Accepted Manuscript

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Lalitha Devarakonda, Tingshu Hu

PII: S0378-7753(15)00253-0

DOI: 10.1016/j.jpowsour.2015.02.030

Reference: POWER 20658

To appear in: *Journal of Power Sources*

Received Date: 10 December 2014

Revised Date: 4 February 2015

Accepted Date: 5 February 2015

Please cite this article as: L. Devarakonda, T. Hu, Effects of rest time on discharge response and equivalent circuit model for a lead-acid battery, Journal of Power Sources (2015), doi: 10.1016/j.jpowsour.2015.02.030.

Effects of rest time on discharge response and equivalent circuit model for a lead-acid battery *

Lalitha Devarakonda[†] Tingshu Hu[†‡]

February 6, 2015

Abstract

This work carries out a detailed investigation on the effects of rest time on the discharge response and the parameters of the Thevenin's equivalent circuit model for a lead acid battery. Traditional methods for battery modeling require a long rest time before a discharging test so that a steady state is reached for the open circuit voltage. In a recent work, we developed an algebraic method for parameter identification of circuit models for batteries by applying discharging tests after variable and possibly very short rest time. This new method opens a door to the understanding of the effects of rest time on battery behavior, which may be used for better simulation, analysis and design of battery powered systems for improved battery efficiency and state of health. As we used the new method to extract circuit parameters after different rest times, we observed some unexpected results on the relationship between the rest time and circuit parameters. The initial voltages on the capacitors can be negative and becomes more negative as the rest time is increased. We also observed that the time constants increase with rest time. Relationships between rest time and other parameters are also reported in this paper.

Keywords: batteries, circuit models, circuit parameters, initial conditions, rest time, time constants

1 Introduction

The effects of rest time during charge or discharge process have been studied for different types of batteries and utilized to design charge or discharge profiles in order to improve efficiency and to prolong the life times of batteries. As the discharge process is interrupted, the cell voltage increases after an ohmic jump and then slowly approaches an equilibrium point. This relaxation effect was investigated in [1] for lithium-ion-insertion batteries via an electrochemical model and explained as a result of relaxation of concentration gradient in the electrolyte and in the solid particles, and a redistribution of lithium. The relaxation effect, also referred to as charge recovery effect, can be exploited to improve battery efficiency by scheduling discharge profiles with proper rest periods [2]. It was shown in [3] that the operation time of discharge cycles of Li-ion batteries can be extended by 7% with properly scheduled rest periods. In [4–6], pulsed discharge strategies were designed and implemented so that maximum charge or energy can be drained from batteries. A parallel operation of batteries was proposed in [7] so that the batteries can take turns to

*This work was supported in part by NSF under grants ECCS-1200152.

†The authors are with Department of Electrical and Computer Engineering, University of Massachusetts, Lowell, MA 01854, United States.

‡Corresponding author. Office phone: 1-978-934-4374. Fax: 1-978-934-3027. Email: tingshu_hu@uml.edu