Assessment of the Master Thesis
Modeling of Electricity Markets Using an Agent-Based Simulator

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The chosen topic is fully in relation to the current development of the electricity market, characterized by transformation with respect to new EU targets. Therefore the motivation of the master thesis is based on reconsideration of applied trading strategies, together with research on the basic principles of the market behavior and demonstration of dynamic analytical methods. The key drivers influencing the reconsideration of current market modeling methods are continuing market integration, decentralization of the generation, RES development and use of innovative technologies on the demand side.

The master thesis is structured into five chapters – introduction, analytical part, model development, exemplary studies and conclusions. The analytical part (Chapter 2) relatively widely describes the object of applied mathematical model. Although the author presented achieved knowledge of the market integration theory sufficiently, there can be found several incorrect formulations. For example, we need to state clearly, that the market coupling is purely a tool to allocate and not calculate cross border capacity (see Abstract). Additionally it is important to distinguish between the needs for the long term and short term trading on day-ahead and intraday markets. It is stated in the thesis that bidding zones are created at regional level. In reality they are considered at European level (consulted by ENTSO-e). The target model of the electricity market hardly could be presented as fully integrated market without any congestion.

Questions to the Analytical part:

a) Could you explain the difference between pricing in bidding zone and nodal pricing?
b) Could you explain the relation between congestions, full market integration and security of supply?

In Chapter 3 the author of the thesis creates own mathematical model to simulate electricity markets. Analytical part (Chapter 2) also contains detailed information about applied agent based models. Therefore I suggest to structure the thesis better, linking together market analysis and discussion on applied mathematical methods with the model development. Further in Chapter 3 the author focuses on the model structure and describing functions of individual agents. Regarding consumption and market price model we can have some concerns related to the drivers influencing the shape of load and simulation of the market price curve. Therefore it is relevant to mention the potential model extension by the prosumers, aggregators and energy communities and use of advanced technologies on demand side. I also recommend to consider sensitivity of the load and decentralized generation to climate conditions. Moreover I did not find in the thesis relevant comment regarding the RES curtailment, which may influence the scope of the agent model.

In addition to the issues related to the model extension, which are also generally discussed in the conclusions (Chapter 5), I expect from the long term perspective extension of the model by the agents simulating the market fundamentals, such as commodity prices or another macroeconomic conditions, e.g. GDP growth or drivers influencing electricity consumption. As result of this approach we can assess the market risk, related margins, and consequently propose relevant trading strategies taking into account acceptable level of uncertainty of the underlying fundamentals. Based on such assumptions we can further quantify expected economic benefits and improve optimal trading of new generation mix, considering holistic approach to the integrated European market modeling.

Besides the concerns mentioned above I assess this part of the thesis as highly scientific, and the author is capable of developing and effectively applying relevant mathematical tools. The thesis could be extended in this part by the details, which would more describe the individual effort of the author to the model development. I have only several comments to the insufficient description of graphs and figures in Paragraph 3.1.

Questions to the Model development:

a) How can we extend applied mathematical model by simulation of the market fundamentals.
b) How can we model by ABM the market newcomers such as prosumers and flexibility aggregators?

In following Chapter 4 are presented the results of Exemplary studies. The author created three scenarios of pan-European market, combining different configurations of the market coupling with different cross border auction type. Base case reflects on current situation (2019) and Scenarios 2 and 3 are combining application of implicit NTC and flow-based central Europe (CEE). Based on this scenarios are compared individual reinforcement algorithms. Due to the fact, that algorithms show different patterns, the author is proposing further investigations and plausibility checks. I agree with author conclusions at the end of paragraph 4.2.2, but without previous clear formulation of the hypotheses this could be understood as a speculation. The scientific level of the master thesis could be improved by formulating the research hypotheses in this part. The reason is, that form long term perspective some assumptions (see paragraph 4.2.3 page 74) can change significantly in the future, for example the export balance of Germany.

Questions to the Exemplary studies:

a) Current N-1 criterion is limiting cross border capacity at 50% of physical capacity. In the latest proposal of the European legislation (Clean Energy Package) are provisions ensuring the use of the capacities up to 70%. How could it influence bidding strategies of the market players and European market coupling?
b) Could you rank the latest learning IT technologies use in the Gartner hype cycle loop?

Conclusion:

Proposed reconsideration of the analytical tools for market modeling by ABM is in accordance with current requirements, available data and expected market development. The chosen topic corresponds with current level of emerging IT technologies in power industry. From this point of view such topic can be interesting for large generation portfolio providers or trading companies integrating generation positions of individual renewable recourses. This model also can be proposed to the transmission grid operator for the optimal balancing energy procurement.

The author of the master thesis demonstrated excellent level of scientific knowledge and skills to develop and test the analytical model applying advanced IT technologies. Apart from better description of initial hypotheses that seems to be missing, the master thesis is structured in accordance with the academic requirements. In case of adequate reaction of the author to the comments and complementary questions, I propose the final evaluation – **A (excellent).**

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