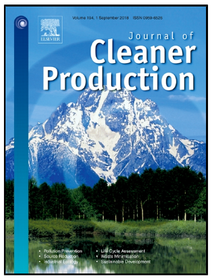
Accepted Manuscript



Open circuit voltage and state of charge relationship functional optimization for the working state monitoring of the aerial lithium-ion battery pack

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PII:	S0959-6526(18)31997-8
DOI:	10.1016/j.jclepro.2018.07.030
Reference:	JCLP 13484
To appear in:	*Journal of Cleaner Production*
Received Date:	18 April 2018
Accepted Date:	03 July 2018

Please cite this article as: Shun-Li Wang, Carlos Fernandez, Chuan-Yun Zou, Chun-Mei Yu, Xiao-Xia Li, Shi-Jie Pei, Wei Xie, Open circuit voltage and state of charge relationship functional optimization for the working state monitoring of the aerial lithium-ion battery pack, *Journal of Cleaner Production* (2018), doi: 10.1016/j.jclepro.2018.07.030

Open circuit voltage and state of charge relationship functional optimization for the working state monitoring of the aerial lithium-ion battery pack

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Abstract –The aerial lithium-ion battery pack works differently from the usual battery packs, the working characteristic of which is intermittent supplement charge and instantaneous large current discharge. An adaptive state of charge estimation method combined with the output voltage tracking strategy is proposed by using the reduced particle - unscented Kalman filter, which is based on the reaction mechanism and experimental characteristic analysis. The improved splice equivalent circuit model is constructed together with its state-space description, in which the operating characteristics can be obtained. The relationship function between the open circuit voltage and the state of charge is analyzed and especially optimized. The feasibility and accuracy characteristics are tested by using the aerial lithium-ion battery pack experimental samples with seven series-connected battery cells. Experimental results show that the state of charge estimation error is less than 2.00%. The proposed method achieves the state of charge estimation accurately for the aerial lithium-ion battery pack, which provides a core avenue for its high-power supply security.

Keywords: lithium-ion battery pack; open circuit voltage; working state monitoring; state of charge estimation; unscented Kalman filter

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1. Introduction

The lithium-ion battery packs are used for the warplanes and no-man-machines in United States instead of the nickel cadmium battery packs such as military A10, MQ-9 and AH64, which are also supplied by the Eagle-Picher company as described (X. S. Hu, Zou, Zhang, & Li, 2017). The cargo and military aircrafts also use the lithium-ion battery packs gradually. However, due to the electro-chemical reaction, material aging and undesirable operation environment, in which the SOC (State Of Charge) value is essential to be estimated accurately.

A large number of solutions have been proposed by researchers, which have been gradually applied the SOC estimation process of lithium-ion batteries. An SOC estimation study was conducted based on the OCV (Open Circuit Voltage) method (Dang et al., 2016). The online SOC estimation was realized using the lagging OCV model (Dong, Wei, Zhang, & Chen, 2016). An overview can be conducted for the SOC estimation methods of the lithium-ion batteries (Farmann & Sauer, 2016). The dual Kalman algorithm was also used to achieve the high-precision SOC estimation of lithium-ion batteries (Y. J. Wang, Zhang, & Chen, 2016). The OCV-based EKF (Extended Kalman Filter) correction function can be used together with the time-hazard integral method, proposing a KF (Kalman Filter) correction algorithm to reduce the estimation error within 6.0% (Feng, Weng, Ouyang, & Sun, 2016). An adaptive square root UKF (Unscented Kalman Filter) approach was proposed for SOC estimation of lithium-ion batteries (Liu, Cui, & Zhang, 2017). The adaptive SOC estimation was conducted using a split battery model for electric vehicle applications. An SOC estimator was constructed using a first-order RC (Resistance and Capacitance) battery model and achieved an working state estimation error of 5.00% (Gao, Zhang, & Wen, 2015).

The Bayesian technology was also used in the working state monitoring of the lithium-ion batteries. The Bayesian technology is used to implement the SOC estimation framework (Sun, Xiong, & He, 2016). An exploratory research on the SOC estimation was conducted using the sparse Bayesian learning method, improving the robustness working characteristic of the SOC estimation (C. Hu, Jain, Schmidt, Strief, & Sullivan, 2015). The accurate and versatile simulation methods of transient voltage profile were studied for the lithium-ion secondary battery by employing internal ECM (Equivalent Circuit Model) (Tanaka et al., 2015). A radial basis function neural network was used to construct a robust adaptive sliding mode observer (X. P. Chen et al., 2016). The SOC modeling of lithium-ion batteries realized by using dual exponential functions (Kuo et al., 2016). A mixed SOC estimation algorithm was proposed with high accuracy in various driving patterns of EVs (Electric Vehicles) (Lim, Ahn, Kim, & Lee, 2016). The charge and discharge voltage and temperature pattern recognition method was studied using the double EKF, improving the SOC estimation effect to adapt different temperature working conditions (Kim et al., 2015).

The KF-based algorithms were implied in the SOC estimation process. The SOC estimation of lithium-ion batteries was realized by using the dual filters of KF and UKF (Sepasi, Ghorbani, & Liaw, 2014). The electrochemical model parameter identification of a lithium-ion battery was conducted using particle swarm optimization method (Rahman, Anwar, & Izadian, 2016). The state-space modeling and observer design was realized for lithium-ion batteries using Takagi-Sugeno fuzzy system (Samadi & Saif, 2017). A SOC estimation method was developed using the adaptive UKF and support vector machine (SVM) (Meng, Luo, & Gao, 2016). The life cycle assessment was studied for lithium-air battery cells (Zackrisson, Fransson, Hildenbrand, Lampic, & O'Dwyer, 2016). The adaptive EKF and wavelet transform matrix were used to realize the SOC estimation of lithium-ion batteries (Zhang, Cheng, Lu, & Gu, 2017). A hybrid SOC estimation algorithm was proposed (Alfi, Charkhgard, & Zarif, 2014). The spatiotemporal modeling of internal states distribution was conducted for the lithium-ion batteries (M. L. Wang & Li, 2016). A two-scale particle filter-based energy state prediction algorithm was proposed for the lithium-ion batteries (Xiong, Zhang, He, Zhou, & Pecht, 2018). Zhang *et al.*[Error! Reference source not found.] A SOC estimation study was conducted for the