Modeling and Optimal Control of a Redox Flow Battery

D. Wrang[1,2], T. Faulwasser[2,4], J. Billeter[2], V. Amstutz[3], H. Vrubel[3], A. Battistel[3], H. Girault[3], D. Bonvin[2*]

[1] Royal Institute of Technology (KTH), Stockholm, Sweden
[2] Laboratoire d'Automatique, EPFL, Switzerland
[3] Laboratory of Physical and Analytical Electrochemistry, EPFL, Switzerland
[4] Institute for Applied Computer Science, Karlsruhe Institute of Technology, Germany
* *dominique.bonvin@epfl.ch*

Vanadium Redox Flow Batteries (VRFB) can be used as energy storage device, for example to account for wind or solar power fluctuations. In VRFBs charge is stored in two tanks containing two different vanadium solutions. This approach decouples the storage capacity and the power supply which is dependent only on the number and size of the cells [1].

A control specific model of a VRFB is proposed, which captures the essential dynamic properties of the battery while ignoring all fluid mechanical elements. The model of the battery is a nonlinear DAE comprising a differential equation for the state of charge *SoC* and algebraic equations based on the Butler-Volmer equation for the current I and the voltage U, the power $P = U{\cdot}I$ being set by the operator. The battery typically operates in constant power mode, but the control system limits its operating range by switching to a constant voltage when upper or lower voltage thresholds are reached. In addition, this VRFB contains a secondary flow circuit, where the electrolyte discharge reactions produce hydrogen and oxygen [2].

Model parameters are estimated by minimizing the difference between the measured and modeled *SoC* over time, the other states (I, U and P) being compared with measured data. The model is validated using independent measurements, which show good fits (see Figure).

Finally, the dynamic model will be used to formulate and numerically solve the problem of optimal battery operation in different scenarios.

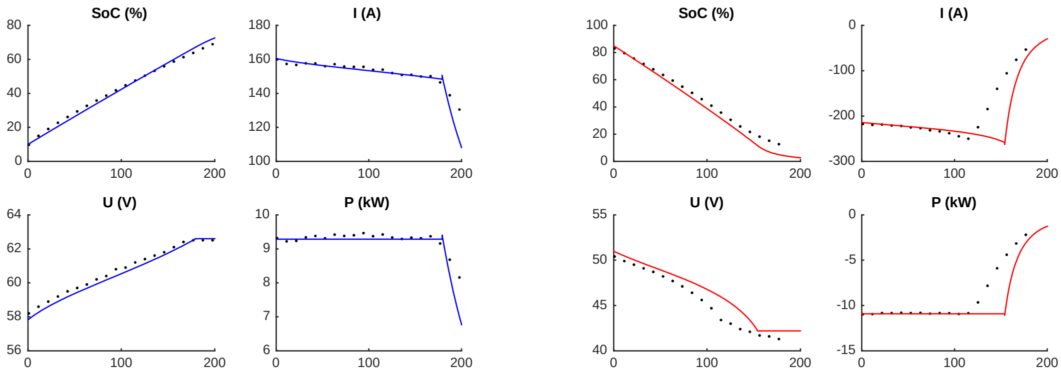

Figure: Measured (•) and modeled (—) states over time (in minutes) during the charge (left) and discharge (right) of a Vanadium Redox Flow Battery at the constant power of 10 kW.

Keywords*:* Vanadium redox flow battery (VRFB), Modeling, Parameter estimation.

[1] C. Blanc and A. Rufer, Chapter 18, in Paths to Sustainable Energy, InTech, 2010
[2] V. Amstutz et al., Energy and Environmental Science 7, 2350-2358 (2014)