Implementation of an Equivalent Circuit Model into a Battery Management System

Degree programme: BSc in Electrical Engineering and Information Technology
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Determining the precise state of charge of a battery is an essential task, especially for electric vehicles, where an accurate range indication is crucial. In this project, a state of charge indicator was developed and implemented in the Bern Racing Team‘s battery management system. This technical development serves to optimise the use of battery energy under racing conditions.

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Objectives

The aim of the bachelor‘s thesis is to determine the state of charge of the high-voltage battery that powers the Bern Racing Team‘s racing car. For this purpose, the equivalent circuit model (ECM) of the battery cells, which was developed in a preliminary project, is improved by incorporating it within an extended Kalman filter (EKF) and embedding it in a battery management system (BMS).

Methodology and Implementation

Due to its balance between calculation speed and accuracy, the combination of an ECM with an EKF is an established method to determine a battery’s state of charge within the BMS.
The Extended Kalman Filter uses mathematical models and algorithms to estimate the response of non-linear systems. In order to adapt the mathematical operations of the EKF to the battery used, some adjustments were made, optimising the estimation accuracy for the application environment by:

- restricting the error interpretation
- adapting the sensitivity of the open-circuit voltage to changes in the state of charge
- implementing the physical limits of the state of charge
- linearising the values in the look-up tables to 0.01 % intervals
- modelling the influence of temperature using an interpolation function
- rounding the input values to mV in order to reduce the size of the algorithm in the memory of the BMS

Result

The improved SOC estimation was tested on a 22-minute real-world power profile of the Bern Racing Team. The SOC calculated by the laboratory battery tester was used as a reference value. The SOC estimate deviates most when the state of charge reaches 0 %, with a maximum deviation of 0.5 %. In comparison, using pure Coulomb counting results in an error up to 2 %. The EKF improves SOC accuracy by a factor of 4.

Conclusion

The developed SOC algorithm works reliably and accurately in the simulation and has been successfully implemented in the BMS. Through the HIL test, the stability of the algorithm was validated on the BMS hardware.