A Comparative Analysis of Cell Balancing Techniques For Battery Management System

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Abstract - *Automobile industry is moving toward the development of fully electric vehicles (EVs) in near future. This new architecture requires a large battery pack that serves as the vehicle's main source of energy. This larger battery pack allows electric vehicles to run longer distances by utilizing more parallel strings to increase the overall energy storage capacity of the system. The longevity and performance of the battery pack are of prime importance. It is critical to maintain a charge balance of a series/parallel configured battery module because of manufacturing inconsistencies and unique performance characteristics of individual cells. Two balancing techniques are proposed and analyzed in this paper. An active balance system and a passive balance system are proposed and applied to a battery module that has such a configuration in order to balance the individual battery cell voltages. The effects of these balancing techniques have been simulated using the MATLAB simulation tool over a series/parallel battery pack. The simulator provides a way to measure and compare both balancing techniques by varying circuit parameters. This allows a thorough examination of the balancing system by establishing a trend based on the effects of circuit parameters on system performance.*

Key Words*: *Battery pack, Cell Balancing, Battery Management system, Passive balancing, Active balancing, Capacitors, Resistors.

1. INTRODUCTION

In lithium-ion battery packs, cell balancing is necessary when multiple cells are arranged serially. Designing electronic components in such a way that they continuously balance the cell voltages is very important. Not only is it vital for the battery pack's performance, but it is also essential for optimal life. We can design a battery with a larger capacity for an application, since the battery is able to achieve a higher State of Charge (SOC) because of cell balancing. Cell balancing is not used by many companies at the beginning of their design process to reduce cost; however, the SOC cannot proceed to 100 percent without investing in balancing the hardware and software.

1.1 Cell Imbalance

Lithium cells are subject to accelerated degradation either when they are overheated or overcharged. As a result of thermal runaway conditions, they can catch fire or even explode. When the voltage of a lithium-ion cell goes beyond 4.2 V by just a few hundred millivolts, it can still experience the above mentioned conditions.

1.2 Cell Balancing

Fig 1 depicts the process of cell balancing. The process of balancing cells after they have been fully charged, or when they are at their maximum charge, can be defined as equalizing the voltage among them. Negligible differences are always there in the Self-discharge rate, State of Charge, capacity, characteristics of temperature and impedance between two cells. Though they are of the same manufacturer, model, and production lot, this remains to be true. Manufacturers will group the cells with similar voltage so that they coordinate as closely as possible, but still, there can be slight differences in the capacity, impedance of individual cells and self-discharge rate over time which can contribute to voltage separation.

Full charge will be detected by typical battery chargers through validating if the voltage regulation point has been reached by the voltage of all the cells. As long as the overvoltage protection limits aren't exceeded, individual cells may vary their voltage. In contrast, weaker cells tend to exhibit higher voltage at full charge termination than the cells in series. The weakened cells are then subjected to continuous overcharging. At charge completion, the weaker cells' voltages are higher, which accelerates their degradation. The rate of degradation will increase by thirty percent even in the case of maximum charging voltage being exceeded by just ten percent.

Either due to a faster rate of discharge or higher internal resistance caused by their lesser capacity, weak cells tend to discharge at a lower voltage. As a result, when any of the weak cells hit the cell under voltage protection, the battery's complete capacity will be never used even when sufficient voltage of the pack is available to power the system, because over discharge will be prevented by the pack protector by stopping the discharge of the entire pack in the case of any cell voltage being below the cell under voltage threshold, which is approximately 2.7 V.

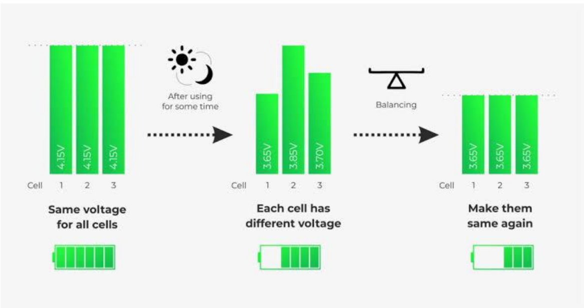

Fig -1: Cell Balancing

1.2.1 Passive Cell Balancing

It is a simple and straightforward cell leveling approach in which the cells are discharged via a dissipative bypass route. This strategy is advantageous in the application of a low-cost system. The passive cell balancing approach is the least popular since one hundred percent of the excess energy of a higher-energy cell is wasted as heat during discharge, resulting in a significant reduction in battery runtime.

Fixed and switching shunting resistors are the two types of cell balancing methods. The one which prevents the circuit from being charged too much is usually linked to the fixed shunting and is known as the Fixed shunting resistor. The maximum voltage of every cell can be regulated without

causing harm to them by using resistors in the passive balancing circuit. As a result of the energy consumed by these resistors, thermal losses may occur to balance a battery in the management system of the battery. Hence, Fixed shunting resistor method is demonstrated to be inefficient.

The most common cell equalization approach is the switch shunting resistor cell balancing circuit. It has two modes, one of which is continuous and the other of which is sensing. The continuous mode instructs All switches are instructed to turn on or off simultaneously in the Continuous mode. Each cell, however, needs a voltage sensor which is concurrent in the sensing mode. Due to the presence of balancing resistor, this cell balancing circuit consumes a lot of energy. For a battery system that needs to be charged or discharged at a low current, this kind of Cell balancing circuit is designed. This cell balancing circuit uses a lot of energy because of the resistor used for balancing. This circuit is suited for a system of battery which requires less current when it is either discharged or charged. Passive cell balancing with a switched shunt resistor is shown in Fig 2.

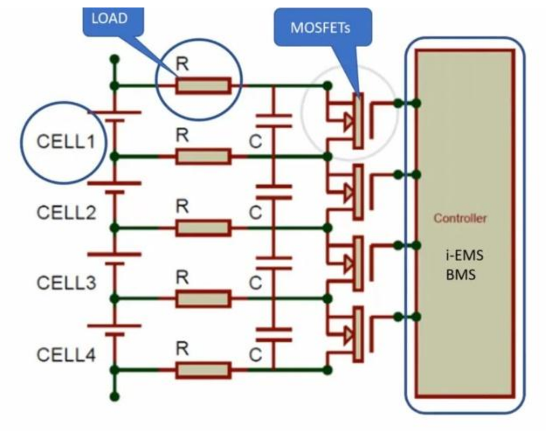

Fig -2: Passive Cell Balancing

1.2.2 Active Cell Balancing

Energy is transferred from one cell to another using active cell balancing, which uses capacitive or inductive charge. That is, from a cell with a greater charge state to one with a lower charge state. By transferring energy from the cell having more energy than the other in the pack, the active balancing technique tries to extend the life or state of charge of a pack of lower capacity cells. Instead of squandering energy as heat through tiny converter circuits, an active cell balancer efficiently balances cells by sending energy from the highest voltage cells to the lowest voltage cells. Charge shuttling and energy converters are two forms

of active cell balancing technologies. The process of actively shifting charges from one cell to another to maintain equal cell voltage is known as charge shuttling. Energy converters transmit energy between the cells of a battery pack using transformers and inductors. Active cell balancing with a switched capacitor is shown in Fig 3.

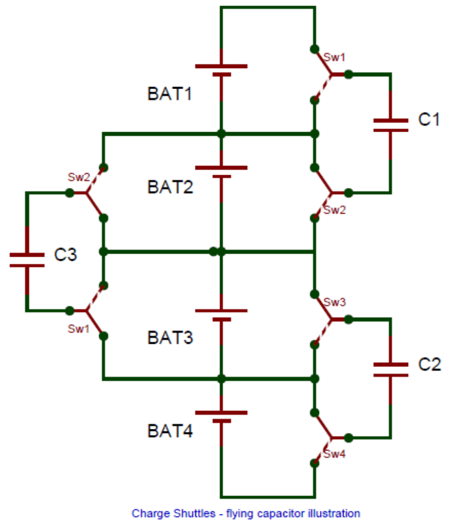

Fig -3: Active Cell Balancing

2. LITERATURE REVIEW

Jonathan Carter, Zhong Fan, and Jun Cao[1] have highlighted the strategies utilized for cell balancing, such as the Active and Passive methods. The best solutions are split down into resistor, capacitor, inductor, and transformer-based methods. Each circuit is described in length, including its benefits and drawbacks, as well as noticeable variations. The differences between the various methods are compared, and the issues that arise are examined. A

suitable solution is proposed. The paper then goes on to explore the difficulty in directly comparing the performance of different CECs (Charge Equalization Circuits) as well as the ambiguity of a CEC's industrial needs. Finally, future study will consider modern components in order to improve existing solutions. Finally, it includes a fully flexible battery pack that can be adjusted to meet a variety of voltage and current needs.

Hemavathi Sugumar[2] has highlighted the major characteristics of Cell balancing techniques for battery packs of Lithium-ion. They are evaluated and contrasted in terms of charge/discharge capability, cell balancing speed, cost, applications, complexity of regulation, and key components necessary to equalize the cells. According to

the author, Lithium-ion batteries are affected by overcharge and discharge current, thermal runaway, undervoltage, overvoltage, and cell voltage imbalance. Following a thorough examination, we have determined that the Passive cell balancing technique is best suited for applications with low power, whereas the Active cell balancing technique is best suited for applications with high power. Since a result, cell balancing is a key aspect of the Battery Management System, as it improves the battery pack's performance, extends its cycle life, and assures safe operation under all conditions.

Paul Sathiyan S and Calvin Immanuel S[3] have discussed the importance of Lithium-ion batteries in electrical applications, as well as the need for safe battery pack operation. The requirement for cell balancing is also mentioned in order to extend the battery pack's life cycle. It is mentioned what considerations should be taken when integrating Lithium-ion batteries. The authors go on to say that because Lithium-ion batteries are the most popular, proper methods for extending the battery's life cycle and efficiency should be used. This study aims to convey complicated information and concepts concerning Batteries, Systems of battery management, Procedures of cell balancing, and other related topics. The work is primarily concerned with the design, development, and modeling of a passive cell balancing circuit in detail.

Peter Van, Noshin Omas, Joeri Van Mielro, Den Bossche, Mohamed Daowd[4] have worked on Battery balancing using Capacitor for balancing. Capacitor for Battery Balancing System being the title. The system of battery management is the most vital as it helps in increasing of the

life of a battery pack. The paper studied talks about the capacitor-based topologies for battery balancing. The paper compares between the methods. It is simulated with the MATLAB Simulink. The highly charged cell, capacitor and lovely charged cell energy shuttling has become function of the capacitor, switching frequency, voltages between the unbalanced cells and also duty cycle. Based on the above factors the SSC balancing was proposed. The proposed methodology has helped in control strategy to reduce system cost and also balancing time.

Mailier Autoine, Peter Van,Mohamed Dawod, Noshin Omar, Joeri Van Mierlo, De Bossine[5] The title of the report is Single switched capacitor-based balancing of battery for improvements of the system. The paper explains the methods for reducing size of used system for battery management. This paper has reviewed the battery balancing using the Single Switched capacitors. This was achieved by increasing transferring of the energy between cells and also the capacitors.

Adha Imam Cahyadi, Erika Loniza, Dwi Dharma Arta Kusuma, Johans Andrino Situmorang [6] The title for the report Passive balancing of a Lithium Polymer battery using fixed shunt resistor method. In the above study, condition of voltage of every battery was designed. The technique used for the study was Passive shunt resistor for balancing. The resistor and removing of excess voltage was done to balance value of voltage of the battery cell using resistor. The circuit designed was able to do balancing of the voltage in each cell.

Ali Farazan Moghaddam, Alex Van Den Bossche[7] explain the Active cell balancing methods of li-ion batteries for the single transformer which has two times fewer secondaries than cells. A full bridge driver in the circuit is used in this paper, having two times less number of transistors than cells, that controls the N Channel MOSFETs as switch. As result switching losses are less. Efficiency, Equalization pace and complexity of implementation in terms of performance.

Yunlei Zhang, Cungang Hu, Weixiang Shen and Xiudong Cui[8] describe that the report is based in Fuzzy logic controller for the balancing of a fast multi switched inductor in Lithium-ion battery packs for electric vehicles. Instead of using a proportional integral controller, a fuzzy logic controller based on a multi-switched inductor circuit is used to improve the performance of balancing in Lithium-ion battery packs. Thus, paper also has low-cost battery balancing for FL controller on basis of MSIBC. Therefore, less time was taken by the proposed FL Controller to achieve balancing of the battery pack.

Blanco Riesco, Angel[9] The title of the report An Efficient Cell Balancing Method For LiFePo4 Batteries Based On Inductors. In this paper a circuit has been designed and programmed through which the balancing of cells is performed using inductors. It is theoretically and practically created to simulate the behaviour of an electric vehicle battery. Inductor method more precision and speed is achieved when charging the inductors.

Dwi Dharma Arta Kusuma, Johanes Andriano Situ Morang, Adha Imam Cahyadi, Erika Loniza[10] devised a mechanism to track the voltage of each battery cell. The passive shunt resistor balancing approach was adopted in this investigation. To stabilize the value of voltage in the battery cells and further to remove the excess of it, an electronic circuit was constructed with the help of resistors. Simulation and execution of a three-cell Lithium-ion battery series' balancing method are the main themes of this article. The result implies that the electrical circuit can keep each cell's voltage balanced. The 0.1 C rate of discharge has the best performance based on the findings of the experiment with various load values since it has no significant effect on the battery voltage characteristic, resulting in superior sensor reads.

3. CONCLUSIONS

A battery charging system that eliminated mutual influence between adjacent cells in battery charging was proposed by the papers studied, thereby demonstrating that battery efficiency can be enhanced, size of system can be reduced and charging time can be reduced. Mutual cell balancing using passive and active elements is performed by the conventional systems to balance each cell individually. From the papers studied we infer passive cell balancing methodology will be most suitable for less powered applications whereas active cell balancing is applicable in high power application. Therefore, Battery Manage system is an essential feature in the balancing of cell as it helps in enhancing battery pack performance, also this increases the life cycle and hence ensures a very safe operation during most challenging conditions.

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