LEAFS – ASSESSMENT OF ELECTRICITY STORAGE SYSTEMS AND FLEXIBLE LOADS IN THE DISTRIBUTION GRID

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Overview

Today, layout and dimensioning of distribution grid infrastructure is based on statistical assumptions and historic data for load and generation behavior over time. New technologies, especially small-scale home storage systems and aggregation of demand flexibility by virtual power plant operators, can result in market-driven load profiles based on price signals with potentially high synchronous behavior in a given distribution segment. Without consideration of the local distribution grid limits this might cause thermal overload or voltage band violations. Conversely, a grid coordinated operation has the potential to relieve power grids and reduce such constraints.

This paper analyses the potential benefits of various operation strategies for small-scale energy storage systems and flexible loads using a techno-economic model-based approach. An economic efficiency analysis indicates the added value of each operation strategy.

Methods

The analyses are carried out for a generic distribution network section consisting of 146 households (resp. prosumers). Each prosumer is represented by a PV system, a storage device, a flexible and inflexible load (Figure 1) and pursues a certain strategy (e.g. maximization of self-consumption). Several different strategies to operate a storage system and flexible loads have been considered (Table 1). Each operation strategy is interrelated with a linear optimization problem considering PV generation and the prosumer's inflexible load as exogenous input time series and the storage and flexible load dispatch as decision variables.

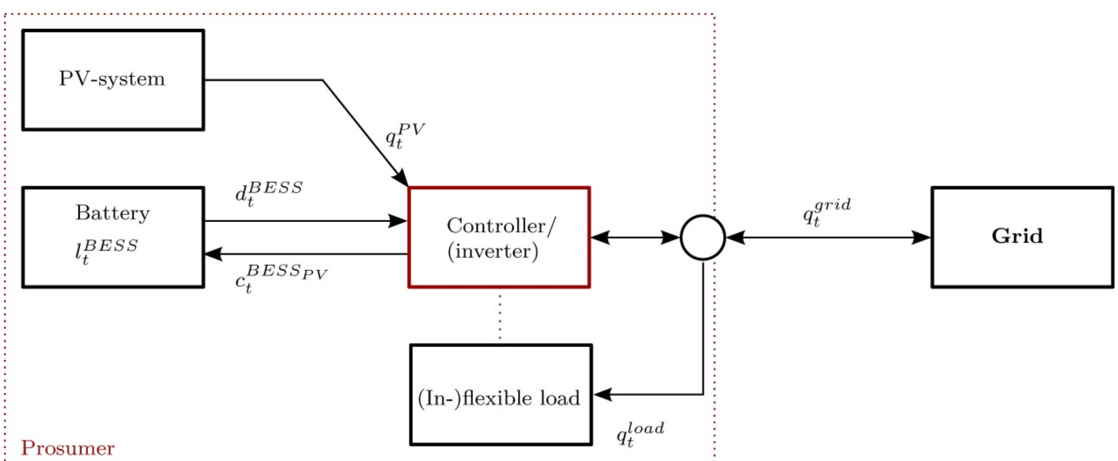

Figure 1. Schematic diagram of a prosumer (a household). It is represented by a photovoltaic (PV) system, a battery energy storage system (BESS), it's flexible and inflexible load.

Table 1. Overview of operation strategies for small-scale storage systems and flexible loads on household level.

Operation strategy	Objective
Maximize self-consumption	This operational strategy aims to minimize the amount of energy a prosumer with access to distributed energy resources (DER) procures from (respectively feeds into) the grid by operation of battery energy storage systems (BESSs) or flexible loads.
Minimize electricity procurement cost	In the event of time variable electricity prices and/or grid tariffs, battery storage and flexible load dispatch aims to minimize the prosumer's total electricity procurement cost by shifting consumption to times with corresponding low prices.
Minimize PV spillage	Assuming the distribution system operator (DSO) is authorized to limit the feed-in power of any PV system within its electricity grid in order to avoid voltage band violations, battery storage and flexible load dispatch aims to limit spillage of PV generation.
Minimize peak load (generation and procurement)	Storage unit and flexible loads are used to minimize the annual peak load and the annual peak feed-in of PV generation of a prosumer.

For each individual consumer in the distribution grid section, a synthetic household-load time series is generated by means of a load profile generator (based on [1]) considering the household's annual energy consumption. PV generation time series are based on historical time series (metered data). The temporal resolution of these time series and thus the optimization models is 1 minute. Consequently, it is possible to derive the short-time peak load in the distribution grid section. which were implemented in MATLAB.

The beneficial effects of each operation strategy for the individual prosumer as well as the distribution grid are evaluated in terms of increase in self-consumption, level of self-sufficiency, total electricity procurement costs, accumulated peak load and peak generation. Revenues resulting for the dispatch of the battery storage system and flexible loads are compared with the costs of each technology in a cost-benefit analysis.

Results

Preliminary results suggest that a simple operation strategy that aims to maximize the prosumer's self-consumption only, have little or no beneficial effects on the distribution grid and fails to reduce the accumulated peak load in the grid section.

Conclusions

Fixed tariffs in electricity prices do not provide incentives to operate a small-scale battery storage system in a grid beneficial way. The development of incentives, such as time variable electricity prices and kW-based grid tariffs on end user level could promote the integration of high amounts of DER in the distribution grid.

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References

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