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LOCAL PRICING WITH AGENTS IN THE DISTRIBUTION GRID

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Overview

Currently the distribution network is subject to significant changes: The increasing amount of RES capacities implies a volatile and decentralized feed-in instead of a centralized energy production based on large controllable units. And for the near future even more changes are to be expected with the spread of new technologies (e.g. electric cars or heat pumps) that may lead to extreme load situations.

At the same time the development of smart grids promises a flexible grid usage by integrating even small participants such as private households. A bidirectional data exchange and widespread availability of data via smart meters are key elements of such a smart grid environment. A huge amount of storage capacities could then be unleashed in conjunction with new loads and their flexibility – batteries of electric cars and heat capacities of buildings. And smart devices for automation processes may enable an improved power allocation. In the context of increasing amounts of flexible load and RES feed-in, a smart matching of infeeds and demand could avoid costly grid extension.

Yet this requires signals to indicate current grid situations to the participants. Grid congestion arises locally and thus decentralized coordination of supply and demand is necessary. For economists, local prices are a natural candidate for providing such coordination.

But local prices rely on some crucial requirements: Information concerning the load and infeed situation is needed and must be evaluated. Hereby also reactions to changing prices have to be anticipated to avoid avalanche effects. Since the necessary local information is close to detailed individual information of participants the issue of privacy has also to be taken into account.

Method

We use an agent based simulation platform implemented in Java with the framework Jade to simulate real grid situations under various scenarios – with varying market design as well as different rates of RES capacities and weather conditions. Agent-based simulation allows describing in detail the different elements affecting grid and market operation. E.g. an agent of type ‘solar system’ has different characteristics determining its grid usage than a ‘household’ agent. And further on each instance of the agent types has some individual features (e.g. solar radiation at a certain place, equipment and attendance of private consumers etc.).

Local prices are implemented in the agent-based environment via a separate market agent. This market agent computes surcharges (or deductions) to the wholesale-market prices depending on the current congestion situation. As the relief of a congestion situation depends on the individual behavior of each market participant, the market agent organizes a negotiation process. Herein the price is determined using a search algorithm and quantity responses of demand and supply agents to local prices. This approach does not requires centralized storage of supply and demand curves and thus corresponds to a decentralized market design..

Results

We simulate a small network area as a test case, simulating the feed-in and demand behavior of participants. The resulting congestion situation and corresponding local prices are determined in the context of simulated extreme load situations. Thereby we consider two variants: Flexible loads may be available or not. We also investigate two market designs: one the one hand we implement the current German regulation with fixed feed-in remuneration for RES facilities and on the other hand a possible full market integration of renewables, including the use of local prices.

The results show that prices can help improving the grid situation as critical voltage situations are avoided in our test case. But to reach an improvement, prices have to be adjusted locally and taking into account the whole context, namely feed-in, demand, network capacity and available flexibility.

In the case of local prices, the resulting price levels depend on which agents have a price-elastic behavior. The possibility of load adjustments leads to less extreme prices (price adjustments of 30-40€/MWh). In contrast, price adjustments based solely on supply-side flexibility may reach approximately 60€/MWh or even more, when valid fixed feed-in tariffs have to be compensated.

Conclusions

Local prices are computable and can help to improve the network usage. The algorithm is stable and avoids overreactions or unnecessary adjustments. Therefore we have shown the theoretical feasibility of an approach to integrate high amounts of RES capacities and new flexible energy demands. Hereby costly grid extension can be avoided or reduced and deferred. Furthermore we have provided an approach for a decentralized market design and a way to use smart grid environments efficiently.

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