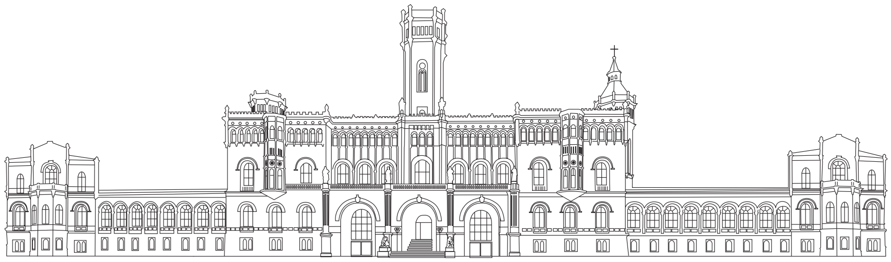

Techno-economic Analysis of Peer-to-Peer Energy Exchanges in Microgrids

Masterarbeit

zur Erlangung des akademischen Grades "Master of Science (M. Sc.)" im Studiengang Wirtschaftsingenieur der Fakultät für Elektrotechnik und Informatik, Fakultät für Maschinenbau und der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover

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1 Introduction

"The combined profits of the largest energy companies in the first quarter of this year [2022] are close to $100 billion. I urge governments to tax these excessive profits [...] to support the most vulnerable people [...]." - António Guterres (United Nations (UN) Secretary-General) [87]

Energy prices have risen very strongly, because of different crises, thus benefiting large energy corporations for the most part [86]. UN Secretary-General, António Guterres, calls those profits made by the energy companies "immoral" and suggests applying a higher tax to them in order to use the money to help people who are in desperate situations [87]. A BRIEF published by the UN Global Crisis Response Group on Food, Energy and Finance focuses on the role of renewable energy sources in tackling high fossil fuel and energy prices, to make energy accessible to everyone [86]. Otherwise energy will always go to the person who can pay the most for it. While higher taxes might be a short term solution to some problems, it is no long term solution. Because without a change in how energy is distributed and how it is generated the cause of the problem is not dealt with. Focusing on renewable energy systems and managing technologies will not solve all problems resulting from those global crises, but it can help to lead the way to a more secure and cleaner future. Therefore, investing in renewable energy and systems to support a more people focused approach would increase the robustness of energy grids and help to decentralize distribution centers [86]. Enabling stakeholders in entering markets directly, while at the same time increasing the quantity of renewable energy components, would lead to a reduction in emissions of carbon dioxide and increase the quality of the produced energy [74]. Markets, where energy trades are proceeded, are not fit to integrate each individual energy producer. This is why until now energy produced through renewable sources by an individual had to be sold directly to the energy company. Those participants have to accept prices from fixed contracts set by the retail market [58], further benefiting large companies. Within the past years, the number of DERs increased significantly [77], but the generated power is still not able to compete with the production from more traditional systems. New models are introduced in order to adapt to these changes, in the literature, smartgrids are one of these systems, scaling back from one large controlling system to a number of smaller systems, with the benefit of being self-controlled [74].

Using a system in which each participant has the free choice from where and to whom energy is bought or sold is argued to be beneficial both for the individual and the general market utilization. The aim of this work is therefore the development of a new model that is simulating a market with a variable number of participants who trade energy. They can either be only consuming energy from the market or consuming while simultaneously being able to produce energy with the help of DERs and selling that energy to others in the market. A program is developed which is closely connected and based on the existing software NESSI. Thus resulting in the following research questions:

How can participants in energy networks be helped to make freer decisions about selling and buying energy without having to accept market prices provided by a central supplier?

To accompany this, a new approach is developed to test and analyse energy transmissions within a peer-to-peer trading model. While the individual person owning a building, or their energy producing components, should be profiting from a newly developed system, it is also important to keep in mind the complete network. This will also profit a way of less transmission utilization, because of less energy being traded from and to the main power grid. Management of energy is a new upcoming challenge in the field of information systems (IS) [27]. For this purpose, this work is structured as follows: Section 2 explains the theoretical background knowledge as well as the related literature, while section 3 focuses on the methodology. In section 4 the simulated program is developed with objectives derived and the simulation drawn out. In section 5 the testing of the developed program is presented with first establishing an example case, in section 6 results from the applicability check are analyzed and discussed in a more general sense. Section 7 explains limitations to this work as well as recommendations for further enhancements. The last section 8 covers the conclusions of this work and in addition to that a short summary of the sections mentioned above.

8 Conclusions

With the rising number of crises in the energy sector, increasing complexity with the emergence of DERs and a switch towards a more end user focused approach, a new model has to be established to tackle these challenges. In this work, it is shown how market participants are able to make freer choices in using a more decentralized approach and what effects this can have likewise on energy management systems overall. The usage of an agent based model was chosen to manage energy transactions between multiple participants in a local market with connection to a central power grid, as well as different methods to execute these transactions.

Therefore a new simulation program is developed, influenced in its structure by the design science research approach. Objectives are defined to verify the simulation results to be sufficient. Different trading and market clearing model approaches are created to show variations between them and reference cases. Those models are developed with the goal to have an outcome that is economically advantageous for each agent. One of these models is a trading approach with individual pricing rules, where agents in the market send bids to a central system and only matched trades can proceed. Agents are free in the choice of how high those bids are. In the other model a fixed price is set by the user, before starting the simulation to trigger the uniform pricing rule. Benefiting from uniform prices are all agents, not dependent on any personal preference or risk appetite. NESSI is used as a starting point and results from that system are used to run the new pricing models. This is why there is a need to consider special cases to be able to connect from NESSI to the newly developed simulation. The logic of the program is explained and because this version is run from a script, suggestions for the interface design are given to make future implementations into a web based version easier.

Making use of the programmed artifact, it is applied to an example from the literature to verify the models developed. Setting up the script is explained simultaneously and the results of the reference case from a multiple commercially used building complex in Norway compared to the outcomes of the simulation results from both individual pricing and uniform pricing models. Multiple differences in the setup process led to deviations in the outcome. However, it is shown, that the newly developed simulation is able to generate outcomes within a relatively small margin and more importantly, both the individual pricing model and the uniform pricing model are able to outperform the case without applying any model.

The applicability check is analysed both generally and individually for each agents performance with comparing not only the models but also the reference case in cost reduction and energy transmissions. Those results are further discussed on a more general level. Both models are applicable for further development and an ABM is shown to let users make freer decisions and achieve better results. With the simulations it was possible to save approximately 5 % of money, when trades were enabled between agents in the local market. It was shown as well, that the use of peer-to-peer trading in a microgird relieves the main power grid. There is not enough evidence to support any statement about the specific models and which one would perform better, more tests and research has to be done here. It was possible however to make the general remark on performance of those models which was positive.

Limiting factors are the applicability to real life examples, because in this version any energy loss of the transmission are neglected and it's assumed that all agents have a connection to each other in some way. Price findings are also not done with day-ahead trading data, but fixed values and the number of buildings simulated could become a factor, when using the program with high building numbers. With each building the calculations for bids and request is getting more complex and more possibilities have to be checked. It is recommended to further develop the price finding models and add new ones for special cases. Trading money could be done with the blockchain technology, because trades for now are only written down and assigned to agents. An implementation to the NESSI web app version should be done to make the simulation available to a broader audience.

The results of the applicability check as well as the discussion support the conclusion, that using an approach which is following the concept of peer-to-peer trading is beneficial for market participants. Furthermore it is shown, that the amount of energy transmitted over the main power grid connection is decreased through this approach, which can lead to lowering abrasion. It is therefore recommended to develop this further and to add the simulation as one of the options to the web application of NESSI.