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Electric Vehicle Battery States Estimation During Charging Process by NARX Neural Network

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Abstract
The electric vehicle battery state prediction in real time is an important issue to avoid the risks of burning the battery due to over-charging or dead batteries that are caused by aging. Based on the past works, it is found that the State of Charge (SOC) can be predicted, while predicting the State of Health (SOH) is a difficult challenge. Usually, the SOH is predicted after the end of the driving or the charging cycle under constant conditions; this method is practically impossible because the battery can reach the end of the battery life before achieving the prediction process. In this paper, a SOH prediction method is proposed based on SOC prediction because there is a relation between the SOC and the SOH as indicated by deriving a mathematical model. The prediction process of battery age is achieved during the beginning of the battery charging process under constant conditions of charging, in which a SOC estimation has been implemented by the nonlinear auto-regressive with exogenous input neural network (NARX) with two initial values of SOC, the default value (0%) and practical value (10%) and two charging current rates (0.5C and 1C). The proposed method has been simulated by MATLAB, which several scenarios have been achieved to validate the proposed method. The root-mean-square error (RMSE) values are very promising for both predicting SOC and SOH that are 0.5% and 0.018%, respectively.

Keywords Electric vehicle · Lithium-ion battery · NARX · State of charge · State of health

1 Introduction

Some of the most important problems that face the world are air pollution, climate change, greenhouse gases, and many other problems that are caused by consuming petroleum products; these are some reasons that lead to the increased demand for electric vehicles (EV). The EV has a portable energy source, which is the rechargeable batteries, the battery type affects the mileage of the EV, and more battery capacity leads to longer driving mileage of the EV; therefore, the evolution of the EV is strongly related to improvement in the performance of the battery. The charging process is affected by many conditions such as the initial charging level, the environment temperature, the behavior of the driver and road conditions and many other conditions (Gorbunova and Anisimov, 2020; Thammarak et al., 2022). The charging stations can be developed by many ways to increase the efficiency of them; beside the charging estimation system within the vehicle, an automated registration system can be used to register the charging vehicle and the information of it inside the charging station (Brustad, 2020). The challenges that face the EV industry are the battery states estimation, which means when to charge the battery before it reaches zero capacity, when to stop charging, and when to replace the battery before it dies. These states are important to be estimated because of the burning risks that face the drivers if the battery is over-charged, over-discharged, or the problem of dead battery in the middle of driving. In this work, the battery states are estimated using a neural network at the beginning of the charging process instead of the end of it, which could override the problem of battery over-discharging and over-charging.
The most important battery states that should be observed are State of Charge (SOC) and State of Health (SOH), in which SOC means when to recharge the battery, and SOH means when to replace the battery. The accurate estimation of SOC

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