Research on Power Battery Balance System

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Abstract. This article introduces the importance of the balance system in the battery management system, and analyses the reasons for the inconsistency between battery cells. Also, it introduces the differences between passive balance and active balance management control strategies, and analyses the capacitive, inductive, transformer and DC/DC converter balance management control strategies in the lithium battery active balance management control strategy.

1. Introduction
Nowadays, problems such as the global energy crisis and the deterioration of the living environment of mankind are getting worse. Many countries make great efforts to the development of new energy vehicles. In order to meet the power requirements of automobiles, a high-capacity, high-power power supply is required. Therefore, hundreds of battery cells are required as a power source. The occurrence of unbalanced power will reduce the service life and energy utilization of the battery pack, and cause certain safety hazards. Therefore, in the battery management system, it is of great significance to use the balance system to achieve the balance of the battery power. [1].

2. Causes of inconsistency
Because the battery will go through many complex procedures in the production process, because of the difference in materials, processing procedures, transportation and storage procedures, and the experience of different working conditions in the use process, there will be inconsistency between the battery cells.

2.1. Production process
In the production process of battery packs, first of all, there are differences in the raw materials used in battery pack processing. Even the same material will have certain differences in density and material. In addition, there are many types of battery pack processing technology, and the processing process is very complicated, and it is very easy to produce individual differences in the processing process, resulting in inconsistencies among the battery cells produced. The current processing technology is gradually mature, so the inconsistency produced in the production process is relatively small.

2.2. Storage
Generally, lithium-ion battery packs will be stored for a period of time after they are produced and shipped. During the battery storage process, the inconsistency between battery cells will be further aggravated due to different temperature and humidity. During the storage process, the self-discharge of the batteries will cause the battery capacity to decrease.
2.3. Use process
As the power source of electric vehicles, the driving conditions of electric vehicles are very complicated, and there are certain uncertainties in acceleration and deceleration, up and downhill, etc. during driving. At the same time, the environment during use will also have a certain impact on the battery. Then as the number of cycles of battery pack use continues to increase, the differences caused by production and storage will be enlarged. The differences between batteries are mainly reflected in parameters such as battery capacity, battery internal resistance, battery voltage and coulomb efficiency[2].

3. Solution
In view of the inconsistency generated in the production process, the only way to reduce the difference between battery cells is improving the production level and optimizing the processing technology. This difference can only be reduced but cannot be eliminated. Therefore, the measures that can be taken are to solve the inconsistency caused by the storage and use process. When assembling the battery panels, select cells with small parameter differences, and at the same time, use equalization technology to reduce the inconsistency that occurs during battery use.

4. Battery equalization management
The passive balance management control strategy consumes the excess power in the large capacity battery in the form of heat to achieve the balance of the entire battery voltage. The passive balance strategy has a simple structure and is easy to control. The advantages of electromagnetic interference and low cost, but will cause energy waste, and if the balance current is too large, a lot of heat will be generated, which will cause safety hazards to the battery pack and the circuit[3].

Active balancing is a non-energy-dissipative control strategy, which realizes energy transfer between battery cells through switches and energy storage components. The circuit structure of the active equalization method is relatively complicated and difficult to control, but it can effectively reduce the waste of energy and improve the safety and overall performance of the battery pack.

4.1. Passive equalization
The passive equalization strategy is shown in Figure 1. The working principle is that when a certain single cell in the battery pack reaches the equalization opening condition, the corresponding circuit switch is closed, thereby forming a discharge path. Wang Qi [4] et al. designed a voltage-based passive equalization control strategy, incorporating the battery pack temperature into the equalization condition, and the battery pack temperature can be turned on within a certain range. This strategy was simulated by MATLAB/Simulink and verified The effectiveness of this balanced approach. The temperature added to the battery pack improves the safety of the battery pack.

![Figure 1. Example of passive equalization.](image)

4.2. Active equalization
Active equalization mainly uses energy storage elements such as capacitors and inductors to achieve energy transfer. The traditional capacitive balance management strategy can be divided into switched capacitor method and fit capacitor method [5]. Inductive equalization is similar to capacitive
equalization. In addition, there are transformer equalization and DC-DC conversion equalization strategies[6].

4.2.1. Switched capacitor method
As shown in Figure 2, the battery cells are connected in series, and a capacitor is connected between every two batteries. The switch controls the selection of the loop. By comparing the voltages between two adjacent cells, first let the high voltage cell and the capacitor form a loop. When the battery is discharged, the capacitor is charged. After the charging is completed, the circuit is opened, the switch is closed to the low-power cell, and the capacitor charges the cell, balance the power between two cells[7]. This method can only realize energy transfer between adjacent cells, and the equalization efficiency is low[8].

![Figure 2. Example of switched capacitor method](image)

4.2.2. Flying capacitor method
As shown in Figure 3, the switches are formed into an array. Through the control of the switch array, different on-off conditions are obtained. According to the set circuit, the battery with high power charges the capacitor. After the charging is completed, the switch is turned off. Then the switch of low power loop is turned on, and the capacitor charges the cell with low power[9]. Through the energy transfer between the battery and the capacitor, the energy transfer between the batteries. Hanbin Zhao [10] et al. proposed an improved dynamic balancing strategy for fit capacitance. This method can realize the power transfer between any cells, and the efficiency is high.

![Figure 3. Example of flying capacitor method](image)
4.2.3. Inductance equalization method
The inductor has no energy loss and is often used as an energy storage element. Figure 4 shows an example of an inductance equalization circuit. Similar to the capacitance method, the energy transfer between the battery and the inductance is realized through the on and off of the switch. The relationship between inductance energy and voltage is as follows:

\[ u = L \frac{di}{dt} \]  
\[ i = \frac{1}{L} \int ud\tau \]  
\[ W = \frac{1}{2} L i^2(t) \]

It can be seen from Equation 2 that when the voltage is constant, the current flowing through the inductor increases linearly with time and is inversely proportional to the size of the inductor. From Equation 3, it can be seen that the energy stored in the inductor is proportional to the square of the current and the inductance value. The equalization circuit is generally used in the equalization system with SOC or voltage as the equalization variable [11].

4.2.4. Transformer equalization
Figure 5 shows an example of an equalizing circuit for a single-coil transformer. A transformer with a turns ratio of N:1 is combined with a diode. When the detection circuit detects that the voltage of a certain cell is too low, the control centre sends an equalization signal, and the corresponding switch is turned on to transfer energy to the cell[12], thus realizing the single The balance of energy between the bodies [13]. The multi-coil transformer is shown in Figure 6, and the principle is similar to the single-winding transformer.
4.2.5. *Equilibrium Control with Bidirectional DC/DC*

Figure 6 is an equalization circuit with a buck-boost structure. L is an inductance, which is the energy carrier. The MOS tube controls the on and off of the equalization circuit through a driving signal; D3 and D4 are diodes used to form a discharge loop. The structural circuit can be applied during charging, discharging and static state.

When the inconsistency between battery cells exceeds the threshold, for example, when the voltage value of B3 is higher than the voltage value of B2, the equalization starts, as shown in Figure 6, the PWM drive circuit sends a control signal, MOS3 is turned on, then B3, L2 and MOS3 form a discharging loop, the electrical energy is converted into magnetic energy in the inductor. In the B2 charging phase, MOS3 is disconnected, and the energy stored in L2 is released to B2. When the current in L2 decreases to 0, charging ends. This structure is easy to expand when the number of batteries is large, the equalization process is controllable, and the efficiency is high.

Yonghong Huang [14] designed a bidirectional DC-DC converter active balance control strategy for lithium-ion battery packs. Bruce Lee et al. [15] proposed a two-way equalization circuit with inductance. The equalization circuit uses a combination of Buck-Boost converter and switch matrix to achieve the balance of the entire battery pack. Independent battery balance control. Tiezhou Wu et al. [16] proposed a two-level equalization circuit structure based on a reconfigurable circuit. A reconfigurable circuit is adopted between the resistors, and the battery pack structure of the access circuit is controlled by the on-off control of the switch. The Buck-Boost circuit is used in the group to realize the electric balance between the battery cells. Simulation analysis is carried out, and the equalization time is reduced by 66.2%, which improves the equalization efficiency.

![Figure 6. Example of buck-boost structural balance.](image)

5. Conclusion

The battery balance management in the electric vehicle battery management system is significant to improve energy utilization, safety and service life of the battery pack. When the batteries’ energy is about the same, passive balancing can be used. When the inconsistency between the cells increases, passive equalization is no longer applicable due to its large energy consumption and heat accumulation. The equalization strategy of capacitors, inductors, transformers or DC-DC converters should be adopted to balance the energy. The balance of battery energy improves the performance of the energy system.

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