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Adaptive mode control strategy of a multimode hybrid energy storage system

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Abstract

To improve the efficiency of the multimode hybrid energy storage system (HESS), a novel adaptive mode control strategy (ADCS) based on logic threshold and hysteresis control strategy is proposed. The operating modes of the multimode HESS are first analyzed. Then, the adaptive target voltage of the ultracapacitor and the adaptive goal function are established. On this basis, the ADCS is designed. At last, the simulation model is established in Matlab. Simulation results show that the multimode HESS with the ADCS can avoid the excessive output power of the lithium battery and the UC absorbs all the braking energy, which ensures the battery safety. Compared to the logic threshold and hysteresis control strategy, the ADCS can obviously improve the overall system efficiency of the multimode HESS.

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Keywords: Hybrid energy storage system, Ultracapacitor, Adaptive mode control strategy, Lithium battery

1. Introduction

Hybrid energy storage systems (HESSs), which include lithium battery and ultracapacitor (UC), have been widely studied in recent years [1, 2]. Because of its perfect performance with high power and high energy density, the HESS can be used in energy storage systems of urban energy systems, solar energy system, electric vehicles etc. [3, 4]. Various configurations for HESSs have been developed [1, 3, 5]. These HESSs included Battery/UC HESS, UC/Battery HESS and multimode HESS etc. [3, 5]. Compared to the Battery/UC and UC/Battery HESS, The multimode HESS has more operating modes [2]. It can

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improve the operating efficiency since the multimode HESS can select the most suitable mode to meet the specific power demand of the load. However, the mode control strategy is more complex than the Battery/UC or UC/Battery HESS.

The mode control strategy of the multimode HESS can be divided into two modules: mode switch and power distribution. Many control strategies have been applied to do the mode control of the HESSs [2, 3, 5]. The rule-based control strategies, such as hysteresis control of the UC voltage, power balancing control strategy between the lithium battery and UC, state of charge (SOC) compensation of the UC, and so forth, have been widely studied [2, 6, 7]. These mode control strategies could be simple, but the efficiency of the HESSs might be unsatisfactory. Fuzzy logic control strategy as an important branch of artificial intelligence technology, has been successfully used to improve the efficiency of the UC/Battery HESS [8]. However, the control parameters of the multimode HESS are different from the UC/Battery HESS. It might be changed significantly in accordance with the mode switch. The fuzzy logic controller could not deal with large parameter variations.

The adaptive control strategy could be a perfect solution for these control systems with large parameter variations. The adaptive control strategy can identify the parameter variations and change control models effectively [9]. So the multimode HESS with the adaptive control strategy might do better to improve the overall system efficiency. In this paper, an ADCS is proposed for the multimode HESS. By analyzing the operating modes and the component efficiency of the multimode HESS, the adaptive target voltage of the UC and the adaptive goal function are established. On this basis, the constraints of the adaptive goal function and the power compensation rules are designed. Furthermore, the simulation mode is established in Matlab. Simulation results demonstrate the ADCS can ensure the battery safety and improve the overall system efficiency of the multimode HESS.

2. Proposed multimode HESS and its operating modes

Compare to the Battery/UC HESS, the multimode HESS adds only one switch and one power diode in the circuit. The multimode HESS is shown in Fig.1. The main originality in the multimode HESS is that the operating mode can be actively switched. Furthermore, the multimode HESS can reduce the energy loss in the DC-DC with the ADCS. In addition, the battery is isolated from frequent charges.

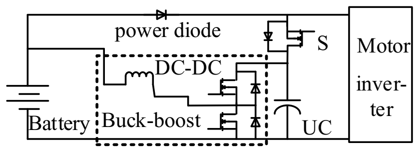

Fig. 1. The multimode HESS

When the switch S is on, the UC can directly provide the power to the motor inverter, and the lithium battery must work with the DC-DC operating in boost mode. When the switch S is OFF, the lithium battery can provide power to the motor inverter through the power diode, the UC must work with the DC-DC operating in buck mode. By controlling the buck/boost mode of the DC-DC and the ON/OFF mode of the switch S, six operating modes can be realized in the multi-mode HESS. Fig. 2 shows these operating modes.

To select suitable modes in accordance with different power demands of the motor inverter and obtain a high operating efficiency, the operating modes of the multimode HESS should be analyzed. What's