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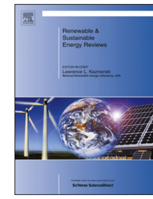

Technical and economical assessment of distributed electrochemical storages for load shifting applications: An Italian case study

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ABSTRACT

Time-of-use (TOU) energy cost management involves the use of energy storage systems (ESSs) by customers to reduce their electricity bills. The ESS is charged during off-peak time periods, when electricity energy prices are low, and discharged during times when on-peak energy prices are applied. This article addresses the question whether it is economically viable to install medium-scale distributed ESSs designed to lower the electricity cost for a customer-side application, assuming flexible electricity tariffs. The technical/economical evaluation is carried out referring to lithium-ion (Li-ion), sodium sulfur (NaS) and vanadium redox battery (VRB) technologies, performing a parametric analysis by changing the capital cost of the batteries and the difference between the maximum and minimum electricity price. A case study is performed to show the advantages/disadvantages of the proposed approach. The analysis reveals that, at the current costs of ESSs, the use of batteries for TOU applications is economically advantageous for a public institution facility in Italy only if there is a significant difference between the maximum and the minimum electricity price. The decrease in the cost of storage, stimulated by the implementation of support policies, will make ESS even more convenient for load shifting applications.

Contents

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Nomenclature

AEEG	Regulatory Authority for Electricity and Gas
BESS	Battery Energy Storage System
BOP	Balance Of Plant
CAES	Compressed Air Energy Storage
DEIM	Department of Energy, Information Engineering and Mathematical Models
DOD	Depth-Of-Discharge
DSO	Distribution System Operator
ESS	Energy Storage System
IRR	Internal Rate of ReturnLi-ion Lithium-ion
NaS	Sodium-sulfur
NiCd	Nickel–cadmium
NiZn	Nickel-zinc
NY	New York
NPV	Net Present Value
O&M	Operation and Management
PBP	Pay-Back Period
PCS	Power Conversion System
PLS	Permanent Load Shifting
PHS	Pumped Hydroelectric Storage
PNNL	Pacific Northwest National Laboratory
PV	Photovoltaic
RTP	Real-Time Pricing
RES	Renewable Energy Source
SGIP	Self-Generation Incentive Program
SOC	State-Of-Charge
SMES	Superconducting Magnetic Energy Storage
TOU	Time-Of Use
TSO	Transmission System Operator
T&D	Transmission and Distribution
VRB	Vanadium Redox Battery
WACC	Weighted Average Cost of Capital

1. Introduction

Decentralized production and the introduction of variable, fluctuating sources (such as solar or wind energy) pose severe disadvantages for the competitiveness of renewable energy sources (RESs) in the electricity market and could ultimately limit their expansion. The variability and non-dispatchable nature of renewable sources has led to concerns regarding the reliability and stability of associated electric systems [1]. Energy storage systems (ESSs) represent the most significant solution to the aforementioned problems and are poised to become a fundamental element of the electricity infrastructure of the future [2]. Besides, the use of storage systems will increasingly be required to alleviate the impact of intermittent generation in the electricity network, as a result of the exponential growth of the photovoltaic (PV) and wind markets all over the world [3–5].

A primary characteristic of the electrical system is that generation and demand need to be in balance for each time interval. In order to ensure this condition, the transmission system operator (TSO) is obliged to keep additional capacity available in order to meet deviations from the forecast demands and to compensate for losses on transmission lines and in traditional power plants, or other contingencies [6]. At present, only energy producers and large industrial facilities are able to adjust their production and demand in order to stabilize the grid. Public institutions or commercial and residential customers have not yet been involved in balancing the electric system. In Italy, this situation has changed in recent years, as load-dependent tariffs have been introduced.

A first example of dynamic pricing tariff is TOU pricing, that provides two or three periods of different electricity price (generally “on-peak”, “mid-peak” and “off-peak” prices), depending on the hour of day. Electricity users are advised in advance about electricity prices, that are not normally modified more than once or twice per year. A more flexible electricity pricing scheme is real-time pricing (RTP), for which the retail electricity price closely reflects the wholesale energy price. In this case, customer electricity prices can vary hourly depending on the wholesale market and electricity users can manage their power consumption in a more flexible and economical manner, taking advantage of the price differential.

2. Literature review and contributions

The evaluation of the economic feasibility of a storage system is a very important issue. Works in the literature differ on the economic feasibility of storage devices. Some authors find that load shifting benefits are not sufficient to offset the upfront investment cost of the storage systems, while other authors find more promising results.

Walawalkar et al. [7] consider sodium–sulfur (NaS) batteries for arbitrage and flywheels for frequency control in the New York (NY) City region. The analysis indicates that both NaS batteries and flywheels have a high probability of positive NPV for both energy arbitrage and regulation. They also conclude that storage efficiency is a primary factor for developing storage systems in a competitive electricity market. This optimistic results contradict the results of the Pacific Northwest National Laboratory (PNNL) [8] which is pessimistic on the prospects of battery systems for load shifting applications.

In [9] Sioshansi et al. analyze the arbitrage value of a price-taking storage device in PJM (a regional transmission organization in the U.S.) during a the six-year period from 2002 to 2007, to understand the impact of fuel prices, transmission constraints, efficiency, storage capacity, and fuel mix.

In [10] the authors assert that, in order a wind–battery system to be economically profitable in Spain, the selling price of the energy provided by the batteries during peak hours should be between 0.22 and 0.66 €/kW h, depending on the technology and the cost of the battery. This selling price is significantly higher than the electricity rates currently applied.

In [2] Ekman et al. take into account a number of large scale electricity storage technologies relevant for the Danish power system, concluding that the possible revenues from arbitrage on the spot market are significantly lower than the estimated costs of purchasing an electricity storage system, regardless of the storage technology.

In [11] Mulder et al. carry out a complete investment analysis, based on real system prices and best future expectations, considering the German tariff system. They conclude that batteries supporting household PV systems can already be cost-effective today without subsidies, but without a return on investment, if the electricity price does not increase more than the inflation. However, if the electricity price increases with 4%, batteries become quickly attractive and do not need subsidies.

In [12] McKenna et al. assess the economic and environmental impact of the use of lead-acid batteries in grid-connected PV systems under current feed-in tariff arrangements in the U.K., concluding that the net benefit of the battery is negative, even when considering an idealized lossless battery.