL). While load and production shedding are usually the last resort, there are multiple possible steps before them, such as emergency trades with other TSOs.

As opposed to the traditional static sizing (i.e., evaluating historical realizations of system imbalances and choosing the volume that would have covered 99% of the cases), *dynamic sizing* aims **at determining a non-constant reserve volume under the assumption that the TSO can anticipate high and low-risk situations based on day-ahead forecasts.**

Elia implemented a similar methodology in Belgium, where *N-SIDE supported and delivered Elia* with the decision-making software.

In their vision for balancing, the Nordic TSOs are focusing on developing and implementing innovative solutions to address the challenges posed by the increasing integration of renewable energy sources and the need for more flexible and dynamic power system operations.

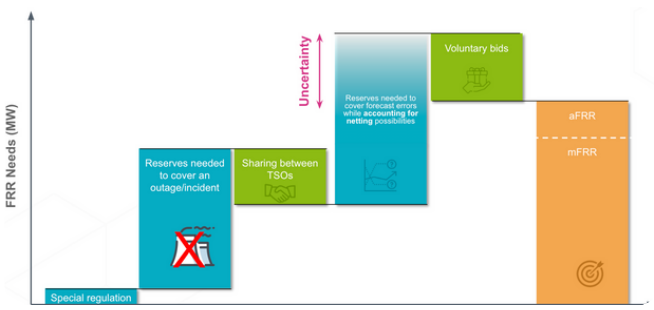
The on-going massive integration of renewable energy sources in the Nordic power systems is expected to create larger absolute values of mismatches between electricity production and consumption, given the intermittent nature of weather patterns and their correlation with electricity production and consumption.

In light of these changes, the Nordic TSOs are embracing an extensive reform of the balancing market in the Nordic Synchronous Area. Among other structural changes, a new Capacity Market (CM) for manual Frequency Restoration Reserves (mFRR) is being developed in the Nordic market area before the day-ahead market runs. Such a market will allow a joint procurement of manually activated FRR balancing capacity by the four Nordic System Operators (Energinet, Statnett, Fingrid, and Svenska kraftnät). A similar set-up already exists for aFRR in the Nordics since December 2022. In the short term, the common mFRR CM will be a trilateral cooperation between Denmark, Sweden, and Finland.

Within the project with the Nordic TSOs, we are focusing more specifically on dynamic reserve sizing. This innovative approach, which captures the fact that the imbalance risk is not constant over time, is set to improve how we manage system conditions such as load, HVDC flows, and inflow of renewable generation. Dynamic dimensioning aims to determine non-constant reserve volumes on the basis of interferences between potentially varying imbalance risks. A potential decrease in capacity reserves should maintain the security of supply.

The ongoing Nordic development of a dimensioning methodology foresees the following principles:

- Each control area must be able to cover its own imbalances and its own reference incident
- TSO-TSO sharing principles allow reserve sharing between control areas for the reference incident of each area.
- TSO-TSO netting cooperation to prevent counteracting activation of balancing energy in adjacent TSO zones.
- Historical, available voluntary bids can be considered in the dimensioning process, considering that the presence of the capacity market can reduce these bids.
- Determination of a minimum procurement level for each area.



Sizing of reserves with multiple LFC Areas
Adapted from Energinet: Outlook for Ancillary Services 2023-2040

From dimensioning a single zone to multiple areas simultaneously: regulation, methodologies, and potential gains

One of the novelties introduced by the Nordic TSOs is that, in contrast with continental TSOs, they do not take the maximum between the deterministic method (N-1) and the stochastic method (expectation of forecast errors). Instead, the proposed approach aims at, once the reference incident per area and the sharing capabilities are estimated, the so-called normal imbalance (coming from the forecast and scheduling errors) is added on top while considering netting. Imbalance netting avoids counteracting the activation of balancing energy in neighboring TSO zones. These TSO-TSO coordination (sharing, netting, exchange of reserves) are well documented in Cross-Border Exchange and Sharing of Generation Reserve Capacity, where Baldursson et al. model the potential gains from cooperation between countries.

It should be noted that the European Energy Regulator (ACER), a key regulatory body in the European energy market, is currently developing methodologies for harmonizing processes for allocating cross-zonal capacity for the exchange of balancing capacity or sharing of reserves. The primary motivation lies in decreasing the volume of balancing capacity to ensure operational security and allocating cross-zonal capacity to balancing capacity, enabling the power system to be balanced more efficiently. Potential reduction of costs by coupling the capacity procurement of reserves between countries also falls within the motivations from regulators.

In this context, the end goal is to accurately forecast netted imbalances on hourly resolution per area to assess the demand for mFRR. Ideally, such a model will support the daily procurement of mFRR capacity, and predictions will be available before the actual auction. Moreover, it has to be fine-tuned for each Nordic TSO. Such forecasted value will then provide a common view on the imbalance risk level and provide crucial information for estimating the amount of balancing energy needed, as well as to assess sufficient access to balancing energy from the different TSOs

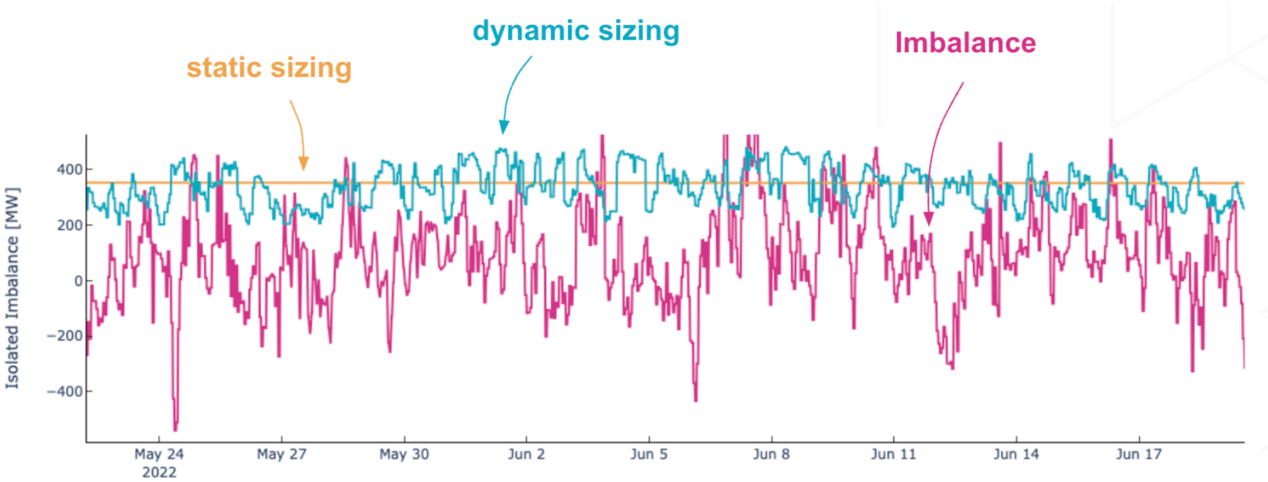


Figure: Example of dynamic sizing in practice. Here, we feed our model with system information available in day-ahead (wind, load, weather forecasts) to predict, with a certain reliability, a value above the realized system imbalance which we aim at minimize.

N-SIDE, a leading provider of energy transition solutions, supported the Nordic TSOs by:

- **Replicate operations** as if a dynamic model was available to estimate the mFRR balancing capacity needs for each LFC Area and direction.
- **Developing customized models** to cast the introduction of dynamic dimensioning in the Nordics.
- Building a tool to **find optimal models** w.r.t. different objectives (decrease volume needs, maximize correlation, or minimize quantile losses) by automatically sweeping through features, model types and hyperparameters.
- Evaluation of the potential **gains** (higher reliability, lower mFRR needs, or better management of high-risk and low-risk periods) that can be achieved with such models, both **quantitatively** and **qualitatively**.
- **Recommendations** towards moving from the existing framework to an operational tool at the core of the Nordic TSOs.

Overview of the algorithms, results, and recommendations

Our analysis showed that our developed models reduced the need for procurement by between 2 and 20% depending on the direction (upwards/downwards) and the LFC area. The predictive models arrived at these results by correctly identifying the low- and high-risk periods from exogenous features, such as load and renewable forecasts, and adjusting the predicted procurement needs.

Our models were benchmarked against the so-called static approach, a model that estimates the reserve needs by simply computing the 99% and 1% percentiles over the previous 12-month imbalances. The 'static approach' is a traditional method that does not consider the dynamic nature of imbalances and relies solely on historical data.

The figure below shows how dynamic models based on clustering (such as kNN) or gradient boosting algorithms (like LGBM) perform against high and low-risk periods. A high-risk period is defined as when a realized imbalance falls above the 75th percentile (P75) (for downward) or below the 25th percentile (P25) (for upwards), i.e., the tails of the distribution. A low-risk period is defined when the imbalance is below the 75th percentile (P75) (for downward) or above the 25th percentile (P25) (for upwards), i.e., less severe imbalances.

In general, dynamic models are capable of (a) lowering the volume of reserves in low-risk periods without compromising its reliability (100% of the imbalances are still covered in these periods) and (b) increasing the reliability for high-risk periods by precisely procuring more reserves which can be anticipated thanks to day-ahead conditions.

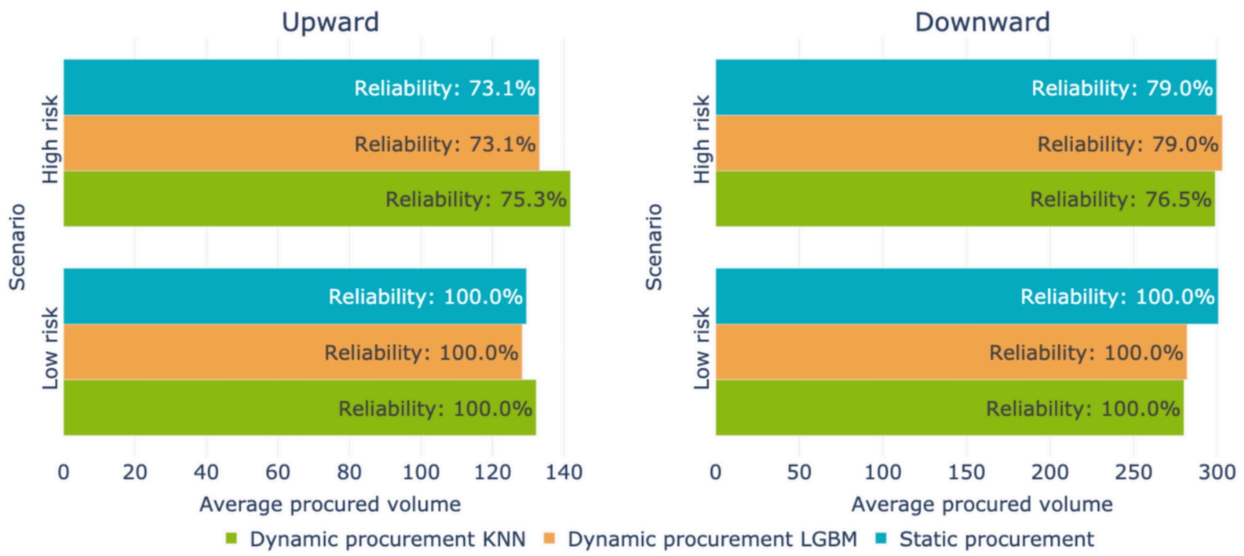
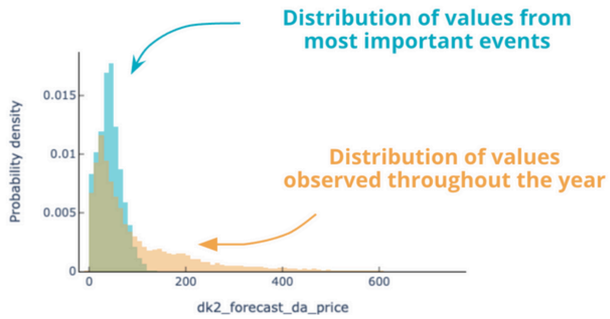


Figure: Average reliability and Average Procured Volume in high and low-risk periods, for upwards and downwards, for LGBM, kNN and static models targeting netted imbalances

To increase trust in the predictions, we have developed an analytical approach to identify which subset of the training data is relevant for each prediction. We called this method the 'tracking of events' and measured the impact of each feature for each prediction (i.e., a local explanation). In the figure below, we can observe how, for a specific prediction the model finds relevant for its prediction a subset of historical observations of relatively low forecasted day-ahead prices in DK2. In practice, this means that the model has learned to associate expected low values of day-ahead prices with certain values of imbalances. Such information can be useful for the operator since it can help understand why the prediction has taken a certain value for a certain period, increasing transparency in the application.

On a more qualitative note, N-SIDE recommends the TSOs to
(i) develop a precise definition of metrics to evaluate,
(ii) access to reliable, validated, and large datasets, and
(iii) streamline operations for the computation of netted imbalances.

We also noted that implementing dynamic dimensioning methods impacts policy, regulatory, and market operations, which TSOs and regulators should address appropriately and compare in a cost-benefit analysis against the effort behind moving forward with the estimated gains.



Authors


Dries Hugaerts
Energy Consultant


Alberte Bouso
Senior Energy Consultant