Abstract #476, 223rd ECS Meeting, © 2013 The Electrochemical Society

High Power Density Redox Flow Battery Cells

M. L. Perry, R. M. Darling, and R. Zaffou
United Technologies Research Center (UTRC)
East Hartford, CT, 06108, USA

A Redox Flow Battery (RFB) system is an Electrical Energy Storage (EES) approach that was originally conceived by NASA during the energy crises of the 1970s. Analogous to conventional secondary batteries, a RFB utilizes reversible electrochemical couples on two electrodes to store chemical energy. However, instead of storing the electrochemical reactants within the electrode, as in a conventional battery, the reactants are dissolved in electrolytic solutions and stored in tanks external to the reactor. The RFB reactor is a stack of cells; each cell contains sites where electrochemical charge-transfer reactions occur as the reactants flow through the cells. Therefore, the energy and power capacities of a RFB system are independent variables, unlike in conventional secondary batteries. This modularity, and other unique attributes of RFBs (*e.g.,* cycle lifetimes that are independent of depth-of-discharge), makes RFB systems potentially attractive for grid-scale energy storage [4].

The capital cost of a RFB system has been the major barrier to commercialization of this technology. Cell stacks are a key module of any RFB system and also represents a substantial part of the total system cost. This is especially true at relatively low production volumes, since cell stacks are custom modules composed of custom-designed components (*e.g.*, bipolar plates, separators or ion-exchange membranes, electrodes, and seals). Therefore, substantial reductions in RFB cell-stack cost can result in significant RFB system cost reduction, which is required for successful commercialization of this technology.

UTRC has developed RFB cells with substantially higher power densities than conventional RFB cells. An example is shown in Fig. 1, which compares the performance of different Vanadium-Redox Battery (VRB) cells that have been reported in the literature with one of UTRC's VRB cells. The high power densities reported here can theoretically be obtained with any true flow-battery chemistry (*i.e.*, no plating, or storage, of reactants in the electrodes), since one key factor to obtaining these high power densities is to design cells for maximum power, not to accommodate the storage of reactants (*e.g.*, utilize relatively thin electrodes). UTRC's high power density cells utilize the same set of cell materials as conventional RFB cells (*i.e.,* carbon bipolar plates, porous carbon electrodes, and ion-exchange membranes). The key to substantially higher cell performance is cell design.

High power density cells are a previously unexploited advantage of RFBs; namely, RFB cells can be designed to operate at much higher current and power densities than conventional secondary batteries, because of the inherent power and energy independence of the RFB architecture. In addition to being capable of storing a large amount of active material relative to inactive materials (*i.e.*, high energy-to-power ratios), the RFB architecture also enables a further reduction in the amount of inactive materials required by utilizing high power density cells, which is also fundamentally enabled by the power and energy independence of the RFB architecture.

Other groups have also begun to report on the development of high power density RFB cells, such as Lawrence Berkeley National Lab (LBNL) with Hydrogen-Bromine cells [5] and the University of Tennessee, Knoxville with VRB cells [3] (which is included in Fig. 1). Some basic cell design differences between these high power density RFB cells and conventional RFB cells will be presented here. Additionally, the impact of high power density on cell-stack cost will be briefly reviewed and compared to other cost-reduction approaches (*e.g.*, development of lower cost cell materials). The status of UTRC's scale-up of this advanced RFB technology will also be presented.

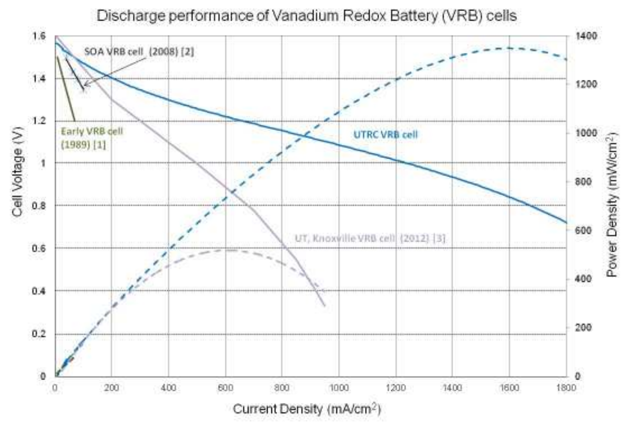

Figure 1. Performance comparison of different VRB cells reported in the literature (references cited below) and one of UTRC's high power density VRB cells.

Acknowledgements
The authors would like to thank their colleagues at UTRC who have been a part of UTRC's advanced flow-battery team. The work presented herein was funded, in part, by the Advanced Research Projects Agency - Energy (ARPA-E), U.S. Department of Energy (DOE) under Award Number DE-AR0000149.

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