Reconstruction of Finnish reserve market merit order curves

Project Plan

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1 Background

The operation of a power system is based on the constant equilibrium between generation and consumption of electricity. In practice, supply and demand must be equal at every moment. In Finland and the broader Nordic synchronous system – comprising Sweden, Norway, and Denmark – this balance is reflected in maintaining the system frequency at 50 Hz (Sihvonen, 2025). The interconnection of national systems into a shared synchronous area is designed to improve market performance while strengthening security of supply (Nord Pool, 2026).

The Nordic electricity market structure consists of multiple distinct trading platforms. Transactions take place in financial markets, the day-ahead market, intraday markets, reserve capacity markets, and balancing markets (Fingrid Oyj, 2026b). The segmentation of these marketplaces is illustrated in Figure 1.

Figure 1: Finnish electricity market segments. Modified from Fingrid Oyj (2026b).

Frequency control and system balancing are managed through reserve and balancing markets, which enable real-time correction of power imbalances. Transmission system operators (TSOs) carry the main responsibility for maintaining system equilibrium and ensuring the availability of sufficient flexible capacity (Lieskoski et al., 2024).

In the Nordic power system, frequency stability relies primarily on three categories of reserves: Frequency Containment Reserve (FCR), Frequency Restoration Reserve (FRR), and Fast Frequency Reserve (FFR). FCR is separated into products for normal operation and for disturbance situations, the latter including both upward and downward components (FCR-D up and FCR-D down). FRR is subdivided into automatic (aFRR) and manual (mFRR) forms (Lieskoski et al., 2024). These reserve products differ in terms of response time, activation mechanism, and direction of control, allowing them to address system needs effectively under varying conditions (Fingrid Oyj, 2026a). This project focuses particularly on the mFRR market.

The role of mFRR is to return system frequency toward the nominal 50 Hz level. In addition, it can support congestion management to safeguard operational reliability (Fingrid Oyj, 2026c). Over the long term, the procured volume of mFRR capacity is determined by projected imbalance magnitudes, the availability of backup generation resources, and the expected need for voluntary balancing energy bids to address both common and exceptional imbalance situations (Fingrid Oyj, 2025). The required activation time for mFRR is 12.5 minutes, which is slower than the other reserve products discussed above, indicating that it is not intended for the fastest response actions. Participation in the mFRR market requires a minimum bid of 1 MW, with bids submitted in 1 MW increments (Fingrid Oyj, 2026c).

2 Objectives

Hytrade operates in a market where optimal short-term decision making plays a crucial role in success. In electricity markets, supply curves are stacked using merit order. In the day-ahead market (DA), generators often bid with the short-run marginal cost (SRMC) of their generation source, which are effectively known beforehand. On the other hand, participation in the mFRR capacity market implies an opportunity cost in missed revenues from the DA market. However, this opportunity cost is uncertain at the time of decision making. Furthermore, the outcomes of the mFRR market depend heavily on the decisions of other market participants, making the ability to forecast market behaviour accurately valuable.

In mFRR, the demand quantity is set by Fingrid. This demand exhibits effectively perfect price inelasticity, consequently making it compelling to study the behavior of supply curves. Perfect information on the supply curves would enable a market participant to optimize their bidding strategy across mFRR and DA, as well as other reserve and intraday markets.

Perfectly accurate bid curve forecasting is practically impossible due to exogenous uncertainties. However, Hytrade has identified some feasible objectives:

1. Examine whether there exists a static component in mFRR bid curves.
2. Examine how underlying variables, such as day-ahead price, weather, seasonality, affect mFRR bid curves.
3. Examine how mFRR bid curves have changed over time as the electricity system has developed.

A static component in the bid curves, if one exists, could for example be a specific type of capacity, such as battery energy storage systems (BESS). The first objective is to simply identify this component, or some other relatively constant curve dynamics. This static component could also shift given changes in exogenous variables, which are covered in the second objective. In addition to the varying exogenous variables, the curves are likely to have changed significantly in the recent years. This is addressed in the third objective. Furthermore, if the results of these three objectives suggest that the dynamics of some segments of the bid curve could be captured via modeling, the fourth objective would become to forecast the curves.

3 Tasks

3.1 Literature review and familiarization with Finnish electricity markets

Proper understanding of the electricity market dynamics is a prerequisite for starting further project planning. On a related note, we will explore current literature about the market dynamics and possible modeling methodology while also observing daily market fluctuations. This task is expected to continue throughout the project.

3.2 Project planning and scoping

The project topic is possibly very broad, and thus further scoping is needed. One of the tasks in the beginning has been and is clarifying the objectives and scope of the topic, forming a plan for subsequent tasks. For example, during initial scoping we have determined that our primary focus will be on mFRR capacity markets and after that, mFRR energy markets and all of these preliminarily in Finnish and Swedish bidding zones.

3.3 Data retrieval

In order to formulate models, we need to determine what types of data are available for the reserve market bids and possible explanatory factors. This task also includes setting up data retrieval pipelines and requesting API access keys where necessary, ensuring the quality of data is also done.

3.4 Modeling methodology

We need to weigh alternative modeling methodology, decide the type to model to build and implement it. One of our primary goals is predicting the mFRR curve, in addition to individual statistics such as the marginal price. Predicting the price curve can be done on bid-level (predict individual bids), curve-level (predict the shape of the curve using for example functional analysis tools), or something in between (identify components that can be modeled separately).

3.5 Out-of-sample testing

In order to determine whether our model is useful for predicting price formation, we need to define validation metrics and build a validation framework. One option is to define a simple baseline against which we compare our model performance.

3.6 Project deliverables

We prepare a project plan, an interim report, and a final report of our work.

3.7 Project management

Throughout the project, we plan meetings, share responsibilities and decide on intermediate goals and deadlines within the group. Continuous communication is upheld with Hytrade representative Elias to ensure a focused workflow and share updates as they occur.

4 Schedule

Table 1 displays the planned timeline for completing the project tasks. Below, we describe how we plan to carry out the tasks in relation to the three project deliverables.

Now – 6.3, Project plan and first presentation
Project plan includes explanation of project background, objectives, tasks, schedule, recourses and risks. Project plan is presented.

6.3 – 10.4, Interim report and second presentation
After first presentation, problem scoping and data retrieval are continued. Modelling methodology research is started and initial models tested. A literature review is conducted and the project is tied to relevant literature. This work is presented during the second excursion.

10.4 – 22.5, Final report and last presentation
The results are validated, and the deliverables are finalized. Results are presented at the last presentation.

Table 1: Planned timeline for the project tasks.

	Week											
	Jan	**Feb**	**March**				**April**					**May**
Phase	3–5	6–9	10	11	12	13	14	15	16	17	18	19–21
Project plan												
Literature review												
Data retrieval												
Problem scoping												
Formulating model												
Interim report												
Model testing												
Final report												

5 Resources

5.1 Data

Our primary data source will be ENTSO-e Transparency Platform (ENTSO-E, 2015) which offers historical data of accepted reserve market bids. Fingrid (Fingrid, n.d.) publishes information about the hourly total capacity demand and marginal prices, which will be important for verifying the accuracy of the bid data. Additional datasets may be used to retrieve possible explanatory variables, such as day-ahead electricity price predictions or weather data.

5.2 Contributors

Our project group consists of five M.Sc. students equipped with varying specialties suited for the project work, ranging from energy market expertise to more specialized methodological strengths.

- **Veikko Hokkanen** is an OR major and has the focus of studies on simulation, optimization and decision analysis.
- **Mikael Kari** is an Energy Systems and Markets major with a B.Sc. in energy engineering. His strengths and interests include energy markets, energy storage systems, and using mathematics to solve problems in the energy field.
- **Joel Niemi** is an OR major with a B.Sc. in mechanical engineering. Experienced in energy markets in both academia and industry, with a current focus on electricity market modeling and forecasting.
- **Timo Norrkniivilä** is an OR major with a focus on data science and applied statistics. He is experienced with e.g. Bayesian data analysis and building complete data science pipelines.
- **Tuomas Rajala** is a OR major with a B.Sc. in bioinformation technology. Interested lie in decision-making under uncertainty and risk analysis. Experience in data science and mathematical modeling in academia and industry.

5.3 Hytrade

Hytrade representative Elias has agreed to provide guidance and insight on the project if needed. Naturally problem scoping is also done in participation with Hytrade.

6 Risks

The risks associated with this project range in severity. In qualitative risk analysis, risks are ranked by likelihood and impact to recognize the most relevant risks to mitigate. With this project we recognize a few relevant risks associated with team work and list relevant mitigating measures below. Recognized risks are shown in Table 2.

Risk	**Likelihood**	**Effect**	**Impact**	**Mitigation**
Group dynamics, uneven workload	Low	Poor cohesion within group, missed deadlines	High	Continuous and open communication within the group
Hytrade personnel drops out	Low	No support for project development	Medium	Continuous discussion with Hytrade
Project topic too ambitious	Medium	Time wasted on too complex tasks	High	Clear, stated, and realistic project goals
Data is inaccurate	Medium	Created model is not suitable and possibly useless	High	Data validation before model building
Project goal becomes redundant	Low	Goal of project already solved	Medium	Researching existing solutions
Time runs out	Medium	Projects goals are not met	Medium	Sticking to schedule

Table 2: Risk table.

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