Modeling of a Vanadium Redox Flow Battery for Energy Storage

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With the fast development of renewable energy, energy storage is being seriously considered as one of the key technologies. Vanadium redox flow battery shows promising characteristics for energy storage due to low cost and long life cycles. System energy storage capacity and output power can be designed independently. This study intends to develop a model that simulating the behavior of vanadium redox flow battery during different charge and discharge conditions. Effects of various operating condition on the battery characteristics were evaluated.

With the rapid development of renewable energy, energy storage technology is becoming the key issues. Energy storage technologies can be used to smooth intermittent fluctuations of renewable energy generated due to external environmental factors, such as: solar power and wind power, etc. Vanadium redox flow battery (VRFB) is low-cost cost and high cycle life. The power and storage energy of VRFB can be design separately for specific application. Several MW level VRFB demonstration systems were in operation. System optimization will be costly by experimental trial-and-error. This study is aimed to development a mathematical of vanadium redox flow battery system. The charge/discharge behavior and characteristics of the VRFB at different operating conditions and design parameters were calculated.

LabView from National Instrument was used for this modeling work. LabView has a good interface for data acquisition and control. Model developed in this work could be used to control and monitoring the charge/discharge behavior of VRFB. Figure 1 is the front panel display of this model. Charge/discharge current, cell internal resistance, volume of electrolyte storage can be adjusted by the dial on the front panel. Equation [1] was used to calculate the cell voltage as function of charge/discharge time (t). The energy storage efficiency was calculated by equation [2].

$$E = \left(E_{0,+} - E_{0,-}\right) + \frac{RT}{F}\ln\frac{\left(C^{0}_{5,in} + \frac{I \times t}{F \times V_{+}}\right)\left[C^{0}_{H,in}\right]^{2}\left(C^{0}_{2,in} + \frac{I \times t}{F \times V_{-}}\right)}{\left(C^{0}_{4,in} - \frac{I \times t}{F \times V_{+}}\right) \times \left(C^{0}_{3,in} - \frac{I \times t}{F \times V_{-}}\right)} + R_{\Omega} \times I \qquad [1]$$

$$\varepsilon - \frac{\int E_{discharge} \times I\,dt}{\int E_{charge} \times I\,dt} \qquad [2]$$

Figure 2 is a typical result calculated by equation [1] at different charge/discharge currents. For a given size of electrolyte storage and vanadium concentration. The voltage of VRFB was calculated as a function of charge/discharge time. Based on the charge/discharge curves, the energy storage density was calculated as given on Fig. 3. The energy storage density is decreased as the charge/discharge current increased. This is primary due to the higher charging voltage and lower discharging voltage at high charge/discharge current than low charge/discharge current.

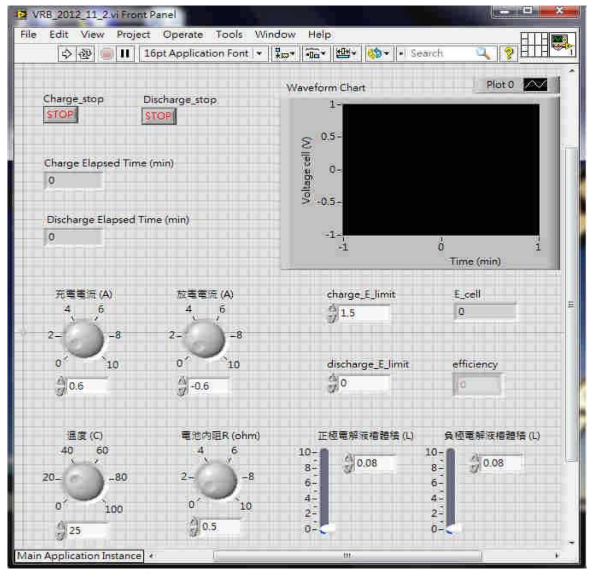

Fig. 1 LabView front panel display

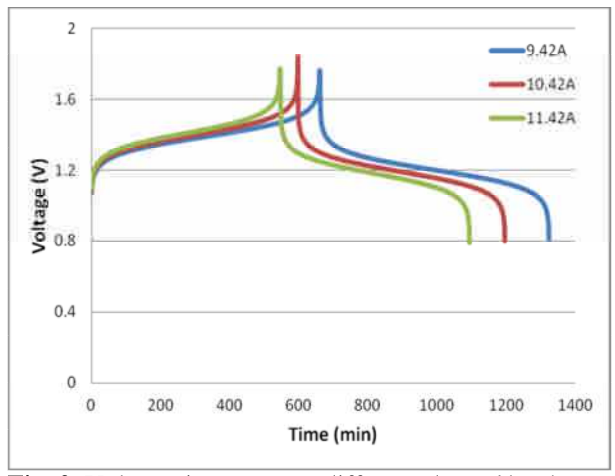

Fig. 2 Voltage-time curve at different charge/duscharge currents.

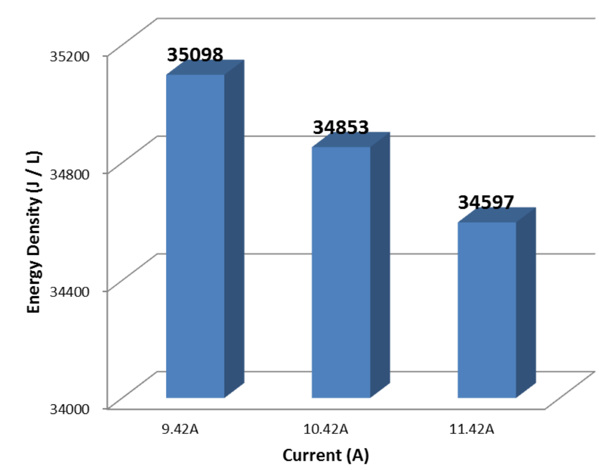

Fig. 3 Energy storage density as function of charge/discharge current.

The VRFB system characteristics were evaluated at different charge/discharge current, cell internal resistance, volume of electrolyte storage, and electrolyte concentration. The energy density, storage efficiency were calculated.

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