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Evaluation of business possibilities of energy storage at commercial and industrial consumers – A case study

Bálint Hartmann[a,*], Dániel Divényi[a], István Vokony[b]

[a] Budapest University of Technology and Economics, Department of Electric Power Engineering, Egry József út 18, 1111 Budapest, Hungary
[b] E.ON Business Services Hungary Kft., Váci út 17, 1134 Budapest, Hungary

HIGHLIGHTS

- Multiobjective optimisation of energy storage strategies based on linear programming.
- Cost reduction possibilities for commercial and industrial consumers through use of energy storage.
- Flexible toolset for cost-benefit analysis of battery energy storage.
- Case study of real consumers.

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ABSTRACT

As the interest in energy storage units is increasing in the power sector, significant effort is being put into evaluating technological and business opportunities. However, many studies narrow their examinations and pursue a single goal, which may create false enthusiasm for energy storage. To tackle such issues, complex technical-economical case studies are necessary, with solid input data and real life applications, where the application of storage could generate revenue.

In this paper, a recent study is presented, which aimed to examine the profitability of an energy storage unit, installed at an industrial or commercial consumer. The storage strategy was created through an optimization process considering two aspects: to decrease the power draw from the grid during peak hours and to decrease energy consumption of peak hours by shifting the needs to off-peak periods. A quasi-automatic decision support system was developed, which can determine parameters of the storage unit based on user defined inputs. Market potential of the idea was evaluated using data of a group of potential customers. Results have shown that the specified application can create positive net present value under certain circumstances.

1. Introduction

Recent years have put energy storage applications into the focus of the power industry. Investors and research bodies are both putting enormous effort into evaluating technological and business opportunities, since the flexibility challenge caused by the increasing penetration of renewable generation is expected to be solved at least partly by energy storage. Due to the fast cost reduction the sector is enthusiastic about the future and storage is often entitled as the "game changer" or the "disruptive technology" that is expected to transform the way professionals think about the power sector. It can be said with great certainty that new business models need to be developed to fully exploit the potential of storage [1–3].

To achieve this a new way of thinking should be introduced, especially when creating cost models and defining values of storage. Since these are largely determined by the actual application, the importance of properly defined case studies has also gained more attention. As most of currently discussed storage applications are related to the issue of intermittent renewable production, cost modelling usually follows the same approach that is used in case of renewables namely to use levelized cost metrics (e.g. levelized cost of electricity – LCOE). While this routine is relatively easily used to select the cheapest technological alternative for a given task, it misses an important indicator of storage applications: the added value of energy storage. Aiming to eliminate this problem, the power industry is still discussing the correct approach that enables us to calculate costs and values of storage in a comparable way. One of these approaches suggests the use of a new metric the levelized cost of storage (LCOS), which is a modified and

* Corresponding author.
E-mail address: hartmann.balint@vet.bme.hu (B. Hartmann).

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Nomenclature

P^{contr}	contracted power for the year [kW]
p_q	energy price [HUF/kWh]
P_q^{hist}	historical value of consumption [kW]
P_q^{mod}	power of the consumer, modified with the action of the storage [kW]
P_q^{stor}	power of the storage for given quarter hour (positive in case of charge) [kW]
$P_q^{stor,e}$	power of the storage for given quarter hour if discharged [kW]
$P_q^{stor,f}$	power of the storage for given quarter hour if charged [kW]
$P^{stor,\max}$	rated power of storage [kW]
q	index of quarter hours
SoC_{first}	initial SoC in the beginning of the day – result of the previous energy-optimization iterations
SoC^{max}	capacity of the storage [kWh]
SoC_q	state-of-charge of the storage in the beginning of given quarter-hour
SoC^{req}	required SoC at the end of the day – determined from previous calculations of power-optimization step
η_e	efficiency of discharge actions
η_f	efficiency of charge actions

improved version of LCOE, able to take into consideration not only the energy flow of the storage unit but also possible revenues gained through services, provided by it [4].

It has to be noted though that use of such metric will only lead to valuable results if storage is examined through holistic case studies in context, rather than focusing solely on cost estimations. It is also important to recognize that case studies are always examined in a certain geographical context as it is the local energy market and regulations that critically determine the possible revenues. Present paper aims to answer both challenges as it introduces a specific case study that was ordered by a distribution system operator (DSO) company, aiming to find profitable scenarios for energy storage application. The storage strategy had to be optimized for two aspects: to decrease the power draw from the grid during peak hours and to decrease energy consumption of peak hours by shifting the needs to off-peak periods. The developed quasi-automatic decision support system has been tested on real client data provided by the DSO, thus market potential of the idea was evaluated on potential customers.

As it has been mentioned, issues related to energy storage are one of the most widely discussed in the literature. Therefore, only a limited summary is given by the authors focusing on recent journal papers while highlighting all that are related to present study. The literature can be grouped per several aspects; the authors have arbitrarily created three such groups with papers sharing something in common. The first group of papers focuses dominantly on the grid integration effects of intermittent renewables, especially in case of high penetration levels. Most of such papers are aiming to create sizing and location selecting methods that can determine the optimal installation and use of energy storage units. The key driver in these studies is that generation patterns of variable renewable energy sources are studied to characterize the uncertainty, which can later be used to determine rated power and energy levels of energy storage. Most of these studies are primarily focused on technical issues and it is also very common to use general energy storage models instead of narrowing the choice to a few technologies (usually batteries). The authors of [5] use linear programming for peak load management of a grid-connected hybrid solar photovoltaic-storage system. Net present values are calculated based on prices from 2011. In [6] two complementary simulation methods are proposed to determine optimal size of energy storage to support integration of wind power. A rule-based power management operation is discussed in [7], where the goal is to smooth the output power of a solar photovoltaic plant. System integration of intermittent renewables is also a focal point of [8]. The authors use mixed-integer linear programming to compare profitability of conventional generators and storage technologies in this aspect. A decision-tree based approach is used is used by the authors of [9] to aid planning of energy storage systems within microgrids with significant renewable generation. Low-voltage network services (namely the reduction of consumption peaks) are examined in [10], where both placement and sizing aspects are discussed. A similar demand-side management approach is introduced in [11] by the use of thermal energy storage coupled with photovoltaic production and controllable loads of industrial consumers. Optimal sizing an operation planning are among the goals of [12], where energy storage is operated in order to reduce adverse effects of renewable sources. In a two-step process first an approximate solution is determined, then operation of the storage is set by a rule-based control scheme.

The second, well characterized group puts more emphasis on the actual operation of the storage by examinations that optimize the location and/or the charge-discharge pattern of the unit. In [13] optimal allocation of distributed energy storage systems is examined in a distribution network environment, aiming balancing and grid support services. A Lagrangian relaxation-based mechanism is introduced in [14] to optimize active and reactive power coordination in microgrids with high variable renewable energy penetration and energy storage units. The results are also supported by case studies that increase the contribution of the paper. The cooperation of storage and demand-side management is modelled in [15], using a multistage optimization, showing that centralized installations are more beneficious on distribution level. Active distribution grids are put in focus in [16] as well using probabilistic optimal power flow simulations to properly determine the best use of energy storage. A stochastic programming model is used in [17] to optimize the operation of a renewable-based grid, and in [18], where costs of the storage are also considered. In [19] an intelligent, heuristic based battery scheduling system and forecasting is used to perform and optimal scheduling of the storage unit, installed in low-voltage distribution networks. The two main objectives are peak-shifting and balancing of the three phases, which were met through the use of the proposed system. However, most studies focus on distribution network issues there are also examinations considering the installation of storage units in the transmission grid e.g. [20].

The third group consist of papers that are closely related to present study in terms of methodology and key points of the research. They are aiming to solve actual and relevant technical and/or business issues, and to achieve this detailed cost modelling is inevitable. It can be recognized that many of these issues are still related to variable renewable energy sources, but different motivations are also found. Aggregated economic benefits of utilizing electric vehicles as distributed energy storage in commercial buildings is shown in [21]. By using a mixed-integer linear programming, the storage is dominantly used to transfer low-cost electricity from residential buildings to the commercial microgrid, thus minimizing costs.

A mixed integer linear programming model is proposed in [22] to coordinate interdependent services, provided by a group of energy storage units on distribution level. Several high-level statements are made by the authors, which all reflect on the complex nature of optimizing the profit of the portfolio. Auxiliary services, namely arbitrage options are also examined in [23], where optimal size of pumped-hydro storage is determined under different market constructions. It is shown that however storage does have a value in such operation, this value significantly decreases as markets become more integrated. Authors of [24] address management and sizing problems of energy storage

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