Machine learning-based State-of-Health estimation of Lithium-Ion batteries from narrow voltage intervals

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Accurate estimation of lithium-ion battery state of health (SOH) is essential for safe and efficient operation; however, many existing methods require long measurement periods or full charge–discharge cycles, limiting their practical applicability. This work presents a fast data-driven SOH evaluation approach based on a narrow voltage interval measured during a fully controlled charging phase. The method enables reliable SOH assessment using only a short segment of the voltage curve, allowing frequent evaluation during normal battery operation. The approach is validated using eight open datasets from Aalto University and the Joint Research Centre (JRC), covering four different current rates and four temperature values, and spanning the full range of battery aging from a brand-new state to end-of-life. An optimal voltage interval is identified based on its strongest correlation with SOH across the widest possible range of charging protocols and ambient conditions. The corresponding voltage curve is then used for model-based SOH estimation. A data-driven model is developed to capture the relationship between the measured voltage curve and SOH. A long short-term memory (LSTM) neural network is selected due to its ability to handle short time sequences of consecutive voltage curves. The proposed method achieves high accuracy across all tested conditions, with a worst-case RMSE below 1%. The results demonstrate that accurate SOH estimation can be achieved using only narrow voltage segments, making the method suitable for real-time implementation in battery management systems.