Msc thesis proposal:

Analysis and Forecasting of Intraday Electricity Market

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**Background**

The Dutch energy market operates within the broader framework of the European Union's liberalized electricity market. The market is characterized by multiple stakeholders, including producers, consumers, traders, and Transmission System Operators (TSOs), who interact through a series of structured markets to ensure efficient electricity allocation and system reliability.

The Day-Ahead (DA) and Intraday (ID) markets serve as the primary venues for electricity trading in the Netherlands. The DA market operates on a daily basis, allowing participants to submit bids and offers for hourly electricity delivery for the following day. Market clearing is achieved through a uniform price auction, which balances supply and demand at each hour [10]. The ID market complements the DA market by enabling participants to adjust their positions closer to real-time. It operates as a continuous trading platform, providing flexibility to account for unexpected changes in supply and demand [11].

Electricity prices in the DA and ID markets exhibit distinct characteristics driven by the non-storability of electricity, fluctuating demand, and the variability of renewable energy sources.

These prices are highly volatile, often displaying intraday patterns linked to consumption cycles and renewable generation [2]. Moreover, price spikes are common due to sudden supply-demand imbalances, especially during periods of low renewable output or high system stress [12]. Price dynamics are also influenced by cross-border trading and regulatory interventions aimed at maintaining market stability [13].

Electricity Price Forecasting is a discipline at the intersection of Electrical Engineering, Finance, Statistics and Applied Probability that deals with the forecasting of energy prices.

Accurate price forecasting is crucial for market participants to optimize trading strategies and manage risks.

**Literature review**

In recent years, the literature has explored a range of forecasting methods, including statistical, machine learning, and hybrid approaches. Classical time series models, such as ARIMA and GARCH, have been widely used to capture linear dependencies and volatility clustering in price data [14].

More recently, machine learning methods, such as support vector machines and neural networks, have gained prominence due to their ability to model nonlinear relationships and integrate large datasets [15].

Hybrid approaches, which combine statistical models with machine learning techniques, have been shown to improve forecasting accuracy by leveraging the strengths of both methodologies [16].

Additionally, specialized models that account for market-specific features, such as bid-ask spreads and market coupling effects, are being developed to enhance forecasting performance [17].

Some researchers have suggested that increasing the amount of renewable energy leads to greater volatility of electricity prices. More specifically, as the penetration of renewable increases, so does the dependence of electricity production w.r.t. to weather conditions and, in turn, the volatility in electricity prices. In this situation, it is necessary to improve forecasting accuracy not only when prices are normal, but also when they are extreme. One possible way to tackle this difficulty is constructing different forecasting models under high- and low-price situations, respectively, using a threshold [4]~[8].

Despite the increasing importance of the ID market, the literature covering electricity price forecasting in the ID market is scarce, and more than 90% of this literature refers to the DA market.

A previous Msc thesis from TU Delft [19] investigated the possibility of using stochastic processes to model the ID market prices.

[18] investigates the possible gains from utilizing forecasts of the price spread between the intraday/balancing and day-ahead markets in the decision process of DA-ID arbitrage. It shows that the sign of the price spread can be successfully predicted with econometric models, such as ARX and probit. Moreover, their research demonstrates that the statistical measures of forecast accuracy, such as the percentage of correct sign classifications, do not necessarily coincide with economic benefits.

**Research questions**

The ID continuously trading market behaves similarly to the financial market when the trading time is close to the delivery time, since the trading is done via matching limit orders by exchanges.

The statistical properties of limit order book (LOB) market orders, limit orders and cancellations have been extensively studied in the literature of the financial market. For example, [20] reveals strong evidence of clustering in time, cross-correlation across event types and dependence of the order flow on the bid-ask spread, as well as the presence of a self-exciting property - that a large number of events in a given time period tends to imply a higher probability of observing a large number of events in the following time period.

The research questions that this thesis is expected to investigate and answer are as follows:

1. What are the main drivers of the randomness in the ID-DA spread?
2. What are the main drivers of the price spikes in the ID market?
3. Does the LOB of ID continuous trading market exhibit similar statistical properties as observed in the equity market?
4. If yes, can a multi-dimensional self-exciting point process as discussed in [20] be applied in the ID market?
5. If no, which models from the literature are good candidates for predicting ID prices and/or the price spikes?

**The goal and content of this thesis**

The goal of this thesis is to answer the above-mentioned research questions.

This thesis consists of three parts:

1. **Market analysis:** the student is expected to conduct through statistical analysis of historical factor data and the LOB data to answer the research question 1 to 3.
2. **Modelling and implementation**: Depending on the answer to the research question number 3, the student is expected to answer question 4 or 5 by
   1. studying the above-mentioned literature
   2. replicating promising candidates, and
   3. making improvements when possible
3. **Benchmarking:**
   1. Implement benchmark models: Reinforcement learning and traditional econometrics models
   2. compare and analyze the predictive power of the improved model(s) and benchmark models.

**Contact**

If you are interested to enter the field of quantitative risk analysis, this is a very good starting point. Please feel free to contact me directly if this topic is of your interest, or if you would like to learn more details: [xiaoyu.shen@ffquant.nl](mailto:xiaoyu.shen@ffquant.nl) or [f.fang@tudelft.nl](mailto:f.fang@tudelft.nl)

**Reference**

1. Shahidehpour M, Yamin H, Li Z. “Market overview in electric power systems. Market operations in electric power systems New York (USA)”, John Wiley & Sons, Inc.; 2002. p. 1–20. http://dx.doi.org/10.1002/047122412X.ch1 [chapter 1].
2. R. Weron, "Electricity Price Forecasting: A Review of the State-of-the-Art with a Look into the Future," International Journal of Forecasting, vol. 30, no. 4, pp.1030-1081, Oct. 2014.
3. Lago J, De Ridder F, Vrancx P, De Schutter B. “Forecasting day-ahead electricity prices in Europe: the importance of considering market integration”. Appl Energy 2018;211:890–903. <http://dx.doi.org/10.1016/j.apenergy.2017.11.098>.
4. X. Lu, Z. Y. Dong and X. Li, "Electricity Market Price Spike Forecast with Data Mining Techniques", Electric power systems research, vol. 73, no. 1, pp.19-29, Jan. 2005.
5. J. H. Zhao, Z. Y. Dong , X. Li, and K. P. Wong, "A Framework for Electricity Price Spike Analysis With Advanced Data Mining Methods," IEEE Transactions on Power Systems, vol. 22, no. 1, pp. 376-385, Feb. 2007.
6. N. Amjady and F. Keynia, "A new prediction strategy for price spike forecasting of day-ahead electricity markets," Applied Soft Computing Journal, vol. 11, no. 6, pp. 4246-4256, Sep. 2011.
7. A. Fragkioudaki, A. Marinakis, and R. Cherkaoui, "Forecasting price spikes in European day-ahead electricity markets using decision trees," in 2015 12th International Conference on the European Energy Market (EEM). IEEE, 2015, pp.1-5, Mar. 2015.
8. H. S. Sandhu, L. Fang, and L. Guan, "Forecasting Day-Ahead Price Spikes for the Ontario Electricity Market," Electric Power Systems Research, vol. 141, pp. 450-459, Dec. 2016.
9. Andrea Ippolito, “Stochastic Process Model for Energy Prices in the Intraday Market”, Msc thesis at TU Delft, 2023.
10. Epex Spot. (2023). “Day-Ahead and Intraday Markets.” Available at: https://www.epexspot.com.
11. Meeus, L., Purchala, K., & Belmans, R. (2005). “Development of the Internal Electricity Market in Europe.” The Electricity Journal, 18(6), 25-35. https://doi.org/10.1016/j.tej.2005.05.005
12. Zugno, M., Jónsson, T., & Pinson, P. (2013). “Trading wind energy in a pool-based electricity market: A stochastic programming approach. IEEE Transactions on Power Systems”, 28(3), 3440-3450. https://doi.org/10.1109/TPWRS.2013.2248366
13. Kiesel, R., Paraschive, D., & Christian, R. (2017). “Econometric Analysis of Electricity Prices. Energy Economics”, 38, 217-229. https://doi.org/10.1016/j.eneco.2017.01.004
14. Hyndman, R. J., & Athanasopoulos, G. (2018). “Forecasting: Principles and Practice”. 2nd Edition. OTexts. Available at: https://otexts.com/fpp2/.
15. Lago, J., De Ridder, F., & De Schutter, B. (2018). “Forecasting spot electricity prices: Deep learning approaches and empirical comparison of traditional algorithms”. Applied Energy, 221, 386-405. https://doi.org/10.1016/j.apenergy.2018.02.069
16. Nowotarski, J., & Weron, R. (2016). “Recent advances in electricity price forecasting: A review of probabilistic forecasting. Renewable and Sustainable Energy Reviews”, 81, 1548-1568. https://doi.org/10.1016/j.rser.2017.05.234
17. Kristiansen, T. (2012). “Forecasting Nord Pool day-ahead prices with an autoregressive model”. Energy Policy, 49, 328-332. https://doi.org/10.1016/j.enpol.2012.06.051
18. Maciejowska, K.; Nitka, W.; Weron, T. Day-Ahead vs. Intraday—Forecasting the Price Spread to Maximize Economic Benefits. Energies 2019, 12, 631. <https://doi.org/10.3390/en12040631>
19. Andrea Ippolito, “Stochastic Process Model for Energy Prices in the Intraday Market”, TUD Master Thesis, 2023.
20. Ekaterina Vinkovskaya,“A point process model for the dynamics of limit order books”, PhD dissertation, Columbia University, 2014.
21. Hqo Wang and Baosen Zhang, “Energy Storage Arbitrage in Real-Time Markets via Reinforcement Learning”, 2018 IEEE. <https://www.researchgate.net/publication/329898789>

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