INTISARI

Perkembangan kendaraan listrik menuntut sistem penyimpanan energi yang efisien dan andal. Baterai lithium-ion menjadi solusi utama karena memiliki densitas energi tinggi dan bobot ringan. Namun, performa baterai sangat bergantung pada ketepatan estimasi State of Charge (SOC). Estimasi yang tidak akurat dapat menyebabkan pengisian atau pengosongan berlebih yang mempercepat degradasi baterai.

Penelitian ini bertujuan mengimplementasikan dan menganalisis metode *Extended Kalman Filter* (EKF) menggunakan model Thevenin 1 RC untuk estimasi SOC baterai lithium-ion. Parameter model—resistansi internal (R_0), resistansi polarisasi (R_P), dan kapasitansi (C_P)—diidentifikasi dengan metode *Recursive Least Squares* (RLS) melalui variasi *forgetting factor* (λ). Proses dilakukan secara simulatif di MATLAB menggunakan tiga dataset uji *discharge* baterai yang bersifat independen.

Hasil penelitian menunjukkan bahwa variasi nilai λ berpengaruh terhadap kestabilan hasil identifikasi parameter, di mana nilai λ kecil menyebabkan hasil identifikasi lebih sensitif terhadap noise. Berdasarkan analisis RMSE, diperoleh nilai optimal λ = 0,984 untuk baterai 1, λ = 0,994 untuk baterai 2, dan λ = 0,989 untuk baterai 3. Estimasi SOC menggunakan EKF menghasilkan tingkat akurasi yang lebih baik dibandingkan kontrol PI, dengan RMSE berturut-turut sebesar 0,2284%, 0,2543%, dan 0,2920%. Selain itu, uji ketahanan terhadap gangguan menunjukkan bahwa metode EKF tetap stabil terhadap variasi error hingga ±50% pada parameter model dan sinyal pengukuran. Kesimpulan dari penelitian ini adalah metode EKF dengan model Thevenin 1 RC dan parameter yang diidentifikasi menggunakan RLS mampu memperkirakan SOC secara akurat dan tahan terhadap gangguan.

Kata kunci: State of Charge, Lithium-Ion, Thevenin Model, Recursive Least Squares, Extended Kalman Filter.

ABSTRACT

The development of electric vehicles requires an energy storage system that is both efficient and reliable. Lithium-ion batteries have become the main solution due to their high energy density and lightweight characteristics. However, battery performance greatly depends on the accuracy of the State of Charge (SOC) estimation. Inaccurate estimation can lead to overcharging or over-discharging, which accelerates battery degradation.

This study aims to implement and analyze the Extended Kalman Filter (EKF) method using the Thevenin 1-RC model for estimating the SOC of lithium-ion batteries. The model parameters—internal resistance (R_0), polarization resistance (R_P), and capacitance (C_P)—are identified using the Recursive Least Squares (RLS) method with variations of the forgetting factor (λ). The process is carried out through simulations in MATLAB using three independent battery discharge test datasets.

The results show that variations in the forgetting factor (λ) affect the stability of parameter identification, where smaller λ values make the estimation more sensitive to noise. Based on RMSE analysis, the optimal forgetting factor values were found to be $\lambda = 0.984$ for Battery 1, $\lambda = 0.994$ for Battery 2, and $\lambda = 0.989$ for Battery 3. The SOC estimation using the EKF method achieved higher accuracy compared to the PI controller, with RMSE values of 0.2284%, 0.2543%, and 0.2920% for each battery, respectively. Moreover, robustness tests indicate that the EKF method remains stable under parameter and measurement signal disturbances of up to ±50%. The conclusion of this study is that the Extended Kalman Filter (EKF) method using the Thevenin 1-RC model with parameters identified by the Recursive Least Squares (RLS) algorithm is capable of accurately and robustly estimating the State of Charge (SOC).

Keywords : State of Charge, Lithium-Ion, Thevenin Model, Recursive Least Squares, Extended Kalman Filter