Separating charge and discharge in measuring next-generation car batteries

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Lithium ion phosphate batteries are widely used to power the batteries in electric cars, but, unlike the amount of gas in a fuel tank, their state of charge can't be measured directly by a physical quantity. Instead, they use an algorithm based on measurements of battery voltage and current, which are in turn influenced by conditions such as weather, electrovoltaic state and traffic conditions. However, the algorithms currently used to measure state of charge each carry drawbacks when used in real-time applications.

To better estimate the state of charge in lithium ion phosphate batteries, researchers at Southwest Jiaotong University in Chengdu, China, have recently developed an algorithm that can separately measure the charging and discharging states of the battery. This allows it to function amidst initial inaccurate values and errors in measuring current, as well as distinguish between the performance of each battery in the series.

According to Zhu Xu, a researcher at Southwest Jiaotong University's School of Electrical Engineering, the differences of dynamic characteristics among batteries in series - such as battery capacity, internal resistance and polarization resistance - can cause the state of charge to become unbalanced, which influences the efficiency and lifespan of the battery packs.

Xu and her colleagues discuss their improved Thenevin circuit model this week in *The Journal of Renewable and Sustainable Energy*. The previous work has involved lithium battery management chips and management systems.

The initial value of a battery's state of charge is generally calculated by the open-circuit voltage method, which is based on the relationship between the state of charge and the difference of electrical potential between the device's terminals when disconnected from a circuit. According to Xu, however, this relationship can only be experimentally observed, which carries unavoidable experimental error. Additionally, she said, this relationship could potentially be shifted by the charging and discharging conditions.

The traditional algorithms for estimating a battery's state of charge - Ampere-hour integration, the open-circuit voltage method, neural network modeling and Kalman filtering - all carry drawbacks. Ampere-hour integration, while the most commonly used method, relies heavily on the initial state-of-charge value; the open-circuit voltage method can only be used to estimate initial state of charge; neural network modeling places a massive demand on a microprocessor to estimate multiple state-of-charge values using a large amount of experimental data; Kalman filtering, while effective at estimating the current of time-varying states in a dynamic system even amidst initial incorrect values, highly relies on the accuracy of the battery models.

This can become problematic in a traditional Thevenin equivalent circuit model. In these model circuits, the same internal and polarization resistances are adopted when the battery is being charged and discharged. In practice, however, these characteristics end up varying significantly between the two states, which can lead to inaccuracies - making Kalman filtering less than ideal.

To remedy this, the researcher's improved Thevenin equivalent circuit model works by offering different current paths when the battery is being charged or discharged. This allows the researchers to model the characteristics of the battery separately under charging and discharging conditions, with the added ability of the Kalman filter to estimate the battery's state of charge amidst incorrect initial values.

"The proposed improved Thevenin equivalent circuit battery model and state-of-charge estimation algorithm can estimate the battery's state-of-charge more accurately, without many unwanted disturbances," Xu said.

Future work for Xu Zhu and her colleagues includes developing systems to measure a battery system's state of health, which in its current operating conditions is expressed as percentage of ideal performance.

More information: "LiFePO4 battery state of charge estimation based on the improved Thevenin equivalent circuit model and Kalman filtering," is authored by Zhu Xu, Shibin Gao and Shunfeng Yang, *Journal of Renewable and Sustainable Energy* March 29, 2016. DOI: 10.1063/1.4944335

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