ADAPTIVENESS OF EQUIVALENT ELECTRICAL CIRCUIT FOR VANADIUM REDOX FLOW BATTERY (V-RFB) USING EXTENDED KALMAN FILTER (EKF)

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Abstract

Vanadium Redox Flow Battery (V-RFB) is a rechargeable battery and in order to store chemical potential it employs vanadium ions in different oxidation state. Kalman Filter (KF) generally applied to approximate the state of a system using measured input and output. Currently, studies on equivalent electrical circuit for V-RFB are inadequate in publications but available. This paper presents the proposed equivalent circuit for V-RFB that are suitable in any V-RFB system design and use Extended Kalman Filter (EKF) in MATLAB/Simulink for identification. The simulation result through a recursive EKF algorithm was analyzed and shows the adaptability of the circuit.

Keywords: Vanadium redox flow battery; Equivalent electrical circuit; Extended kalman filter; Energy storage

1.0 INTRODUCTION

Energy is one of the most important thing for human lives. It is all over the places and has the capability to make changes but can neither be created nor destroyed as stated in the law of conversion of energy and statement for the First Law of Thermodynamics [1]. The production of energy is captured for later used is known as energy storage. There are many type of energy storage and electrochemical energy storage is one of it [2]. Electrochemical energy storage is a conversion of chemical to electricity potential and vice versa for storage. This storage describe various type of batteries and almost all of them are technically advanced [3].

Batteries store energy from hours to days. It can be extended the storage capacity without need to upgrade the power generation system so it is easily scalable. Redox Flow Battery (RFB) was established in 1970s [4], there are many type of RFB that have been invented; vanadium, vanadium bromine, iron chromium, zinc bromine, zinc cerium, and etc. RFB is devices that store electrochemical energy where it undergo the chemical reaction reduction and oxidation, it will discharge and charge and the electrolyte solution will store the energy. Although RFBs density of current is low compared to fuel cells, it had advantages in low cost, easy to handle, and higher power density [5]. During discharge, oxidation reaction occurs at anode from high chemical potential state that the electron release through an external circuit and at cathode electron is accepted by reduction reaction from low chemical potential state while charging the current and reaction direction are reversed [6]. Vanadium Redox Flow Battery (V-RFB) efficiency is high, it long lifespans, and has reasonable cost out of all RFBs. It undergoes oxidation and reduction reaction during discharge and charge process at anode and cathode. Both sides of V-RFB system selective membrane use vanadium compound, it is fundamentally reliable and simple maintenance procedures different from the other flow battery technologies. V-RFB was allowed by eliminating cross-contamination, the electrolyte does not require to be changed it lasts indefinitely and highly efficient as the charge acceptance of the system is optimal and nominal. Therefore, it last long and no losses of system integrity

For easier analyzation on system behaviour, simple circuit can be used by modelling complex circuit. Proper way to describe dynamic process of chemical reaction on the system electrodes of V-RFB are based on electrochemical model [7]–[9]. However, to describe V-RFB electrical behaviours are not well appropriate due to the requirement of battery chemical parameters. Publication on studies that have been carry out on the electrical circuit model for V-RFB are very few available so far. To date, Chahwan et al. [10] and M. R. Mohamed et al. [11] had proposed equivalent electrical circuit for V-RFB. Chahwan presents equivalent circuit with parasitic and pumped losses with no Resistor-Capacitor (RC) network but there is no explanation on how the losses being estimated whereas Mohamed present equivalent circuit with a pair of RC network for better representation within battery but there is no inductor. Inductor should be consider as it maintain the flow of