Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 99 (2016) 35 – 43

Energy Procedia

10th International Renewable Energy Storage Conference, IRES 2016, 15-17 March 2016, Düsseldorf, Germany

Lithium-based vs. Vanadium Redox Flow Batteries – A Comparison for Home Storage Systems

Martin Uhrig[a,*], Sebastian Koenig[a], Michael R. Suriyah[a], Thomas Leibfried[a]

[a]*Karlsruhe Institute of Technology, Institute of Electric Energy Systems and High-Voltage Technology, 76131 Karlsruhe, Germany*

Abstract

Since May 2013, more than 35,000 home storage systems have been installed in Germany. Due to superior performance and significant price degression, lithium ion batteries (LiBs) are the dominating technology in this market. However, in 2015, a new technology became available for this application. Several manufacturers are now offering flow batteries in the required scale.
This technology has low variable costs (€/kWh) and uses a wider SoC range. On the other hand, efficiency is lower than for the LiB and fixed costs (€/kW) are rather high. In this work, we examine how those properties influence the cost effectiveness for the use case of home storage. Therefore, we compare the performance of LiBs and vanadium redox flow batteries (VRFBs) using a household simulation framework. A unique approach of combining a sophisticated multi-physical flow battery model to obtain efficiency and operational limits with an advanced method of evaluating the economic contribution of a PV home storage system is applied.
The benefit of increased self-consumption by a battery system is determined over a period of 20 years using a temporal resolution of 15 minutes. Simulated households are characterized by their individual annual energy demand (1,000 to 10,000 kWh/a) and annual energy generation by rooftop PV plants (500 to 15,000 kWh/a).
The study shows, that under the given assumptions, home storage for individual households is not an economically viable use case for any of the evaluated battery technologies. It has been found, that the batteries are not in operation and completely discharged for the better part of the year. This demonstrates the large potential for additional use cases, especially during winter time.
In addition, it is shown that LiBs outperform VRFBs for every studied household. The efficiency gap between the two technologies is too large to become compensated by the larger useable SoC range. However, in terms of cost, especially for larger capacities, the VRFB can be competitive compared to the LiB. Therefore, further efforts should be undertaken to improve VRFB performance.

Peer-review under responsibility of EUROSOLAR - The European Association for Renewable Energy

Keywords: PV battery, home storage, economics, flow battery, lithium battery, energy storage, battery storage, photovoltaic, ESS, VRFB

* Corresponding author. Tel.: +49-721-6084-3065; Fax: +49-721-695-224
E-mail address: martin.uhrig@kit.edu

Peer-review under responsibility of EUROSOLAR - The European Association for Renewable Energy
doi:10.1016/j.egypro.2016.10.095

1. Introduction

Due to increasing electricity tariffs, decreasing feed-in tariffs for PV plants and decreasing storage costs, supporting the self-consumption of rooftop PV plants has become the fastest growing market for stationary energy storage systems (ESS). In Germany, 20,000 units have been installed in 2015 [1]. Customers can choose between lead-acid, lithium or vanadium-redox-flow technology. For the latter, small scale home storage is a completely new application. Currently, the lithium battery (LiB) dominates the home storage market, but also lead-acid systems hold large shares in the expanding market [2]. However, the vanadium redox flow batteries (VRFBs) have some advantages that could make them a serious competitor.

First of all, their power and energy rating is decoupled. With the same power unit (stack), and a different tank size, the requirements for a variety of households could be met very well. Especially for larger capacities, the low energy related costs (€/kWh) could benefit its market penetration. In addition, the VRFB makes use of a larger part of its gross capacity and is expected to perform more than 10,000 cycles without significant aging (lead acid: ≤2,000 cycles; LiB: ≤5,000 cycles) [1]. Finally, the technology is very resistant against deep discharge. A significantly lower efficiency and comparatively high power related costs (€/kW) are disadvantages of the VRFB.

This study is supposed to give an insight into how lower energy related costs, use of a larger state-of-charge (SoC) range, lower efficiency and higher power related costs influence the economical viability of VRFB compared to a standard LiB.

2. Methodology

2.1. Simulation run

To determine optimal capacity values for different households, simulations are performed over a period of 20 years in temporal resolution of 15 minutes. Households' energy demand varies between 1 MWh/a and 10 MWh/a in intervalls of 0.5 MWh/a. Respective electrical load profiles are modeled statistically based on the approach presented in [3]. The profiles are normalized to 1,000 kWh/a and scaled with the given annual energy demand, while preserving load profile characteristics from different household sizes. The size of the PV plant varies between 0.5 kW_{peak} and 15 kW_{peak} in intervals of 0.5 kW_{peak}. For modeling the PV infeed, solar data provided by the *Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht Rheinland Pfalz* is utilized [4]. The PV module efficiency is assumed to degrade by 1 %/a for the simulation period of 20 years. Further a variable PV inverter efficiency is considered, with a maximum of 96 %.

For each of the 570 simulated households, the gross storage capacity is raised in steps of 0.5 kWh, until the net present value (NPV) increases by less than 50 €/kWh. The NPV results from an electricity tariff of 0.28 €/kWh for standard loads, which is assumed to increase by +2 %/a over the whole simulation run. The feed-in tariff for the PV plant is 0.12 €/kWh neglecting reductions for installed capacities larger than 10 kW_{peak}. Further a discount rate of 2 %/a is assumed.

For the simulation run, a simple load management approach is implemented, that bases on maximizing the self-consumption of the generated PV energy: Surplus energy is preferential consumed directly or stored in the battery. If the battery is fully charged, energy will be fed into grid. Household's energy demand is preferably covered by the storage and in case of an energy deficit taken from the grid. Because other charging strategies are affected by forecast errors, this one is the benchmark for maximizing the grade of autarchy.

Battery efficiency is a core topic of this study and is considered using two battery models, one for the LiB and one for the VRFB. Both storage systems are assumed to be AC-coupled. Self-discharge in standby is neglected. VRFBs still have large potential in boosting the efficiency. Thus a more efficient variant is considered as well, to study the influence of increased efficiency on economic viability.