# Understanding Shunt Currents in Flow Batteries: A Multiphysics Approach to Analysis and Mitigation

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## Abstract

The transition to renewable energy systems is critically dependent on the development and optimization of large-scale energy storage technologies, among which Vanadium Redox Flow Batteries (VRFBs) stand out for their scalability, flexibility, and long cycle life. However, the operational efficiency and lifespan of VRFBs are significantly undermined by shunt currents—unwanted internal currents that bypass the electrochemical reaction zones, leading to energy losses and accelerated degradation. Previous studies have predominantly employed lumped electrical circuit models to investigate these currents, a method that, while providing initial insights, substantially oversimplifies the complex interplay of ionic and electronic transport mechanisms within the VRFB electrolytes.

This study proposes a novel multiphysics modeling framework that eschews the simplifications of previous models in favor of a detailed representation that captures the coupled dynamics of ionic conduction, electronic conduction, and fluid flow within the VRFB. By integrating the Navier-Stokes equations for fluid dynamics with the Nernst-Planck equation for ionic transport, and the Poisson equation for electric fields, this model aims to provide a holistic view of the factors contributing to shunt currents. This approach not only facilitates a deeper understanding of the underlying physical phenomena but also opens new avenues for identifying effective mitigation strategies.

The superiority of this multiphysics approach lies in its ability to accurately simulate the complex interdependencies within the VRFB system, which are overlooked by simpler models. This enables the identification of specific structural and operational factors that contribute to shunt currents, facilitating the development of targeted optimization strategies. Through the application of this advanced modeling framework, the research can precisely quantify the impact of various physical parameters, such as membrane permeability, electrode porosity, and flow channel design, on the magnitude and distribution of shunt currents, guiding the engineering of VRFB components for minimal energy loss and enhanced efficiency.

Moreover, the multiphysics model paves the way for innovative optimization techniques, such as the strategic placement of barriers or the adjustment of flow patterns, to disrupt or redirect shunt pathways effectively. These strategies, informed by a deep understanding of the underlying physics, promise to significantly improve VRFB performance, offering a path to more reliable, durable, and efficient energy storage systems.

The implications of this research extend beyond academic interest, offering practical insights for the design and operation of more efficient and sustainable VRFBs. As the demand for reliable large-scale energy storage solutions grows in the context of global renewable energy integration, the findings of this study promise to contribute significantly to the advancement of VRFB technology, aligning with the broader goals of energy sustainability and environmental stewardship.

**References**


- Tang, J. McCann, J. Bao, M. Skyllas-Kazacos, Investigation of the effect of shunt current on battery efficiency and stack temperature in vanadium redox flow battery, J. Power Sources, 242, (2013) 349 - 356, doi: 10.1016/j.jpowsour.2013.05.079.

- Viswanathan, A. Crawford, D. Stephenson, S. Kim, W. Wang, B. Li, G. Coffey, E. Thomsen, G. Graff, P. Balducci, M. Kintner-Meyer, V. Sprenkle, Cost and performance model for redox flow batteries, J. Power Sources, 247, (2014) 1040 – 1051. doi: 10.1016/j.jpowsour.2012.12.023

- Skyllas-Kazacos, J. McCann, Y. Li, J. Bao, A. Tang, The Mechanism and Modelling of Shunt Current in the Vanadium Redox Flow Battery, ChemistrySelect, 1(10), (2016) 2249–2256. doi: 10.1002/slct.201600432

2256. doi: 10.1002/slct.201600432.

- Moro, A. Trovò, S. Bortolin, D. Del Col, M. Guarnieri, An alternative low-loss stack architecture for vanadium redox flow battery: comparative assessment, J. Power Sources, 340, (2017) 229-241.**doi:**10.1016/j.jpowsour.2016.11.042.
- Trovò, G. Marini, A. Sutto, P. Alotto, M. Giomo, F. Moro, M. Guarnieri, Standby thermal model of a vanadium redox flow battery stack with crossover and shunt-current effects, Appl Energy, 240, (2019) 893-906. doi: 10.1016/j.apenergy.2019.02.067.
- Trovò, F. Picano, M. Guarnieri, Comparison of energy losses in a 9 kW vanadium redox flow battery, J. Power Sources, 440, (2019) 227144. doi: 10.1016/j.jpowsour.2019.227144.

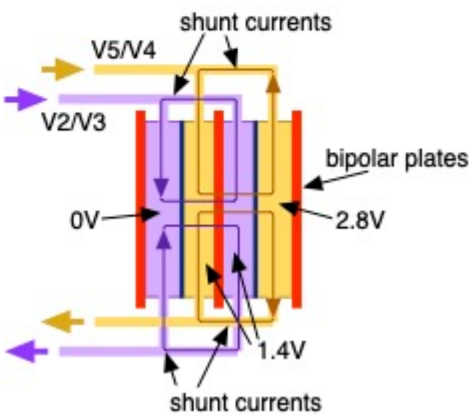


Figure 1

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