Energy flexibility in industry: an economic model-based analysis of parallel revenue streams from batteries

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Overview

The growing share of volatile renewable electricity is increasing the stress on the electricity grid: electricity producers must balance sudden power shortfalls on the supply side and distribution system operators need to overcome an increasing number of congestions in the distribution grid. To counter these challenges and generate higher flexibilities on the demand side, different market measures have been implemented. The market for ancillary services has been opened to a growing number of prequalified suppliers of balancing power. The feed-in tariffs for renewable energy have also been drastically reduced, which alongside the achievement of grid parity for some technologies such as photovoltaics (PV) encourages a higher rate of energy self-sufficiency. Furthermore, through grid service charges or bilateral agreements, electricity consumers are motivated to shift their peak loads. (Bolay et al. 2016; Jochem et al. 2014)

Because of their high energy demand, industrial companies can profit from these new flexibility measures. They can generate additional revenue or optimize their cost function. To provide these flexibilities, industrial energy consumers can choose to adapt their production processes to electricity or capacity prices with demand response measures. Especially individual energy intensive processes can be linked to energy prices (Rodríguez-García et al. 2016). In other cases electricity can be integrated as a time-dependent production factor into the production planning process (Atabay et al. 2014; Schultz et al. 2015). On the other hand, many producing companies do not have these options, as their production systems are laid out to achieve the highest utilization of their machine capacities. Additionally, there are further regulatory and knowledge based hurdles for such demand response schemes (Shoreh et al. 2016).

An interesting alternative to demand response is the installation of a battery storage system (BSS). A BSS provides a pseudo-flexibility: a flexible electricity demand can be offered to grid operators and electricity markets via different revenue streams while the production remains unaffected. Like self-sufficiency-optimization, peak shaving or the provision of ancillary services, various marketing schemes for the flexibility from BSSs in industries have been individually examined (Thielmann et al. 2015; Gallo et al. 2016). But one unique attribute of BSSs is the ability to follow different business models simultaneously (Reid und Julve 2016). In many publications, this possibility is mentioned but the potential has never been thoroughly studied (Stephan et al. 2016), especially not with the focus on an industrial application.

An additional incentive to combine a BSS and industrial production is the opportunity to charge the BSS through different revenue streams and use the stored energy in the internal production process. In the case of balancing power, after a period of negative balancing power demand the stored energy can be fed into the production process to maintain the state of charge (SOC) of the BSS of 50%.

This paper evaluates the economic potential of energy flexibility in different German small and medium-sized enterprises (SMEs) through the installation of a Battery Storage System following different marketing schemes in parallel. The focus is on peak shifting and shaving, optimized self-sufficiency, provision of primary balancing power and energy-arbitrage-trading.

Methods

The energy system of an industrial manufacturing plant is modelled as a mixed integer linear program (MILP) with an extended version of the energy model presented in (Merkel et al. 2015). With a 15-minute resolution, the model optimizes the integration of energy profiles from self-generated PV and wind power, considering the industry's electricity load profile. The model offers the option to invest in BSSs with different capacities, with the objective of minimizing the overall cost and identifying the optimal size of the BSS. Previous versions of the model focus on one objective, namely that of minimizing costs, but in this contribution the model will be extended to account for multiple, partly competing objectives. Hence, the combination of peak shifting and shaving, optimized self-sufficiency, provision of primary balancing power and energy-arbitrage-trading, will be optimized based on a maximisation of achieved revenues. The model chooses the most profitable business model to charge the BSS and can choose more than one revenue stream simultaneously. To further compare the results, a previously developed flexibility indicator is used.

Input Data and Assumptions

This paper analyses the electricity demand profiles of ten case studies of German SMEs. The profiles range from a peak power demand of around 100 kW to roughly 4.7 MW. The analysis covers homogeneous power profiles for example in a water treatment plant as well as heterogeneous profiles in manufacturing companies. The demand profiles are anonymous and have a 15-minute resolution for the complete year of 2016. On the power supply side, the study includes the intraday prices at the European Energy Exchange and the prices for primary balancing power both for Germany. This paper focuses on the average bid prices. To access the different markets, the energy demand and battery capacities of multiple industrial companies can be aggregated. On the cost side of the model, different cost levels for the BSS are evaluated to examine the effects of reducing BSS prices through technological advances. Furthermore, systemic costs are considered, especially costs related to the connection to the grid. Additionally, the model includes the battery degradation effects of the different business models. Different revenue streams are appointed different degradation factors.

Results

The results show the potential to combine these different business models for the BSS under current and possible future framework conditions. For a selection of representative industrial load profiles, the results deliver insights into the profitability of these individual and combined business models for these cases. Specifically, the results consist of energy, CO2 emissions, achieved degree of flexibility and economic costs/benefits for a combination of business models and industrial consumers. As the model determines the minimal cost of the system, the optimal size of the BSS, the dispatch schedule of the BSS, the CO_2-emissions and the battery lifetime, insights related to the trade-offs between different strategies are obtained. Depending on the industry’s load profile, the BSS may follow more than just one business model, for example charging the BSS to avoid peak loads. In parallel, this determines the amount of balancing power offered for grid stability. In order to maximize the battery lifetime, the model avoids high depth of discharge and therefore excludes energy arbitrage trading. In contrast, the extended lifetime lowers the economic return.

Conclusion and Outlook

This paper shows that the profitability for industrial companies to install a BSS can be increased if the BSS is allowed to market its stored energy via different business models simultaneously. During times when the BSS is neither actively charging nor discharging, the storage capacity represents idle capital. Enabling the BSS to follow various business models simultaneously can increase a company’s return on investment. This depends strongly on the individual load profile of the industrial producer. The heterogeneity inside industrial sectors presents a challenge to obtaining a general conclusion about the profitability of BSSs. However, aligning the operation of the BSS with the company’s goal of minimizing the overall CO_2-footprint, might lead to an extension of the battery lifetime, which in turn represents a compromise compared to the optimal cost scenario.

For future studies, additional revenue streams should be included in the model, like secondary and minute reserve power as well as the day-ahead energy market. Furthermore, other services provided by the BSS should be considered, for example the provision of back-up power or the increase of power quality. Thereby, the capacity of the battery can be fully exploited. To fulfil the preconditions to access these different markets the bid sizes for the energy and power packages need to be considered. Furthermore, the legal framework should be more closly analysed. The aggregation of demand and supply is an abstraction from the spatial proximity that needs to be given in order to provide power from the BSS to the internal production process. Finally, the systemic costs and battery degradation behaviour should be examined in greater detail as they represent important factors for the profitability of the BSS.

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