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A hybrid criterion based balancing strategy for battery energy storage systems

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Abstract

Balancing is considered as the inevitable method to cope with the unbalanced problem, which commonly exists in series connected battery energy systems (BESSs). Balancing strategies could be categorized as the voltage based balancing strategy (VBBS), the state of charge (SOC) based balancing strategy (SBBS) and the capacity based balancing strategy (CBBS). In this study, a hybrid criterion based balancing strategy (HCBBS) is proposed, in which the advantages of both the VBBS and the SBBS are taken. Thus, the balancing can be carried out throughout the whole SOC range, accelerating the balancing procedure. The proposed HCBBS is deduced and analyzed. To validate the proposed method, the simulation is established. By comparing to the VBBS, the proposed HCBBS owns 50% improvements in balancing speed.

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Keywords: hybrid criterion; balancing; battery energy storage systems; state of charge.

1. Introduction

Due to pollution and the energy crisis, research in new energy, such as electric vehicles (EVs), photovoltaic power (PV), wind power, etc., has increased worldwide[1, 2]. Battery energy storage systems (BESSs) are frequently used in such applications [3-5]. To cope with the power and energy demands for such applications, a large number of battery cells, hundreds or even thousands, must be connected in a series or parallel. Because so many battery cells are utilized in BESSs, the cell unbalanced problem cannot be ignored.

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Manufacturers have tried to select and place the same cells in a battery string, with the same state of charge (SOC), self-discharge rate, capacity, etc. However, no two cells are identical in practice, even when they are in the same production pool and the same production batch. Slight differences in these cells lead to a large mismatch after a certain period of use. Some cells may develop less capacity, and these cells will hit the discharging voltage limitation earlier when they discharge. As a result, the system will have to shut down the entire battery string for safety, and the good cells in the string cannot be fully discharged. The total capacity of the battery string will decrease. The charging process is the same, in which the good cells cannot be fully charged. Treated as an entirety for the cells in the battery string, any cell can influence the entire battery string's performance according to the "bucket effects."

Balancing or equalization is considered as the main solution to this problem, and many balancing schemes and circuits have been presented in previous studies [6-8]. These methods can be categorized as passive balancing methods and active balancing methods. Passive balancing methods [9-11] remove the excess energy from high-energy cell(s) through resistors until the state of the battery matches that of the low-energy cells in the battery string. Active balancing methods [12-14] utilize active switching circuits to transfer energy between cells or between the cell(s) and the battery string.

Besides, the balancing methods can also be categorized as the voltage based balancing strategy (VBBS) [15, 16], the SOC based balancing strategy (SBBS) [14] and capacity based balancing strategy (CBBS) [17, 18]. The VBBS is the most utilized method since the voltages of the cells in the battery string can be measured and the accuracy could be guaranteed. However, since the relationship between the voltage and the SOC is relatively flat that even large SOC differences may lead to small voltage difference, especially for the middle-SOC section, as shown in Fig. 1. The balancing may only be used in the low-SOC or high-SOC section, which is relatively short comparing to the middle-SOC section. As a result, the balancing circuits should own bigger capacity in order to balancing the battery in a short time, which will dramatically increase the cost and system complex. The SBBS was proposed to solve the problem stated above. However, the SOC cannot be measured directly, and errors always exist with SOC estimation method. To consider the state of health (SOH) of the battery, the CBBS was also utilized. However, the CBBS should obtain both the SOC and the SOH of the cells in the battery string, and the resulting capacity may have large error, which will accordingly cause large balancing error.

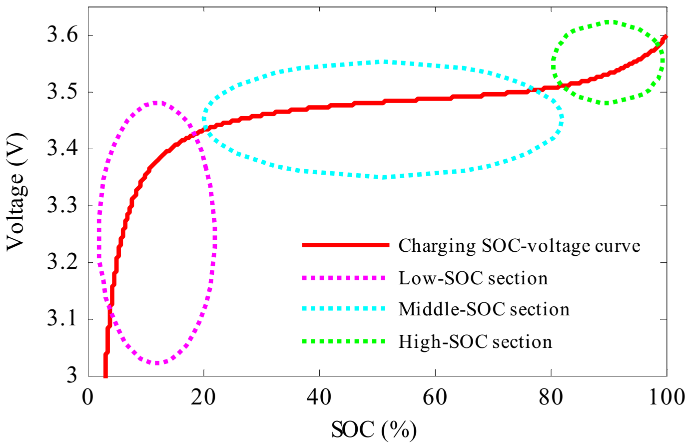

Fig. 1 Relationship between the voltage and SOC when charging for LiFePO4 battery.

To take advantage of the merits of both the VBBS and the SBBS, the hybrid criterion based balancing strategy (HCBBS) for BESS is proposed in this study. The remainder of this paper is organized as follows: In Section 2, the HCBBS for battery energy systems is proposed and analyzed. The simulation is described and the results are analyzed in Section 3. In Section 4, a conclusion is provided.