Vanadium/Oxygen Systems for Energy Storage

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With the increase in renewable energies worldwide, the demand for storage technologies to cover capacity shortages is increasing. Due to their modular scalability and decentralized installation options, batteries are ideally suited for this task. Redox flow batteries (RFB) in particular offer the possibility of potentially low storage costs over a long service life, with simultaneous independent scalability of performance and energy. In the scientific literature there is an almost unmanageable variety of different redox pairs and redox pair combinations for RFBs [1]. However, in addition to the zinc/bromine RFB, the vanadium redox flow battery (VRFB) [2] is almost exclusively in a marketable state of development. To date, hundreds of MWh of electrical energy have been installed or are currently under construction. A disadvantage of VRFBs is the relatively low energy density with a maximum of 30 Wh/L and the necessity to integrate a cooling concept to avoid electrolyte temperatures above 40 °C. The energy density of VRFBs is relatively low with a maximum of 30 Wh/L. These problems were addressed by developments resulting in V/Br-RFBs and VRFBs with HCl/H_2SO_4 mixed acid electrolytes. Vanadium/oxygen systems are another possibility for using vanadium as an energy storage medium that was recognized at an early stage [3]. Vanadium/oxygen systems use the redox pairs V^{2+}/V^{3+} and O_2/O^{2-} in different configurations, whereby the standard potential difference is 1.49 V. With VRFBs, the energy density and temperature stability are largely determined by the behaviour of pentavalent VO_2^+ cations, which is why significantly higher energy densities and temperatures of over 60 °C can be achieved with vanadium/oxygen systems with up to 150 Wh/L [4].

Figure 1:Picture of a Vanadium/Oxygen laboratory scale fuel cell system

Furthermore, only half the vanadium is required. Depending on the mode of operation, vanadium/oxygen systems can function as unitary redox flow batteries with charging and discharging in the same cell or as separate units in two separate cells for charging and discharging. Strictly speaking, this is a combination of vanadium/oxygen fuel cell and vanadium/water electrolyser.

In the context of this overview presentation, the developments of the last years in vanadium/oxygen systems from Fraunhofer ICT and UNSW are presented on the basis of vanadium/oxygen fuel cells and vanadium/water electrolysers. For example, electrolyte studies have been performed to increase concentration and energy density up to 150 Wh/L, cell studies have been performed resulting in a stack of 5 cells and a cell design with two membranes to avoid side reactions. Upscaling into a stackable cell design was performed and furthermore the reversal of reactions with vanadium/water electrolysers was investigated and the feasibility of energy storage was demonstrated. In addition, techno-economic modelling and simulation was performed to calculate investment costs and to investigate the cost distribution especially in comparison with other RFBs.

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