Economics of the Vanadium Redox Flow Battery for home- and community-storage

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Introduction

By the end of January 2016, nearly 35,000 solar home storage systems have been installed in Germany. The average net capacity of 6 kWh gives a total installed net capacity of 210 MWh [1]. Obviously, this is one of the fastest growing markets for stationary storage systems. Today, the dominating battery technology for home storage is Lithium. However, several flow battery manufacturers are willing to penetrate this market as well. The question arises, how competitive the redox flow battery will be for this use case. Exemplarily, the evaluations are conducted for the all-vanadium redox flow battery (VRFB). Long life-time, low energy related cost and the large useable SoC-range are in favour for the VRFB. High power related costs and lower efficiency are the major drawbacks. Thus, this work evaluates how these facts influence the economics of VRFB for the usage as home storage system. In addition, community storage, where several households share a battery, is considered as well. However, in contrast to home storage systems, there exist several regulatory hurdles which yet have to be overcome for the community storage to become a viable use case in Germany.

Methodology

570 individual households with various combinations of annual electricity demand (1 to 10 MWh/a) and rated power of the installed rooftop PV-plant (0.5 to 15 kW_{peak}) are evaluated. Individual load profiles are modelled statistically [2]. For modelling the PV-infeed, solar data provided by the *Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht Rheinland Pfalz* is utilized.

For each household, battery operation with different capacities is simulated over a period of time of 20 years with temporal resolution of 15 min. System power of 2 and 5 kW is evaluated. Electricity tariff is 0.28 €/kWh and is assumed to increase by 5 %/a for the first five years, followed by an increase of 2 %/a for the following 15 years. PV-infeed tariff is 0.12 € and does not vary over time. PV plant degradation is assumed to be 1 %/a. Discount rate is 2 %/a. Detailed information about methodology and results for home-storage systems is provided in [3].

A detailed multi-physics model of the VRFB is used to derive SoC- and load-dependent efficiency, see Figure 1**.** Two battery configurations are evaluated. The first one uses a cell resistance of 2 Ωcm² and the diffusion coefficients of the Nafion 115 membrane. The second one represents a much more efficient VRFB, with a cell resistance of 1 Ωcm² and diffusion coefficients, which are only 50 % of those of Nafion 115.

For the community storage, 2, 5 and 10 kW-systems are evaluated. Characteristics of the evaluated communities are given in Table 1.

Results for home-storage systems

For a single household with an annual electricity demand of up to 10 MWh and an installed PV-capacity of up to 15 kW_{peak}, a VRFB is not an economically viable option, see Figure 2. This is mainly because of the high power related costs and the low partial load efficiency during discharging in the evening and in the night. Energy related cost is assumed to be

400 €/kWh. For the 2 kW-system, power related cost is assumed to be 3,000 €/kW (5 kW: 2,000 €/kW, 10 kW: 1,500 €/kW).

Results for community-storage systems

For deployment as community-storage system, the VRFB delivers a positive return-on-invest (ROI) for communities with at least 45 MWh of annual electricity consumption and a large PV-plant of 90 kW_{peak} (communities 3 and 4), see Figure 3.

The influence of efficiency on economics is significant. Even for community 3, in which the VRFB works best, only the high efficient VRFB delivers a positive ROI. The efficiency gain of around five percentage points (one way) results in an ROI increase of 4,200 € for the 5 kW-system and 5,100 € for the 10 kW-system over a time period of 20 years.

Table 1: Data of considered communities

	No. of households	Electricity demand	PV capacity
Community 1	3	15 MWh/a	15 kW_{peak}
Community 2	9	45 MWh/a	45 kW_{peak}
Community 3	9	45 MWh/a	90 kW_{peak}
Community 4	18	90 MWh/a	90 kW_{peak}

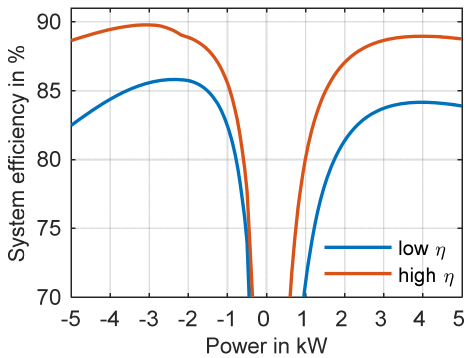

Figure 1: Efficiency over power for both VRFBs at 50% SoC

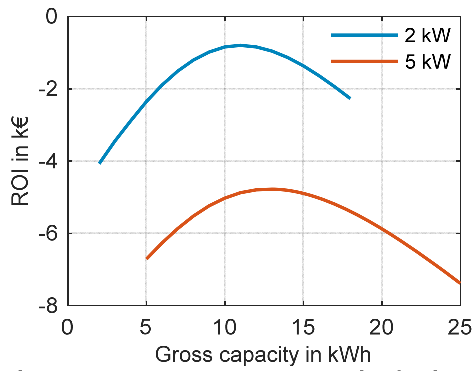

Figure 2: ROI over gross-capacity for home-storage system, high efficient VRFB

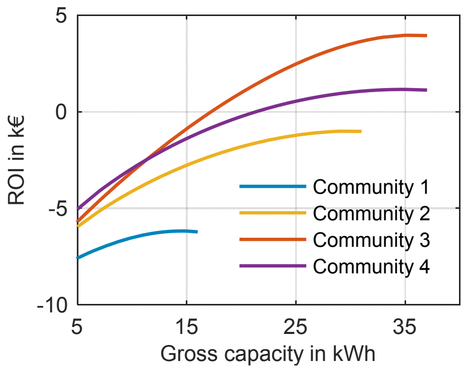

Figure 3: ROI for 5 kW-community storage system, high efficient VRFB

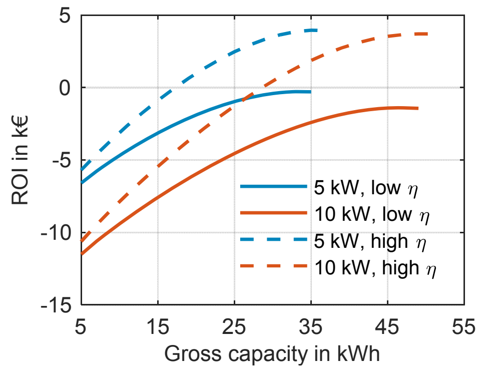

Figure 4: ROI over gross capacity for community 3, both VRFBs

References

[1] K.-P. Kairies et al: Jahresbericht zum Speichermonitoring, Aachen, 2016

[2] M. Uhrig, R. Mueller and T. Leibfried: Statistical consumer modelling based on smart meter measurement data. *International Conference on Probabilistic Methods Applied to Power Systems (PMAPS 2014), Durham, UK*.

[3] M. Uhrig, S. König, M. Suriyah and T. Leibfried: Lithium-based vs. Vanadium Redox Flow Batteries – A comparison for Home Storage Systems. *International Renewable Energy Storage (IRES2016), Düsseldorf, Germany.*