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Economic feasibility of stationary electrochemical storages for electric bill management applications: The Italian scenario

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HIGHLIGHTS

- We examine the convenience of using BESS to reduce customer electricity bill.
- We make a comparison among different types of batteries for end-user applications.
- We evaluate the convenience of using storage in presence of demand charges.
- A parametric analysis changing the BESS cost, electricity prices and demand charges has been carried out.
- A case study is performed to show the advantages/disadvantages of this approach.

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ABSTRACT

Battery energy storage systems (BESSs) are expected to become a fundamental element of the electricity infrastructure, thanks to their ability to decouple generation and demand over time. BESSs can also be used to store electricity during low-price hours, when the demand is low, and to meet the demand during peak hours, thus leading to savings for the consumer. This work focuses on the economic viability of BESS from the point of view of the electricity customer. The analysis refers to a lithium-ion (Li-ion), an advanced lead-acid, a zinc-based, a sodium-sulphur (NaS) and a flow battery. The total investment and replacement costs are estimated in order to calculate the cumulated cash flow, the net present value (NPV) and the internal rate of return (IRR) of the investment. A parametric analysis is further carried out under two different assumptions: a) varying the difference between high and low electricity prices, b) varying the peak demand charges. The analysis reveals that some electrochemical technologies are more suitable than others for electric bill management applications, and that a profit for the customer can be reached only with a significant difference between high and low electricity prices or when high peak demand charges are applied.

1. Introduction

Stationary energy storage systems (ESSs) are gaining a lot of interest in recent years, mainly because of the deployment of renewable energy sources (RESs) in the electricity sector, like wind and solar photovoltaic (PV) (Campoccia et al., 2008; Telaretti and Dusonchet, 2014; Pecoraro et al., 2015; Favuzza et al., 2015). Indeed, the variability and non-dispatchable nature of the energy produced by these renewable sources has led to concerns regarding the stability and the reliability of the power grid (Bueno et al., 2016). ESSs represent a valid solution to the stability problems, mainly thanks to their ability to decouple generation and demand over time, also providing the ancillary services necessary to ensure a proper operation of the power system. For these reasons, ESSs are expected to become a fundamental element of the electricity infrastructure in the coming years. Among energy storage technologies, electrochemical storage systems attracted the interest of the scientific, industrial and political community, thanks to their favourable characteristics such as fast response time, modularity and scalability. Furthermore, many electrochemical technologies have a high cost reduction potential, although several problems remain to be solved, such as safety issues, utility acceptance, and regulatory barriers.

ESSs can provide many benefits to the power grid, that can be classified as (Divya and Østergaard, 2009; Sandia, 2010; Sutanto and Lachs, 1997):

- benefits related to load/generation shifting;

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Nomenclature

BESS	battery energy storage system.
BOP	balance of plant.
DOD	depth-of-discharge.
DOE	department of energy.
ESS	energy storage system.
HV	high voltage.
IRR	internal rate of return.
Li-ion	lithium-ion.
LV	low voltage.
MV	medium voltage.
NaS	sodium–sulphur.
NY	New York.
NPV	net present value.
O&M	operation and management.
PCS	power conversion system.
PV	photovoltaic
RES	renewable energy source.
SLA	sealed batteries.
SOC	state-of-charge.
TEPCO	Tokyo electric power company.
TOU	time-of use.
TSO	transmission system operator.
T&D	transmission and distribution.
VRB	vanadium redox battery.
VRLA	valve regulated lead-acid.
WACC	weighted average cost of capital.

- benefits related to ancillary services;
- benefits related to grid system applications.

A description of energy storage applications according to the Department of Energy (DOE) database is reported in Table A1 of Appendix A (Sandia, 2016). In all these applications, custom devices need to be used to ensure a proper interconnection and a reliable control system, according to national technical specifications (Ippolito et al., 2013; Falvo et al., 2015; Ippolito et al., 2014a, 2014b; Cataliotti et al., 2013).

Among many applications, ESSs can also be used to store electricity during low-price hours, when the demand is low, and to meet the demand during peak hours, thus leading to savings for the consumer. This application, also known as Time-of-Use (TOU) energy cost management, could yield major benefits, including a reduced need for peak generation (particularly from expensive peaking plants) and reduced charge on transmission and distribution (T&D) systems.

This work focuses on the economic viability of stationary battery systems from the point of view of the electricity customer.

The analysis refers to a lithium ion (Li-ion), an advanced lead-acid, a zinc-based, a sodium-sulphur (NaS) and a flow battery. The case study focuses on a commercial facility, a food supermarket located in climatic zone E (RDS, 2008).

The total investment and replacement costs are estimated in order to calculate the cumulated cash flow, the net present value (NPV) and the internal rate of return (IRR) for the battery energy storage systems (BESSs) used in load shifting applications. A range of updated investment and replacement costs is considered for each electrochemical technology, and the economical evaluations are repeated for each extreme value (minimum and maximum). Furthermore, based on the capital cost decrease for each BESS technology estimated in the next five years, the economic indicators are recalculated and final considerations are presented. As a further step, a parametric analysis is carried out under two different assumptions: a) varying the difference between high and low electricity prices, b) varying the peak demand charges. The analysis reveals that some electrochemical technologies are more suitable than others for electric bill management applications and that a profit for the customer can be reached only with a significant difference between high and low electricity prices or when high peak demand charges are applied. Simulation results also show how the facility power profile varies as a consequence of the storage operation.

The remainder of the paper is organized as follows. Section 2 describes the state-of-the art in the electrochemical storage sector. Section 3 provides an overview of stationary electrochemical technologies. Section 4 describes the economic formulation and the operational assumptions. Section 5 presents the case study, showing the seasonal power profiles with and without storage contribution. Section 6 describes the simulation results. Finally, Section 7 summarizes the conclusion of the work.

2. State-of-the art

The evaluation of the economic feasibility of a storage system has been addressed by several authors in the literature. Walawalkar et al. (2007) considered a NaS battery for arbitrage and flywheels for frequency control in the New York (NY) City region. The analysis indicates that both energy storage technologies have a high probability of positive NPV for both energy arbitrage and regulation. Sioshansi et al. (2009) analyzed the arbitrage value of a price-taking storage device in the U.S. during a six-year period from 2002 to 2007, to understand the impact of fuel prices, transmission constraints, efficiency, storage capacity, and fuel mix. Dufo-Lopez et al. (2009) found that the selling price of the energy provided by the batteries during peak hours should be between 0.22 and 0.66 €/kW h, in order to gain the arbitrage breakeven point of a wind–battery system installed in Spain. Campoccia et al. (2009) evaluate the effects of the installation of ice thermal ESSs for cooling on the power daily profile of residential buildings, and examine the economic repercussions on the electricity billing. Ekman and Jensen (2010) analyzed a number of large scale electricity storage technologies, concluding that the possible revenues from arbitrage on the Danish spot market are significantly lower than the estimated costs of purchasing an electricity storage system, regardless of the storage technology.

Shcherbakova et al. (2014) simulated the operation of small storage devices in South Korea, showing that the present market conditions do not provide sufficient economic incentives for energy arbitrage using NaS or lithium-ion (Li-ion) batteries. Telaretti et al. (2014) described the application to a medium-scale public facility of a simple BESS operating strategy which aims to maximize the arbitrage customer savings, highlighting the variation of the power profile as a result of the proposed charging strategy. The battery operating strategy has been further expanded and generalized in Telaretti et al. (2015).

Graditi et al. (2014) and Graditi et al. (2016) have recently evaluated the economic viability of using a Li-ion, a NaS and a vanadium redox battery (VRB) for TOU applications at a consumer level, when flexible electricity tariffs are applied. A parametric analysis is also performed by changing the capital cost of the batteries and the difference between the maximum and the minimum electricity price, revealing that the use of BESSs for TOU applications can be economically advantageous for a medium-scale public institution facility only if there is a significant difference between maximum and minimum electricity prices. Ippolito et al. (2015) evaluated the economic viability