Pricing Mechanisms and Market Designs in Peer-to-Peer Electricity Trading

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Overview

The decline in the price of photovoltaic (PV) cells and battery storages in recent years has led to a broad implementation of small-scale PV installations in households – some including residential storage systems –, transforming customers into "prosumagers" and increasing the rate of self-consumption in those households. This development brought up first pilot projects of local electricity markets in the form of so-called peer-to-peer electricity trading platforms, in part based on the blockchain technology. The market designs and business models in these platforms are however immature, or at an early stage of implementation at best. Most of these pricing schemes lack incentives and opportunities to persuade households to invest, for example, in generation infrastructure or to participate in community trading. In this paper, we compare three pricing mechanisms for local electricity markets with peer-to-peer trading options. We aim at answering the following research questions: Which pricing mechanisms accomplish a fair cost allocation to its participants (prosumagers, prosumers, or consumers)? How should local electricity markets with storage and peer-to-peer trading options be designed to foster the integration of distributed generation?

Methods

We develop a linear model written in the Julia programming language to assess recently discussed pricing mechanisms for a specific local electricity market design. This underlying market design has been developed and analyzed in the seminal papers of Lüth et al. (2018) and Zepter et al. (2019): A smart interconnected community comprises a number of prosumagers and consumers that are allowed to directly trade locally produced electricity among each other. However, the local pricing mechanism applied in these studies follows a limited market driven price scheme and points out room for improvement. Recent studies on pricing schemes (e.g. Fridgen et al. 2018; Liu et al. 2018) concentrate on microgrids, abstracting from practical market integration and neglecting synergy effects of peer-to-peer trading and residential storage options. The aim of this study is, thus, to compare three different pricing mechanisms in order to identify a supportive scheme for peer-to-peer trade in the presence of residential storage systems: (i) cost-optimal community trading activities including pareto-optimality as discussed in Alam et al. (2019); (ii) welfare/profit-maximizing framework including marginal cost curves of distributed generation as developed in Cornélusse et al. (2018), Liu et al. (2018); (iii) auction-based market-clearing algorithms as presented in Khorasany et al. (2019). After an extensive state-of-the-art literature review to define possible pricing mechanisms for local markets, we develop an optimization model depicting a local/regional market comprised of several model households. These represent heterogenous types of consumers, prosumers, and prosumagers with distributed renewable generation as well as battery storage systems. Trading activities are modelled by a transportation model and battery storage operations are incorporated in detail. Figure 1 visualizes a representative community of ten heterogenous households that are clustered in terms of color by their type of community member. The different pricing schemes are evaluated by their monetary value for the end-consumer and their ability to reflect practical market mechanisms.

Figure 1: Community of heterogenous model households (black:prosumagers, light blue: prosumers, dark blue: storage owners, red: consumers)

Source: Own illustration.

Preliminary Results and Conclusions

Preliminary results give an indication how local energy markets should be constructed and operated with respect to remuneration schemes and pricing options. This incentivizes households to partake and invest in necessary infrastructure, for example, rooftop-PV, micro-wind turbines and battery storage systems but also microgrid infrastructure for situations where no grid access currently exists. The choice of a pricing mechanism for local electricity markets highly influences their attractiveness to local participants. All pricing schemes presented in this study lead to a better-off renumeration for locally traded electricity compared to today's flat feed-in tariff structure. However, in most (European) countries regulatory frameworks are still far away from allowing for peer-to-peer trade with independent pricing mechanisms. Recent regulatory guidelines passed by the European Commission (COM 2016, 860 final) ring the bell for a change of long-established market designs. The implementation of local electricity markets with peer-to-peer trade does hence not suffer from technical but rather policy barriers and challenges.

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