

Article

Comparison of Kalman Filter and H-Infinity Filter for Battery State of Charge Estimation with a Detailed Validation Method

Waleri Milde ^{*,†} and Laurin Kerle [†]

Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany

^{*} Correspondence: waleri.milde@ise.fraunhofer.de; Tel.: +49-761-4708-5924[†] These authors contributed equally to this work.

Abstract: Accurate and reliable estimation of the state of charge (SOC) of lithium-ion batteries is essential for the performance and safety of battery management systems (BMS) in applications such as electric vehicles and energy storage systems. However, there is a lack of comprehensive comparative studies evaluating different SOC estimation methods under standardized conditions. In this paper, we address this gap by providing a comprehensive, objective comparison of various Kalman and H-Infinity filter variants for battery SOC estimation, utilizing a detailed validation method based on well-defined criteria. The main contributions of this work are: (1) Implementation of multiple filter variants using a consistent equivalent circuit battery model; (2) Development of a standardized validation method for objective performance evaluation; (3) Detailed mathematical formulations enhancing reproducibility; (4) Evaluation of computational efficiency on a digital signal processor (DSP) to provide practical insights for real-time applications. Our findings reveal that while neither filter type is universally superior, the Extended Kalman Filter (EKF) and H-Infinity Filter (HIF) offer a solid balance between estimation accuracy and computational load, making them reliable choices for general applications. This work advances the understanding of SOC estimation methods and aids practitioners in balancing accuracy and computational efficiency for real-world applications.

Keywords: lithium-ion battery; state of charge estimation; Kalman and H-infinity filter; validation method for different estimators



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1. Introduction

Accurate estimation of a battery's state of charge is crucial. Beyond accuracy, the speed of convergence, temperature dependence, and behavior during long-term measurements are also significantly important. In the field of home storage and in the automotive sector, the reliability of the estimate plays a major role. In the automotive sector, the possible range of the vehicle can be calculated directly from the state of charge [1–4]. Recent studies, such as [4], have investigated various filtering methods for SOC estimation of lithium-ion batteries, observing that filter performance tends to decrease at lower temperatures.

For lithium-ion batteries, various methods and algorithms for state of charge determination exist. The simplest method is to integrate the current flowing in and out of the battery over time. This method is called Coulomb Counting. The advantage of Coulomb Counting is its short computation time, since here only a simple addition and multiplication takes place. The method is therefore also fully capable in real-time and is the basis for other techniques. Coulomb Counting has two significant drawbacks: it cannot detect and correct an incorrect state of charge, and it integrates measurement errors. An incorrect state means that the procedure does not know the initial state, which is however necessary to calculate

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