System-friendly operation of smart energy communities

Topic 4: Active participation of consumers and prosumers

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Motivation and central research question

The expansion of distributed electricity generation and the increasing capacity of installed battery storage systems (BSS) at the community level have posed challenges to efficient technical and economic operation of the power systems [1]. With advances in smart-grid infrastructure, many innovative demand-response business models have sought to tackle these challenges while creating financial benefits for the participating actors. In this research, we investigate the role of real-time pricing in energy communities (ECs) on the alignment of the operation of distributed storage technologies with the larger energy system. In particular, we assess the impact of ECs on the German electricity market and distribution grids with an extensive share of electromobility.

Methodology

Our methodology is threefold. First, we deploy an existing EC model in which the interaction between a profit-maximizing aggregator and users in an EC is modeled as a bilevel optimization problem [2]. As Figure 1 illustrates, the aggregator uses a prediction of upcoming market prices (P^{M}) and maximum allowed grid usage ($\overline{W}$) to create a set of hourly sale and purchase prices (p^{S} and p^{B}) for the users. In reaction, users with BSS consider their load (L) and generation (G) and optimize their consumption (e^{S}) and feed-in (e^{B}) to minimize their electricity costs. Finally, the aggregator trades in the market according to the users' aggregated grid usage ($W = \sum_i (e_i^{\mathrm{S}} - e_i^{\mathrm{B}})$).
Second, we couple the EC model with the agent-based electricity market model AMIRIS [3]. The EC model receives the market price forecast (P^{M}) from AMIRIS and feeds back the aggregator's supply or demand bids (W) in return. We evaluate the EC operation by assessing the selected system indicators in AMIRIS, such as the market prices.

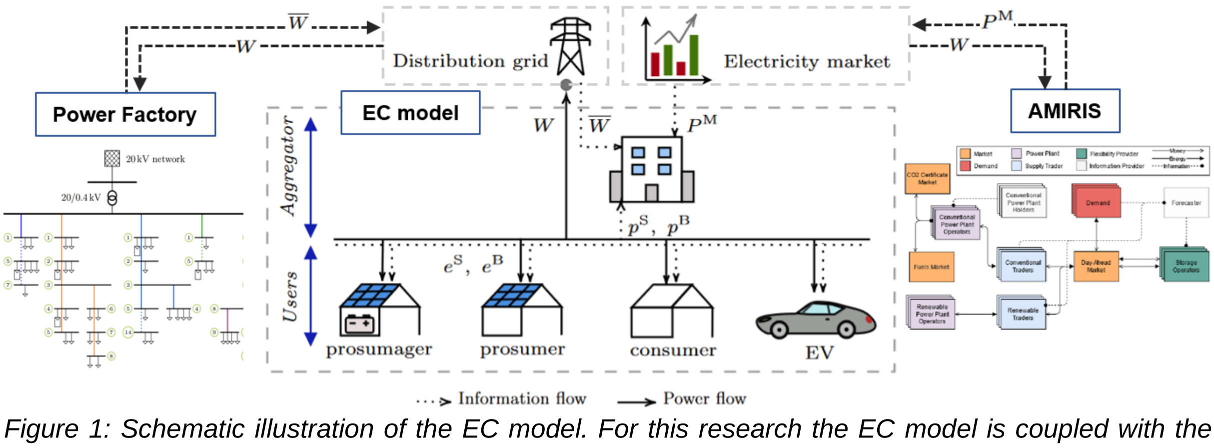

Figure 1: Schematic illustration of the EC model. For this research the EC model is coupled with the electricity market model AMIRIS and a distribution grid modeled using DIgSILENT PowerFactory.

Third, we assess the flexible operation of the EC to ease grid congestions in a low voltage (LV) Simbench grid [5] with many electric vehicles. Our workflow starts with load flow calculations in DIgSILENT PowerFactory, followed by a determination of congestions. On this basis, threshold values $\overline{W}$ are calculated that define power intervals of consumption and feed-in for the EC aggregator within which an improvement of the grid state would be triggered. Next, the EC is optimized, and a new grid

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interaction (W) is delivered to PowerFactory. Finally, considering the new EC dispatch, we perform the load flow simulation again and evaluate the possible improvements in the grid condition.

Results and conclusion

Flexible operation of the newly emerged distributed actors in the power market is crucial for the secure and efficient operation of the energy system. Such operation should be aligned with market signals and respond to the needs of the physical power system. To assess the system benefits of an optimally aggregated EC, we couple an EC model with electricity market and LV grid models.

Figure 2 shows the exemplary dispatch of the EC, parameterized with one prosumager and one consumer for four hours. The market price forecast (Figure 2-A) adopts the minimum value of $P^{\mathrm{M}} = 2.5$ ¢/kWh in the second hour ($t = 2$). In response, the aggregator offers the lowest sale price for this hour ($p^{\mathrm{S}} = 3.5$ ¢/kWh). The prosumager (user 1) takes advantage of the low aggregator price and charges the BSS (Figure 2-B). Due to line capacity restrictions ($W \leq \overline{W}$), the BSS is not charged fully (state of charge (a) reaches 75%, see Figure 2-C). In the next hour ($t = 3$), the EC operates self-sufficient as $\overline{W}$ is set to zero. Lastly, considering the high market price in the last step ($P^{\mathrm{M}} = 9$ ¢/kWh at $t = 4$), the aggregator incentivizes the users to discharge the BSS by offering a relatively high purchase price ($p^{B} = 5$ ¢/kWh). The prosumager discharges the BSS accordingly.

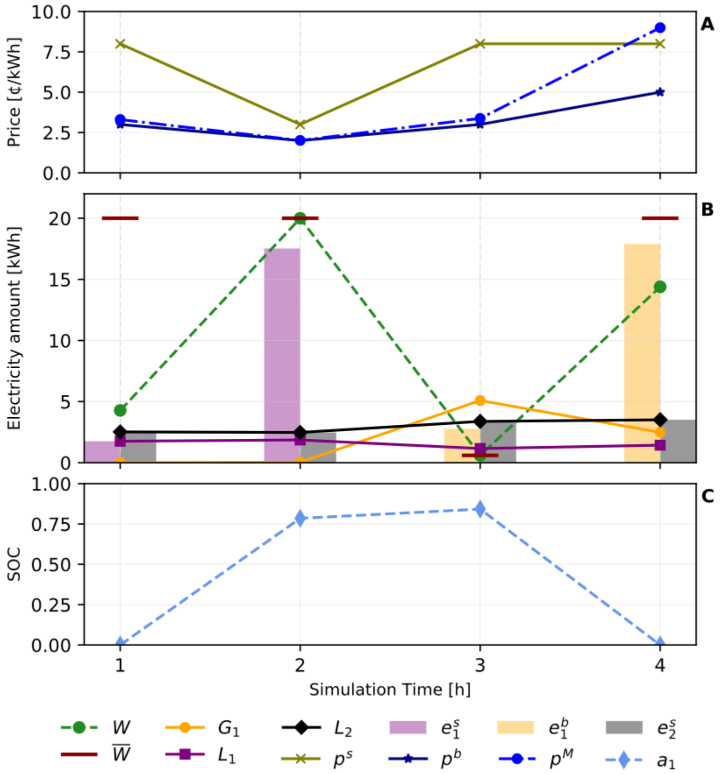

Figure 2: Optimization results for a simple energy community with one prosumager and one consumer. A: Aggregator's and market prices. B: Users' electricity demand and generation, as well as grid usage and feed-in. C: BSS state of charge of the prosumager [2]

Literature

[1] Kakran, Sandeep, and Saurabh Chanana. "Smart operations of smart grids integrated with distributed generation: A review." *Renewable and Sustainable Energy Reviews* 81 (2018): 524-535.

[2] Sarfarazi, Seyedfarzad, et al. " An optimal real-time pricing strategy for aggregating distributed generation and battery storage systems in energy communities: A stochastic bilevel optimization approach." *International Journal of Electrical Power and Energy Systems [Accepted]*.

[3] Deissenroth, Marc, et al. "Assessing the plurality of actors and policy interactions: agent-based modelling of renewable energy market integration." Complexity 2017 (2017).

[4] M Meinecke S, Sarajlić D, Drauz SR, Klettke A, Lauven L-, Rehtanz C, Moser A, Braun M. „SimBench-A benchmark dataset of electric power systems to compare innovative solutions based on power flow analysis." *Energies* 2020;13(12).