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Battery Management System for Cell Balancing in an Electric Vehicle

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Abstract. Batteries are becoming more and more popular for use in homes and cars, which uses because of their high efficiency, minimal self-discharge, and high volumetric and gravimetric energy densities. However, because they can carry a lot of energy, Failure to confirm that they are functioning within their allowed safe operating limitations could result in fire dangers and explosions because they tend to be more unstable than other power sources, such as lead-acid batteries. To maintain battery packs within safe operating parameters & optimum power usage, innovative Battery Management Systems (BMS) are required, hence avoiding endangering users. This inquiry starts with a battery model employing passive components before addressing the crucial components of developing a successful BMS. Additionally, it offers simulation to make a BMS's operation easier to understand.

Keywords. Battery Management System (BMS), Constant Current (CC), Constant Voltage (CV), State of Charge (SOC).

1. Introduction

Single-cell voltages in the battery pack can be adjusted using a process called passive cell balancing. The sum of the voltages of each cell in a battery with numerous cells connected in series determines the battery's overall voltage. However, because to manufacture tolerances, variations in age or usage, or other variables, the value of each cell may vary. These variations may intensify over time, resulting in an uneven discharge and a decreased battery capacity. Without the aid of active electronics or external power sources, passive cell balancing is a technique for bringing the voltages of each cell into balance [1]. Each cell that is at a greater voltage than the others receives a tiny resistance in parallel as part of the passive cell balancing process. The resistance lowers the voltage of the cell by siphoning a tiny amount of current from it. Up until the voltages are balanced, the higher cells' voltage will gradually drop while the lower cells' voltage will gradually rise. Although passive cellular balancing is a quick and efficient way to balance battery cells, it has some drawbacks. It can take a while to balance significant voltage variations and only works when the cells are already somewhat well-matched. Additionally, the balancing resistors can squander a lot of power, which decreases efficiency and shortens battery life. Batteries require cell balancing to make sure that each cell runs within a safe voltage range and adds equally

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to the battery's overall capacity. The total voltage of a battery with many cells linked in series is equal to the sum of all the voltages of each cell [2]. However, because to manufacture tolerances, variations in age or usage, or other variables, the voltage of each cell may vary. Numerous issues can arise if the voltage of one or more cells is much greater or lower than the others. For instance: Lower capacity cells in a battery pack will discharge more quickly and hit their minimum voltage limit earlier, resulting in a reduction in battery life. Performance and overall battery life may suffer as a result; safety risks: Overcharging can result from one or more cells in a battery pack having a higher voltage than the rest. This can cause the battery to overheat, expand, or even catch fire; Reduced performance: If one or more of the battery cells in a battery pack has a lower voltage than the others, this can lower the battery's total voltage and diminish the battery's capacity. The performance, safety, and lifespan of the battery are maximized by cell balancing, which makes sure that each cell in the battery pack is functioning within a safe voltage range and contributing evenly to its overall capacity [3].

2. Battery Management System

Battery management systems (BMS) are electrical devices that control the performance, safety, and longevity of rechargeable batteries. The numerous battery system parameters, such as voltage, current, temperature, or state of charge, are monitored and controlled by it, which is typically made up of hardware and software components that collaborate. A BMS's key duties are as follows:

2.1. Cell Monitoring

A BMS checks that each battery pack's cells are operating within safe ranges by measuring their voltage and temperature. Estimating the battery pack's state of charge (SOC) is crucial for improving battery performance and increasing battery life. A BMS does this using algorithms and models. Cell balancing: To avoid overcharging or undercharging, which can harm the cells and shorten battery life, a BMS makes certain that each battery pack's cell's voltage and capacity are matched [4].

2.2. Thermal Management

A BMS regulates a battery pack's temperature to avoid overheating or undercooling, which can impair performance or present safety risks. A BMS has safety features including overcurrent protection, overvoltage protection, or short circuit protection to guard against battery pack damage and lessen the possibility of a fire or explosion. Electric vehicles, renewable energy sources, and portable electronics are just a few of the applications where BMS technology is frequently used. With the rising need for high-performance, secure, and reliable battery systems across a variety of industries, its significance has grown. Communication: To enable data sharing with other systems or equipment, such as battery chargers, inverters, or monitoring software, a BMS is frequently provided with communication capabilities [5]. This enhances the battery system's coordination and control and contributes to its performance optimization. A BMS is capable of identifying and diagnosing defects or irregularities in a battery system, such as cell deterioration, overloading, or ageing. The battery system's charging and discharging characteristics can be modified using this information, which can also be used to initiate maintenance or replacement procedures. User interface: A BMS could have a user interface, like a display or a mobile app, to let users check on the battery system's performance, make configuration changes, or get alerts or messages about its status. Integration and customization: Depending on the requirements of the particular application, BMS technology is frequently flexible and can be combined with other battery chemistries, cell configurations, or system architectures [6]. Emerging trends include the use of artificial intelligence (AI) and machine learning algorithms to optimise battery performance and lifespan, the incorporation of wireless communication and charging technologies for greater convenience and flexibility, and the creation of smart grid and vehicle-to-grid applications to enable bidirectional energy flow between the battery system and the power grid. The Li-ion battery BMS keeps track of the battery's cells to ensure that they are operating within safe parameters and responds when one of them does. If the voltage fluctuates too much or too little, a BMS will cut off the loads and charges, accordingly. The pack's voltage will also be checked to ensure that each cell is the same; any cells with higher voltages should have their voltage lowered [7]. With an initial value of 3.7 V, lithium batteries are susceptible to bursting & having a reduced shelf life if their voltage dips below 3 V or increases above 4.5 V. A BMS also regulates and modifies temperature. Cell balancing is the process of determining the voltages of each battery in the pack based on some fundamental variables. There are two general types of cell balancing that are used: passive cellular balancing and active cell balancing [8]. A lithium-ion battery's charge and discharge cycles can cause various voltage drops and spikes. It is crucial to precisely define the electric equivalent circuit of the battery to comprehend how these charging and discharging cycles function [9]. Resistors and capacitors, which are passive components, are used to simulate a battery's behaviour during its charge and discharge cycles. The built-in circuit for the Li-ion cell displays pronounced increases and decreases during the charging and discharge intervals [10].

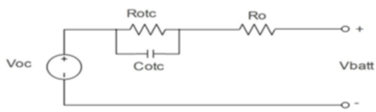

Figure 1. Equivalent of a cell's circuit.

This drop can be modelled using a resistor and is brought on by internal resistance. Electrochemical processes take place inside the battery, causing internal resistance, which prevents a battery from being charged or discharged. As seen, the voltage drop in the cell decreases exponentially. A parallel RC network is connected in series with the cell's internal resistance to prevent exponential discharge. The battery voltage transforms into an exponentially increasing function of the capacitance voltage, whose charge is decreasing through the resistor when the current used for charging is cut off, a voltage source that depends on a circuit (VOC) in line with a parallel RC network is used to simulate the battery with internal resistance (r) (Rotc and Cotc) [11] as shown in figure 1.

3. Techniques for Cell Balancing

Cell balancing involves the process of balancing the voltages for all the cells in the pack of batteries after each charging cycle utilizing passive components. To achieve this, either the most loaded cell is discharged or the charge is moved from one cell/pack to another cell. This is significant because irregularities in the cell voltages will lead to the pack voltage is not where it would be when charging is complete, giving an inaccurate impression of the SoC of the entire pack. Additionally, some cells may be overloaded if the cell voltage is not balanced or monitored throughout the charging cycle, which could be harmful [12]. In passive cell balancing technique, the energy of the cell in a series pack with the highest voltage is dissipated using a resistor. Generally, the weakest cell in the pack achieves a greater maximum voltage threshold for equal current through both cells the safe operational area (SOA) is exceeded by the cell voltage [13]. Once the switch is engaged, the cell can discharge via the resistance up to the point where the SoC and cell voltage are at a safe level, commonly known as a bleeding resistor. This procedure is continued until the voltage in every cell is the same. The voltage is checked by monitoring ICs that use A/D converters to transfer voltage from analogue to digital. Despite being a dissipative technology, passive cell balancing is more commonly used in commerce since it is simpler to operate. Figure 2 shows the passive cell balancing circuit. C-rates control how quickly a battery charges and discharges. Fast discharge losses reduce the time needed for discharge and affect charging times [14, 15]. In active cell balancing the transfers or stores energy between one cell to another is shown in figure 3.

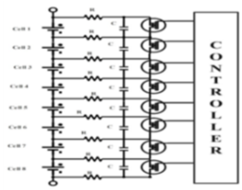

Figure 2. Passive Cell Balancing circuit.

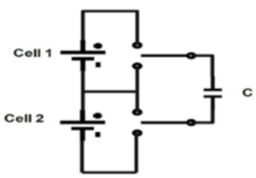

Figure 3. Active Cell Balancing Circuit.

4. Calculations for Analysis

a) Battery Capacity: 2600 mAh = 2.6 Ah (1000 mAh = 1Ah)
b) Current Required for Charging = 2.6 A (as per the datasheet the current used for charging should be 1 C (c-rating). IChr = 1C*2600 mAh = 2.6 A
c) Time required for the Charging = (Total capacity of battery)/(Required Charging Current). In real time analyses the charging time is almost double the required Ampere rating of the battery due to the implementation of the CC-CV charging methodology.
d) Resistance value (Bleeding) = 35 Ohms (ranges between the value of 25-40 ohms)
e) Current (Bleeding) = (Cell Voltage)/(Resistance (Bleeding)) = 0.12 A
f) Dissipated power in the resistance during 1 Charge cycle =I^2 R=0.12^2*30=0.50 W

For a big battery pack, the passive balance of cells technique will be shown to be very dissipative since the amount of loss of power in the resistance is adjusted by changing the quantity of charging current. Parameters used for the Simulation of Cell balancing for Ni-Cd Cells in MATLAB are shown in table 1.

Table 1. Parameters are taken for the Simulation of Cell balancing for Ni-Cd Cells in MATLAB.

Parameters	Details
Cell Type	Nickel Cadmium
Number of Cells	1/8
Cell Capacity (Per each cell)	2.6 Ah
Charging Current	2.6
Nominal Voltage	3.7 V
Charging Methodology	Constant current Constant Voltage
Balancing Technique	Passive Cell Balancing

5. Result and Discussion

A 4.2 V direct current source is linked to the cell, as seen in the figure 4. First, it must be ensured that the cell value is more than the value of 2.7 V. If the value of voltage is less than as said above it is needed to be charged by using a charging method called Trickle Charging method. In that method basically, the battery cell will be charged at a value of current nearly 0.5 A so that the voltage of the cell remains back to 2.7 V and after that, the normal method of charging is solely applied until the voltage reaches the value of 4.2 V max. If the voltage goes beyond the value of 4.2 V the balancing system will be turned on and charging will be stopped. For achieving the passive cell balancing technique in MALAB, The Eight cells of nickel cadmium are connected in combination with series and parallel circuitry as shown in figure 3. Two sets are made having 4 cells in each group after that both are connected in parallel formation. The Simulation has been calibrated at different times so, that all cells must discharge at the same value of SOC at its final value. This is all shown in the Simulink diagram in figure 5. The Simulation run time finally reached a value of 1800 sec which is nearly 30 minutes to get all the cells to get the final discharged SOC of 17.98 at which the cells or the battery will stop providing the charge to the external circuit as shown in figures 6 and 7.

Figure 4. Block diagram for Cell charging Methodology.

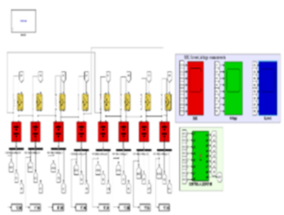

Figure 5. Simulink Diagram of Passive Cell Balancing of Ni-Cd battery cell in MATLAB SIMULINK.

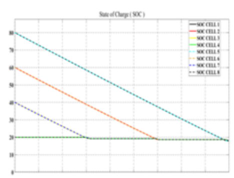

Figure 6. Final SOC value of All 8 cells of Ni-Cd Battery.

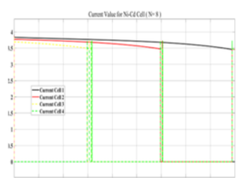

Figure 7. Current value for Ni-Cd Cells (N=8).

6. Conclusion

The fundamentals and significance of the management systems for batteries in a nickel-cadmium battery pack were discussed in this essay. The comparable circuit model is then used to explain the charging and discharging graph, and batteries are eventually symbolized using related circuit theory. The methods of balancing cells are then discussed, with a focus on passive balance (switching resistor) in particular. To make is obvious why passive balance is desirable, the trade-offs of employing active balancing are outlined. Following balancing techniques, the charging and discharging graphs of a single cell or four cells modelled in MATLAB/Simulink are discussed. The charging process for nickel-cadmium battery packs is detailed in the final section, along with the justifications for why it is crucial for charging nickel-cadmium battery packs.

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