# Ukrainian Scientific and Practical Conference

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# «Scientific Research Methodology – 2024»

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# Proceedings

## Ukrainian Scientific and Practical Conference

# Scientific Research Methodology – 2024



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CONTENTS

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# IMPROVEMENT OF THE CHARGING SYSTEM OF A LITHIUM-ION BATTERY

***Abstract.*** *This paper focuses on the development of an electronic control unit (ECU) for lithium-ion batteries (LIBs) in power systems, addressing challenges related to the accurate assessment of state-of-charge (SOC) and state-of-health (SOH). Existing systems often rely on complex algorithms that require high computational resources, making them unsuitable for real-time applications in low-power systems. The proposed solution simplifies the mathematical model while maintaining high accuracy, making it suitable for real-time assessments on resource-constrained microcontrollers.*

***Key words:*** *lithium-ion battery, state of charge, state of health, power systems, control unit, mathematical modeling, real-time monitoring.*

**Introduction**. Lithium-ion batteries (LIBs) have become the primary energy storage solution in many applications due to their high energy density and long lifecycle. However, their performance is highly dependent on environmental conditions and operational cycles. Accurate monitoring and management of SOC and SOH are critical for ensuring the longevity and reliability of battery systems.

Existing battery management systems (BMS) provide basic functionality such as voltage and temperature monitoring but often fall short in evaluating SOC and SOH with the required accuracy. Moreover, the high computational complexity of current algorithms, such as Kalman filtering and neural networks, makes their implementation on low-power hardware difficult. Thus, there is a need for a control unit that can perform these assessments in real-time with limited computational resources.

Objective of the research. The primary goal of this research is to develop an ECU that can accurately estimate the SOC and SOH of LIBs in real-time, even under the constraints of microcontrollers with limited processing power and energy availability. The system should also be robust to the effects of battery degradation and environmental variations, including temperature and self-discharge.

To achieve this goal, the following tasks were addressed:

1. Review of current methods for SOC and SOH estimation in battery management systems and analysis of their computational complexity and accuracy.
2. Development of a mathematical model for LIBs with low computational complexity, capable of real-time numerical calculations on microcontrollers.
3. Creation of an algorithm for SOC and SOH assessment that operates efficiently within the limited processing power of microcontrollers.
4. Validation of the developed method through both mathematical modeling and experimental testing.
5. Development of technical solutions for integrating the algorithms into an ECU with consideration of system constraints and power efficiency.

**Methods and materials.** The research builds upon existing work in the field of lithium-ion battery modeling, particularly using equivalent electrical circuit models. The most common of these is the Thevenin model, which uses resistors and capacitors to simulate the dynamic behavior of the battery during charge and discharge cycles. However, the complexity of such models often makes them impractical for real-time applications.

To reduce computational complexity, we propose a modified Thevenin model with spline functions that interpolate the battery's behavior at different states of charge and temperature ranges. This approach allows for a more efficient computation of the battery's parameters without sacrificing accuracy.

The SOC estimation algorithm integrates this mathematical model with real-time current and voltage measurements. The algorithm uses a simplified version of the Kalman filter to adjust the SOC estimate based on the measured data, while also accounting for the battery's self-discharge and degradation over time.

The SOH estimation is based on the comparison of the current battery performance with its original capacity and internal resistance. The model continuously updates the battery's state parameters as it undergoes charge-discharge cycles, allowing for accurate prediction of battery degradation.

All simulations were performed using MATLAB Simulink to validate the theoretical model. Additionally, a test bench was developed to experimentally verify the accuracy of the model and the proposed algorithms under real operating conditions.

The simulations showed that the proposed mathematical model of the LIB, combined with the SOC and SOH estimation algorithms, achieves a high level of accuracy while maintaining low computational demands. The model's accuracy for SOC estimation was found to be within ±7%, and for SOH estimation within ±10%, across a wide range of operating temperatures and discharge rates.

The use of lithium-ion batteries in various applications presents unique challenges due to the need for high reliability over extended periods. Traditional battery management systems, which rely on complex algorithms or ground-based monitoring, are not always suitable for real-time applications.

The proposed ECU overcomes these limitations by offering a low-power, low-complexity solution for real-time SOC and SOH estimation. The use of spline functions and simplified filtering techniques allows the system to run on microcontrollers with minimal computational overhead, while still providing accurate and reliable data for decision-making.

This approach can be extended to other battery chemistries and applications, where the need for efficient and reliable power management is critical. The system's flexibility also allows for the integration of additional features, such as thermal management or more advanced fault detection.

**Conclusions.** The developed ECU for lithium-ion batteries offers a significant improvement in the real-time monitoring of SOC and SOH. The use of a simplified mathematical model and low-complexity algorithms ensures that the system can operate efficiently on microcontrollers with limited processing power and energy consumption, while still providing accurate assessments of the battery's health and charge state.

Future work will focus on further optimizing the algorithms for different battery chemistries and exploring ways to integrate advanced diagnostic features into the control unit.

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