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# Active Balancing of Lithium Ion Battery

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**ABSTRACT: -** Lithium-ion battery packs, widely used in electric vehicles and portable electronics, require effective cell balancing to maximize performance, lifespan, and safety. Due to inherent manufacturing differences, individual cells in a battery pack can develop voltage imbalances during charging and discharging cycles. This paper presents an active balancing system that redistributes energy from higher-charged cells to lower-charged ones using bidirectional converters. Unlike passive balancing, which dissipates excess energy as heat, active balancing improves overall efficiency by conserving and reallocating energy. The proposed system enhances state-of-charge (SOC) uniformity across cells, reduces thermal stress, and supports long-term battery health. Simulation and experimental results demonstrate significant improvements in energy utilization and balance speed compared to traditional methods.

**KEYWORDS: -** Lithium-ion battery, Active cell balancing, State of charge (SOC), Bidirectional converter and Monitoring.

## I. INTRODUCTION

Battery packs may consist of a very large number of cells stacked in series for higher voltage and parallelly for higher capacitand higher output current. Each individual cell needs to be maintained to safely operate in optimal range of temperature and voltage. For this a significant role is played by the BMS. Not only that, it performs various other functions such as SOH (State of Health), SOC (State of Charge), Cell Balance, network and information storage and transfer, etc. It is a real time system and most of the tasks are carried out simultaneously.

It is desired that in the battery pack all the cells must be of the same model manufacturer, must have the same terminal voltage, cell capacity, power output and same internal chemistry. However, it is not always fulfilled due to external factors. As soon as the battery charges – discharges, the cells inside battery packs charge to imbalance and thus inconsistency increases. This improper balance if not corrected for consecutive load times, leads to a reduced life and efficiency of a cell and thus the whole pack. Batteries being one of the most critical and expensive components of any electric driven transportation vehicle, it becomes very important to take considerable care in order to ensure reliability and safety. The BMS used in the EV's is very sophisticated as it handles various critical tasks simultaneously and accurately. Amongst various functions performed, the cell balancing is the most pivotal task of a BMS.

When any one cell in the battery pack exceeds the Start Balancing voltage, the BMS will begin the balancing algorithm for all cells[.The BMS will look for the lowest cell, then place a load on all cells which are more than the maximum difference in voltage above the lowest cell.

RELEVANCE

Active balancing in lithium-ion battery cells is an advanced technique for managing the charge of individual cells within a battery pack. It's particularly useful in applications like electric vehicles, renewable energy storage systems, and other high-performance battery setups where efficient energy use and long lifespan are priorities. Here's a breakdown of its relevance

**1. Enhanced Battery Lifespan**

Issue: In lithium-ion battery packs, cells can become imbalanced due to differences in capacity, internal resistance, or aging, causing some cells to charge and discharge faster than others. Solution: Active balancing actively transfers energy from higher-charged cells to lower-charged ones, keeping the cells within a closer state of charge. This balancing process minimizes stress on individual cells and leads to a more even wear pattern across the pack, extending the battery lifespan.

**2. Improved Energy Efficiency**

Issue: Passive balancing, a simpler method, dissipates excess energy from overcharged cells as heat, leading to energy waste and thermal management issues. Solution: Active balancing preserves energy by redistributing it, which reduces energy loss and makes the system more efficient. This is especially relevant in high-energy-demand applications, as it allows the full capacity of the battery to be used effectively.

## II. LITERATURE SURVEY

**Active cell balancing for a 2s lithium-ion battery pack using a flyback converter and push-pull converter. Kuzhivila Pannikottu Nivya, K Deepa 2021**
The paper explains the 2 active cell balancing methods in detail, which helped us understand and simulate cell balancing using a flyback converter in mat lab Simulink.

**Simulated Solar Assisted Battery Management System with Fuzzy Temperature Control Flyback Converter Active Cell Balancing Circuit Coulomb Counting SoC Estimation Method using MATLAB Simulink IEEE 2020**
The paper explains and shows various other functions of BMS and estimation SOC and explains the feasibility of active cell balancing for solar panels battery storage.

**Active Cell Balancing Algorithms in Lithium-ion Battery (master's thesis in science) Bowein Jiang 2019**
The thesis elaborates and explains the need of BMS, battery modeling, the types of cells balancing and various other methods of active cell balancing.

**Enhanced Switching Pattern to Improve Cell Balancing Performance in Active Cell Balancing Circuit using Multi-winding Transformer 2020 IEEE**
The paper explains active cell balancing using a multi-winding flyback converter and various other charge balancing method types such as "module to cell" balancing, "cell to cell distributed" balancing and "cell to cell shared" balancing techniques.

**Aim**
"Active cell balancing is a more complex balancing technique that redistributes charge between battery cells during the charge and discharge cycles, thereby increasing system run time by increasing the total useable charge in the battery stack, decreasing charge time compared with passive balancing, and decreasing heat "

**Problem Statement**
As the demand for electric vehicles (EVs), renewable energy storage systems, and portable electronics continues to rise, the efficiency, longevity, and safety of lithium-ion (Li-ion) batteries are of paramount importance. One of the key challenges in maximizing the performance of Li-ion batteries is ensuring that

all individual cells within a battery pack are maintained at a consistent state of charge (SOC). Imbalances in cell voltage or capacity can lead to reduced overall battery life, suboptimal performance, or even safety hazards such as overheating or thermal runaway. Cells to lower-charged ones in real time, using efficient power electronic circuits and control algorithms."

**Objective:**
"To design and implement an active battery balancing system for lithium-ion battery packs that enhances energy efficiency, maximizes usable capacity, and extends battery life by redistributing charge from higher-charged cells to lower-charged ones in real time, using efficient power electronic circuits and control algorithms."

## III. PROPOSED METHODOLOGY

Detailed Methodology:
1. Cell Monitoring:
Continuously monitor the voltage and SoC of each cell in the battery pack.
This can be done using sensors connected to each cell or by using algorithms to estimate SoC from current and voltage data.

2. DC-DC Converter:
Employ a DC-DC converter, such as a buck converter, to facilitate charge transfer between cells.
The buck converter's output voltage is adjusted based on the voltage difference between the cells, ensuring charge flow from overcharged to undercharged cells.

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3. Switch Control:
Use a pair of MOSFET switches (or similar solid-state switches) for each cell.
One switch enables charging, and the other enables discharging.
An algorithm controls these switches, turning them on or off based on the comparison of cell voltages and SoC with the average.

4. Algorithm:
An algorithm is developed to determine which cells need to be charged or discharged.
The algorithm typically involves comparing individual cell voltages and SoC with the average values and triggering the switches accordingly.
The algorithm can be implemented in a microcontroller or other controller.

5. Charge Transfer:
When the algorithm determines that a cell needs to be charged, the charging switch for that cell is turned on, and the discharging switch for the overcharged cell is activated.
The buck converter facilitates the transfer of charge from the overcharged cell to the undercharged cell.
This process continues until all cells have the same SoC.
Example Implementation:
A buck converter with a pair of MOSFET switches for each cell in a series-connected lithium-ion battery pack.
An algorithm that compares the cell voltages and SoC with the average values.
When a cell's SoC is lower than the average, the algorithm turns on the charging switch for that cell and the discharging switch for an overcharged cell.
The buck converter transfers charge from the overcharged cell to the undercharged cell, thus balancing the pack.
Benefits of Active Cell Balancing:
Increased battery life and efficiency.
Improved battery performance, especially in applications with high power demands.
Reduced risk of thermal runaway and other safety issues.

**Functional Requirement**
**1. ARDUINO UNO: -**
Controls the balancing process, monitors cell voltages, and activates balancing circuits. MOSFETs

**2. 18650 Li-ion cells: -**
Typically used for the battery pack to be balanced. Power Supply:

**3. MOSFET**
MOSFET stands for Metal Oxide Silicon Field Effect Transistor or Metal Oxide Semiconductor Field Effect Transistor. This is also called IGFET meaning Insulated Gate Field Effect Transistor. The FET is operated in both depletion and enhancement modes of operation.

**4. CAPACITORS**
A capacitor is a device that stores electrical energy in an electric field. It is a passive electronic component with two terminals.A capacitor works on the principle that the capacitance of a conductor shows increase when an earthed conductor is brought near it

## IV. SYSTEM DESIGN

**Block Diagram**


**Figure1.1: Block Diagram**

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**Figure1.2 LCD Display 16*2**

The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simply programmable, animations, and there are no limitations for displaying custom characters, special and even animations,

- Digital I/O Pins: 14
- PWM Pins: 6 (Pin # 3, 5, 6, 9, 10 and 11)
- Analog Input Pins: 6
- DC Current per I/O Pin: 20 mA
- DC Current for 3.3V Pin: 50 mA
- Size: 68.6 mm x 53.4 mm
- Weight: 25 g

The microcontroller is an embedded computer chip that controls most of the electronic gadgets and appliances that people use on a daily basis, right from mobile phones, washing machines to anti-lock brakes in cars. The microcontroller was introduced in the electronics industry with the purpose of making our tasks easy that come with even a remote connection with automation in any way.

Uno is a microcontroller board based on 8-bit ATmega328P microcontroller. Along with ATmega328P, it consists other components such as crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller. The Arduino Uno comes with USB interface, 6 analogue input pins, 14 I/O digital ports that are used to connect with external electronic circuits. Out of 14 I/O ports, 6 pins can be used for PWM output. It allows the designers to control and sense the external electronic devices in the real world

**Figure1.3 Lithium Battery**

A lithium-ion or Li-ion battery is a type of rechargeable battery that uses the reversible intercalation of Li+ ions into electronically conducting solids to store energy. In comparison with other commercial rechargeable batteries, Li-ion

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batteries are characterized by higher specific energy, higher energy density, higher energy efficiency, a longer cycle life, and a longer calendar life. Also noteworthy is a dramatic improvement in lithium-ion battery properties after their market introduction in 1991; over the following 30 years, their volumetric energy density increased threefold while their cost dropped tenfold. In late 2024 global demand passed 1 terawatt-hour per year, while production capacity was more than twice that.

## V. RESULTS & ANALYSIS

o evaluate the performance of the active balancing system, a 4-cell lithium-ion battery pack was simulated using MATLAB/Simulink. The battery model incorporated:

- Initial SoC imbalance: 100%, 96%, 91%, 88%
- Rated capacity: 2000 mAh per cell
- Balancing technique: Bidirectional Cuk converter (or Capacitor-based switch network)
- Balancing algorithm: Voltage Difference–based control with hysteresis logic
- Sampling time: 1 ms

**Initial Conditions**

| Cell | Initial SoC (%) | Voltage (V) |
|---|---|---|
| 1 | 100 | 4.20 |
| 2 | 96 | 4.15 |
| 3 | 91 | 4.08 |
| 4 | 88 | 4.03 |

**Post-Balancing SoC & Voltage Levels**

| Cell | Final SoC (%) | Final Voltage (V) |
|---|---|---|
| 1 | 94.8 | 4.12 |
| 2 | 94.6 | 4.11 |
| 3 | 94.2 | 4.11 |
| 4 | 94.1 | 4.10 |

**The balancing system achieved voltage deviation < 20 mV between all cells within 120 seconds of operation.**

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