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SPECIAL ISSUE PAPER

Poster Abstract: SmartStability

A multi-agent simulation environment for flexibility trading in households

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Abstract The increasing number of volatile energy sources, such as solar power plants, challenges the power network operators, the energy brokers as well as the electricity market actors. In this work, a multi-agent based approach will be introduced that allows multiple households to trade flexibilities, on top of the usual selling of produced energy to the paying consumer. Flexibility trading allows different optimisations for different actors. They can slightly shift their electricity consumption, e.g. by turning boilers on/off, to optimise the system (e.g. follow a predefined schedule). Simulation results indicate that a flexibility market consisting of only few households can already help to optimise the system.

Keywords Flexibility market · Trading · Multi-agent system

1 Introduction

Demand response (cmp. [3]) aims among other things for influencing the demand, e.g. let them follow the available supply. Here a new approach "SmartStability" is presented: households trade flexibility (i.e. load shifting of their appliances) in a smart grid setting and contribute to the network balance. A (local) market coordinator uses a merit-order approach to choose appropriate offers, which are then accepted. The major difference to other existing approaches (even multi-agent-based approaches [1,2,4]) is that here only the flexibilities are traded but not the overall energy consumption or production. The present approach focuses on achieving a predefined optimisation function, e.g. the exact consumption of the provided energy—not more or less—or the network is operated in its limits (peak shaving). If it is assumed that households are also able to provide energy production (e.g. solar panels), then it become obvious that the volatile energy production in the cooperating households needs to be balanced by flexibility trading.

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2 Approach

Our approach simulates every household as an agent that decides individually about the sharing of its flexibilities. It can decide to which price a flexibility is offered to the market. Each household's characteristics, behaviour and flexibility, i.e. supported appliances, can be configured. As an example, it can be defined that a household has photovoltaics and a boiler. The appliances are simulated with the help of available and published formulas. Furthermore, the electricity consumption profile can be selected—measured data of about 100 profiles are available—and the participation in flexibility trading can be set. During the simulation, the household continuously calculates the state of its appliances, like the temperature of the house, the state of the boiler, heat pump, battery or solar panel. Based on that it determines the current electricity need. Additionally, it repeatedly sends flexibility offers to another agent, the market coordinator. The amount of flexibility to offer and its price is being calculated based

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on the appliances' characteristics and current state as well as the household's needs, such as comfort aspects. If the household can offer the flexibility easily then the price is cheap; if it would be difficult to offer it then the price would be high. If an offer is accepted, the household will control the specific appliance accordingly.

The market coordinator only knows about the network state and the connected households, e.g. how much energy all houses consume. Moreover, it also has additional information about the environment, such as weather conditions or current electricity market prices. Several optimisation strategies are available for the market coordinator. As an example, a specific schedule can be followed; and the coordinator then tries to have as little deviation to that schedule as possible (follow a standard load profile or average of last N cycles). Another approach is the optimisation of the network sustainability, e.g. to keep the energy demand within some band limits (peak shaving or band limits where also lower limits needs to be respected).

The trading is cycle-based (e.g. one cycle = 15 min). First, the market coordinator requests flexibility offers from all households for the next cycle (and the consumed energy in the past cycle). Then the coordinator sorts all offers according to their price and offer type, i.e. consuming or spending energy. It selects the cheapest ones from the appropriate type as long as optimisation function is satisfied (e.g deviation is minimised)—comparable to merrit-order. The selected offers are accepted, the household agents are informed and paid. The next cycle starts (Fig. 1).

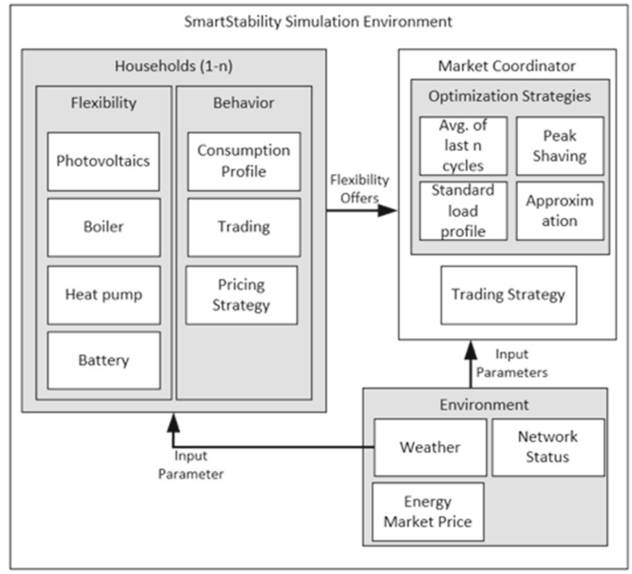

Fig. 1 SmartStability simulation environment blueprint

Table 1 70 households without/with trading

	Without trading (Wh)	With trading (Wh)
Consumption sum	301,708,587	345,881,336
Average objective deviation	15,392	1,620
Maximum objective deviation	74,118	48,055
Sum objective deviation	134,837,936	14,198,585

3 Evaluation

The presented approach was evaluated given the weather data from Basel, 2012, and different simulated load consumptions.[1] In the experiment the number of households was 70, whereas 14 households have a boiler, 16 have a heat pump, four have photovoltaics and 16 have a battery in use. Table 1 concludes the results of the simulation run. The aggregated deviation to the objective decreased from 134,837,936 to 14,198,585 Wh or by 89.5%.

Regarding the households, the presented approach may has the following advantages:

– Each household can decide at any time independently which flexibility it offers. Therefore mitigate the risk that its comfort level is negatively affected.
– Trading of flexibility can bring a financial benefit, which helps to amortise investments in the needed infrastructure but probably also in local energy generation and storage units.

The energy providers benefit from this approach as the flexibility trading gives them the possibility to settle differences from their schedule on the network level, on which the difference occurred. A network operator can balance instabilities and avoid or at least postpone network investments or extensions.

However, at the moment the business model for this approach is unclear. Because flexibilities are traded on top of the normal production/selling principle, only penalties for missing the optimisation goal can be saved by this approach. The amount of the penalties may be too low for a solid revenue stream.

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