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Estimation of State of Charge, State of Health and Power Status for the Li-Ion Battery On-Board Vehicle

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Abstract : Climate change is a rapidly growing global threat caused mainly by increased emissions of carbon dioxide (CO_2) into the atmosphere. These emissions come from multiple sources, including industry, power generation, and the transport sector. The need to tackle climate change and reduce CO_2 emissions is indisputable. A crucial solution to achieving decarbonization in the transport sector is the adoption of electric vehicles (EVs). These vehicles use lithium (Li-Ion) batteries as an energy source, making them extremely efficient and with low direct emissions. However, Li-Ion batteries are not without problems, including the risk of overheating and performance degradation. To ensure its safety and longevity, it is essential to use a battery management system (BMS). The BMS constantly monitors battery status, adjusts temperature and cell balance, ensuring optimal performance and preventing dangerous situations. From the monitoring carried out, it is also able to optimally manage the battery to increase its life. Among the parameters monitored by the BMS, the main ones are State of Charge (SoC), State of Health (SoH), and State of Power (SoP). The evaluation of these parameters can be carried out in two ways: offline, using benchtop batteries tested in the laboratory, or online, using batteries installed in moving vehicles. Online estimation is the preferred approach, as it relies on capturing real-time data from batteries while operating in real-life situations, such as in everyday EV use. Actual battery usage conditions are highly variable. Moving vehicles are exposed to a wide range of factors, including temperature variations, different driving styles, and complex charge/discharge cycles. This variability is difficult to replicate in a controlled laboratory environment and can greatly affect performance and battery life. Online estimation captures this variety of conditions, providing a more accurate assessment of battery behavior in real-world situations. In this article, a hybrid approach based on a neural network and a statistical method for real-time estimation of SoC, SoH, and SoP parameters of interest is proposed. These parameters are estimated from the analysis of a one-day driving profile of an electric vehicle, assumed to be divided into the following four phases: (i) Partial discharge (SoC 100% - SoC 50%), (ii) Partial discharge (SoC 50% - SoC 80%), (iii) Deep Discharge (SoC 80% - SoC 30%) (iv) Full charge (SoC 30% - SoC 100%). The neural network predicts the values of ohmic resistance and incremental capacity, while the statistical method is used to estimate the parameters of interest. This reduces the complexity of the model and improves its prediction accuracy. The effectiveness of the proposed model is evaluated by analyzing its performance in terms of square mean error (RMSE) and percentage error (MAPE) and comparing it with the reference method found in the literature.

Keywords : electric vehicle, Li-Ion battery, BMS, state-of-charge, state-of-health, state-of-power, artificial neural networks
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