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Alternative stack topologies for vanadium redox flow batteries

Andrea Trovò, Bortolin, Del Col, Moro and **Alotto, Guarnieri**
University of Padua, Italy

This work was done within the MAESTRA strategic project of the University of Padua and aims at developing state-of-the-art technologies, for Vanadium Redox Flow Batteries (VRFBs) which are needed for the production of more efficient and flexible devices, by optimizing cell and stack geometries, power management units and supervisor systems. For developing the experimental investigations, a fully-monitored test facility has been built, rated 4 kW-24 kWh, provided with a 40-cell stack and two 500 L tanks. It is provided with two flow pumps powered by analog-controlled brushless motors, a bidirectional power management system, a Labview-based battery management system (BMS), multi-voltage and current meters, pressure and voltage measurements. The test program include stack voltage vs. SOC (state of charge) in charging and discharging, electric power flow, temperature analysis, distribution of stack voltage, polarization curves, electrochemical impedance spectroscopy (EIS), efficiency measurements, and aging effects. The experimental campaign is supported by extensive numerical analyses. Recently, two battery topologies have been studied and compared. In the conventional series stack, cells are connected electrically in series and hydraulically in parallel by means of bipolar plates. The alternative topology consists of cells connected in parallel inside stacks by means of monopolar plates, in order to reduce shunt currents along channels and manifolds. Channeled and flat current collectors interposed between cells have been considered in both topologies. In order to compute the stack losses, an equivalent circuit model of a VRFB cell was built from a 2D FEM multiphysics numerical model based on Comsol®, accounting for coupled electrical, electrochemical, and charge and mass transport phenomena. Shunt currents were computed inside the cells with 3D FEM models and in the piping and manifolds by means of equivalent circuits solved with Matlab®. Hydraulic losses were computed with analytical models in piping and manifolds and with 3D numerical analyses based on ANSYS Fluent® in the cell porous electrodes. The alternative topology with channeled current collectors exhibits pumping and shunt current losses one order of magnitude lower than a conventional battery rated at the same power, resulting in a round-trip efficiency 10% higher, as compared to the conventional topology.

andrea.trovo@unipd.it

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