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Full Length Research Paper

Design and development of unit cell and system for vanadium redox flow batteries (V-RFB)

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Vanadium redox flow battery (V-RFB) has been attracted by many researches; some are under field testing and demonstration stage, but information on construction, experimental characterization, electrolyte preparation, overall systems under study, etc. are still limited. This paper focus on the technical issues faced and the lessons learnt during the development of unit cell and system for V-RFB. Firstly, brief description on problem identification, development and implementation in cell design and system for V-RFB are discussed. Secondly, preliminary experiment on 25 cm^2 laboratory, unit cell V-RFB presents various difficulties such as its high tendency to fall under failure mode are presented. Finally, discussion on experimental result which shows significant improvement on V-RFB system efficiency up to 72% with reduction of contact resistance, recorded an average of 8.6 mΩ. In addition, the newly developed system provides a constructive base for future studies in temperature-controlled system and a divided, open-circuit potentiometric cell for half-cell redox analysis.

Key words: Redox flow battery, energy storage, cell design.

INTRODUCTION

From last century, numerous forms of energy storage having different characteristics and application"s suitability, has been developed. Redox flow batteries (RFBs) that emerge into energy storage technologies (Fedkiw and Watts, 1984) pose a promising prospect for both large scale and automotive applications. RFB is, an electrochemical energy storage device, whereby the electro-active species are stored externally and these reactants are circulated through cell-stack as required (Mohamed et al., 2009). Founded in mid-1980s, vanadium redox flow batteries(V-RFB) uses vanadium reactants on both the anode and cathode half-cells, and consequently, cross-contamination of ions through the ion exchange membrane causes no harm on battery capacity, prolongs their cycle life and operates at high energy efficiencies (over 80%) (Skyllas-Kazacos, 2003). The following features differentiate RFB from conventional batteries: flexible operation, modularity energy and power component ratings are independent to each other (for some RFBs), simple installation lay-out, moderate cost, long cycle life and transportability.

A lot of research has been carried out since pointed out by Skyllas-Kazacos and Robins (1986), yet there are issues in the technology that still needs to be addressed. Shah et al. (2010) highlighted that several challenges remain in optimizing and improving current V-RFB designs, particularly with respect to scaling-up, minimizing gas evolution, improving electrolyte stability, resistance to carbon oxidation and membrane fouling. Perhaps, the most critical part in RFB system is the cell stack; hence, deserve the most attention in analysis and manufacturing. In general, the construction of the cell

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Abbreviations: V-RFB, Vanadium redox flow battery; $\boldsymbol{E_{cell}}$**,** cell potential, measured across unit cell stack; $\boldsymbol{E_{cell(ORP)}}$**,** open-circuit cell potential across two electrode, otherwise abbreviated as $E_{cell(ORP)}$ for oxidation-reduction redox potential; $\boldsymbol{E^o}$**,** open circuit cell potential, $\boldsymbol{E_{V(III)/V(II)}}$**,** positive half-cell potential for V-RFB; $\boldsymbol{E_{V(IV)/V(V)}}$**,** negative half-cell potential for V-RFB; **HEV,** hybrid electric vehicle; **PTFE,** polytetrafluoroethylene; **PVC,** polyvinyl chloride polymer; **RFB,** redox flow battery; **SHE,** standard hydrogen electrode; **V(II), V(III), V(IV) and V(V),** vanadium species at different level of oxidation state.