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Sharing economy as a new business model for energy storage systems

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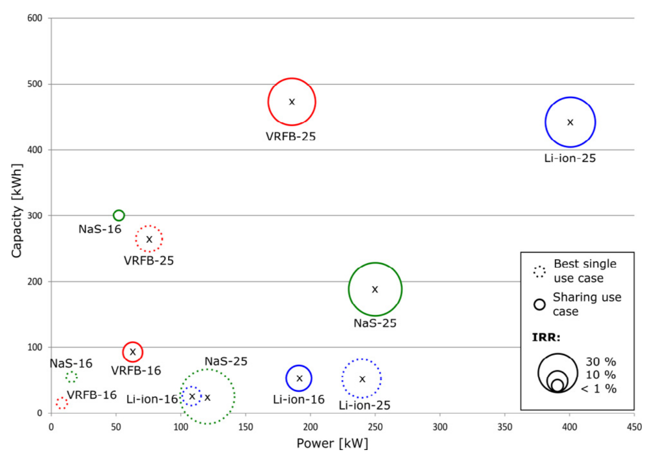
HIGHLIGHTS

- Sharing economy as new business model for Energy Storage Operators.
- More attractiveness of Battery Storage Systems.
- Optimal Dimensioning of Battery Storage Systems for sharing economy application.

GRAPHICAL ABSTRACT



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ABSTRACT

Energy storage systems (ESS) are the candidate solution to integrate the high amount of electric power generated by volatile renewable energy sources into the electric grid. However, even though the investment costs of some ESS technologies have decreased over the last few years, few business models seem to be attractive for investors. In most of these models, ESS are applied only for one use case, such as primary control reserve.

In this study, a business model based on the sharing economy principle has been developed and analyzed. In this model, the energy storage operator offers its storage system to different kinds of customers. Each customer uses the ESS for their single use case. A set of different use cases has been identified to make the operation of the ESS profitable (e.g. peak shaving, self-consumption and day-ahead market participation). Different kinds of stationary batteries (lithium-ion, sodium-sulfur and vanadium redox-flow) have been considered as energy storage technologies, which differ both in their investment costs and their technical properties, such as round-trip efficiency. The simulation of the business model developed showed that a sharing economy-based model may increase the profitability of operating a battery storage system compared to the single use case business model. Additionally, larger battery dimensions regarding power and capacity were found to be profitable and resulted in an increased revenue stream.

1. Introduction

The integration of high amounts of electric power generated by volatile renewable energy sources (RES) is a very complex and demanding issue due to its geographic limitations and stochastic

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Nomenclature

Acronyms

P_{BESS}	charged or discharged power
f_{sd}	self-discharge factor
$f_{d,cal}$	calendric degradation factor,
$f_{d,cyc}$	cyclic degradation factor
$\tau_{li,\ cal}$	projected lifetime
BESS	battery energy storage systems
C&I	commercial and industrial
C_{nom}	nominal battery capacity,
cr	charge ratio
DoD	depth of discharge
EAC	equalized annual costs
EES	energy storage systems
IRR	internal rate of return
LCOE	levelized costs of energy storage
Li-ion	lithium-ion
NaS	sodium-sulfur
NPV	net present value
NRMSE	normalized root-mean-square error
PS	peak shaving
PV	photovoltaic
reBAP	specific imbalance energy price
RES	renewable energy sources
SA	schedule adherence
SC	self consumption
SoC	state of charge
SoH	state of health
TSO	transmission system operators
VRF	vanadium redox flow
η	roundtrip efficiency

nature [1]. More flexible options are necessary to solve this task and ease the stress on the electric infrastructure [2]. Flexibility in the electricity system can be created on the demand side (active customers with demand side management programs) [3,4], on the generation side (e.g. dispatchable power plants) and by grid expansion on the transmission and distribution level [3,5]. A fourth possibility is the use energy storage systems (ESS) [3]. Many studies have depicted the contribution they can offer for integrating the volatile renewables. In [6] the optimal siting of battery storage systems in a low network grid with high penetration of photovoltaic plants has been analyzed. A similar analysis has been done in a medium voltage network with high penetration of onshore wind parks [7]. A technical and economic analysis of an adiabatic compressed air storage system used in a medium voltage network to optimally manage the grid congestion due to the generation by renewables has been analyzed in [8]. An economic analysis of using ESS to avoid and deferral network upgrades has been pointed in [9,10]. The solution to use the "power to gas" technology for integrating RES has been investigated in [11,12]. The contribution offered by mobile storage systems in distributed system with high penetration of RES has been analyzed in [13–15]. Among the ESS technologies, the stationary battery ESS (BESS) are the most versatile in location, size and application [16,17]. Although some battery technologies are already mature and their investment costs have decreased over the last few years, few business models seem to be attractive for investors [17]. The batteries in most business models are used only for a single use case (i.e. to supply ancillary service to the system operator). In such business cases based on a single application, the yearly operating time is very limited (normally a few hundreds of full load hours), which implies a longer amortization time and a high annual capital cost [18,19]. A further improvement of the profitability can be expected if more than one use case is performed by a single battery [20,21]. Operating the battery for multiuse cases could increase the yearly operation time and, thereby, enables the investor (or investors) to generate higher revenue. This leads to a faster amortization time and higher profitability.

The aim of this work is to explore whether a new business model based on the shared battery paradigm is already a feasible business case today or could be a possible business case by 2025. Battery sharing could definitely increase the operator's income, but the business case is also accompanied by technical and legal hurdles that have to be taken in consideration. The temporal accessibility will play an important role and might lower the revenue of the users compared to a single case operation.

In the next sections, the possible battery use cases are presented and the implementation of battery operation into the sharing economy paradigm is illustrated. An overview of the battery parameters employed and the methodology of the simulation model is given in Section 2. The battery use cases and the sharing economy principle are presented in Sections 3 and 4. Descriptions of the use cases are given in Section 5. The following results and issues of the simulation are presented and discussed in Section 6, before Section 7 summarizes the central conclusions and offers a future outlook.

2. Applications and business cases

A BESS is theoretically capable of meeting many different demands. The multitude of applications is classified into two broad categories: short-term power applications and long-term energy applications. Possible economic business cases with regard to (dis-)charge duration and occurrences are visible in Fig. 1. Some business models, such as the primary control reserve, need to charge and discharge the battery for a few minutes and this is required almost every hour. Other business models, such as that for demand side management, require a larger storage capacity (up to different hours) and are in demand once a week or month.

Many power applications are characterized by a transient or at least hourly utilization, which lowers the motivation for additional applications, because the battery is supposedly well occupied. On the other hand, the spectrum of applications with a focus on durations of more than 1 h and infrequent battery demand seems very attractive for a sharing business case. Demand side applications in the form of peak shaving (PS), bulk energy storage in the form of RES self-consumption (SC) and RES schedule adherence (SA) are hence selected as use cases for the simulation in this study. Three battery technologies have been considered: lithium-ion (Li-ion), high temperature sodium-sulfur (NaS) and vanadium redox flow (VRF) batteries. All of them are suitable for the use cases selected [22]. The target customers are small and medium sized businesses, which often lack interest in permanent usage, financial power and know-how to invest in their own battery system.

3. Sharing economy

A huge potential for increasing the non-energetic efficiency of resources is created by substituting private ownership with temporary sharing, which benefits both the environment and the economy [23,24]. The main economic motivation of applying the