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EDITED AND REVIEWED BY
Sheng S. Zhang,
United States Army Research Laboratory, United States

*CORRESPONDENCE
Yujie Wang,
wangyujie@ustc.edu.cn

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Editorial: Hybrid energy storage systems: Materials, devices, modeling, and applications

Yujie Wang[1]*, Kailong Liu[2], Xiaopeng Tang[3] and Guangzhong Dong[4]

[1]Department of Automation, University of Science and Technology of China, Hefei, China, [2]WMG, University of Warwick, Coventry, United Kingdom, [3]Department of Chemical and Biological Engineering, Hong Kong University of Science and Technology, Kowloon, Hong Kong SAR, China, [4]School of Electrical and Electronics Engineering, Nanyang Technological University, Singapore

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Editorial on the Research Topic
Hybrid Energy Storage Systems: Materials, Devices, Modeling, and Applications

Introduction

In smart grids and electric vehicles, the use of lithium-ion batteries can effectively reduce greenhouse gas emissions, thus achieving environmental sustainability and low-carbon purposes. The performance degradation and capacity decay phenomenon seriously restrict the power capacity of batteries, and the problems of battery system mileage, lifespan and safety have become technical bottlenecks that restrict the development of electric vehicles (Tang et al., 2019). Therefore, the management of the energy storage system is important. Wang et al. (2020a) summarized the key problems in battery management systems. Liu et al. (2022a) presented a critical review of AI-based manufacturing and management strategies for long-lifetime batteries. To improve battery life, the hybrid energy storage system (HESS) has become one of the hot spots of energy storage technology research. As a typical complex system, the HESS contains state coupling, input coupling, environmental sensitivity, life decay and other characteristics. How to accurately estimate the internal states of the system, improve the system lifespan, and realize the coordinated and optimal control of power and energy has become the focus and difficulty of the HESS. The key issues for control and management in HESS have been summarized by Wang et al. (2020b).

A HESS consists of two or more types of energy storage technologies, and the complementary features make the hybrid system outperform any single component, such as batteries, flywheels, ultracapacitors, and fuel cells. HESSs have recently gained broad application prospects in smart grids, electric vehicles, electric ships, etc. The harmonic integration of multiple dynamic energy storage technologies offers improved overall performance in efficiency, reliability, financial profitability, and lifespan compared with single energy storage devices. This research topic focuses on all aspects of advanced component energy storage devices and their integration for HESSs.

System modeling and state estimation

Accurate modeling such as equivalent circuit (Tang et al., 2021) or electrochemical models (Liu et al., 2022b) and state estimation are the basis of energy storage system management. Moreover, the accurate estimation of the battery state-of-charge (SOC) is crucial for providing information on the performance and remaining range of electric vehicles. Several filter algorithms are compared and evaluated by He et al. 2022 from the perspectives of algorithm accuracy and complexity. There are indeed many estimation methods for SOC, and good estimation results have been achieved. Zhou et al. proposed an SOC estimation method for lithium-ion batteries at the low-capacity range. The approach has achieved good adaptability to the estimation accuracy of low battery capacity SOC in different cycle conditions. Fang et al. presented a hybrid data-driven method to achieve accurate early predictions of battery capacity and reliable analysis of battery component effects. The research results have certain practical significance and application value.

Power and energy management

It is of great significance to carry out research related to improving the performance of lithium-ion batteries. Chen et al. presented reliable electrode mass loading predictions and effect analysis of manufacturing parameters of interest. Lu et al. proposed a hierarchical power allocation strategy for a CMC-based star-connected battery-SC HESS and solved the challenge caused by the synchronous AC current on the converter arms. The presented hierarchical control aims to achieve asymmetrical power coordination by distributing the output voltage of the SC and battery clusters. Battery balancing is also important to the safe and reliable use of batteries. Liu et al. (2022a) presented an active balancing method for lithium-ion batteries in electric vehicles based on SOC and capacitance. The results indicated that the proposed balancing method has a fast balancing speed and better balancing efficiency.

Conclusion

HESSs are complex systems with the characteristics of state coupling, environmental sensitivity and life attenuation. Accurately estimating the internal states of the system, improving the system lifespan, and realizing optimal control of power and energy systems have become difficult problems. In conclusion, this research topic provided key technologies in HESSs, focusing on system modelling, state estimation, load prediction and energy management. The goal of this topic is to provide new ideas and inspirations for the future study of HESSs.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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