Enhancement of Battery Life Using Passive Cell Balancing Technique

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Abstract:
The braking system is always an important factor for any vehicle. Adaptive braking methods are This paper proposes the concept of cell balancing which can lookout the cells and battery from getting damage and increase the life of a battery. This paper comprises of three parts, first modeling of required parameters, second simulation of the model, and then the final results got from evaluation and simulation explained in detail. In case battery cells are connected in series they are unbalanced. The cell voltages are not the same. Variations in the State of Charge (SoC) of the Battery Cell, Cell Temperature, and Self Discharge Rate can cause imbalanced cells. Passive cell balancing and Active cell balancing are types of cell balancing. In this paper, only passive cell balancing is discussed with the simulation. The paper compares the performances of batteries also. This project is analyzed and evaluated in MATLAB/Simulink
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1. Introduction

In recent years we have seen an exponential increase in the graph of sales of electric vehicles. EVs are potential solutions due to their high efficiency and zero emission of harmful gases in the environment [1]. They are being available with a wider range, improved features, and brilliant performances. EVs consist of Electric motors, motor controllers, traction batteries, BMS, regenerative braking, etc. In EVs, Battery is source of energy, it is used as power storage. However, EVs are not yet a global phenomenon, lack of charging infrastructure, and battery limitations are the various reasons affecting the productivity of EVs. As EVs are evolving rapidly, batteries need to improve and adapt to the important needs of the automobile industry [1]. Battery life influencing factors are charging-discharging cycles, ambient temperature, etc [2]. Currently, there are three types of batteries available in the market- Lithium-ion batteries, Lead-acid batteries, and Nickel-metal hydride. The type of battery used in EVs is Lithium-ion rechargeable batteries. They are compact and light. Due to its unique features, they are most favorite now days. Lithium-ion batteries have acquired most of the market for the application of EVs because of their superiority in low self-discharge rate and high energy density [6]. Previously, lead acid batteries were the favorite because of their high availability and low cost. Energy is stored in cells that are connected to the battery pack. A battery pack is a grouping of cells electrically arranged in a matrix of rows and columns to monitor that the battery delivers a specific value of voltage and current for a given period.

Battery Management System (BMS) is a technique designed for analyzing and monitoring battery systems. BMS is also called as brain of the battery pack. In EVs, BMS plays a critical role to reach maximum battery performance and life of battery [2]. BMS is going to play a key role in the EV era to ensure batteries operate safely and will last for a long period [1]. As per the name battery management system monitors the parameters like DoD (Depth of Discharge), Voltage, SoH (State of health), Functional safety, SoC, Temperature, etc. for batteries. To design an efficient battery management system the right analysis of SoH, SoC, and SoF (State of Function) is necessary [4]. An estimation of the SoC using Coulomb’s method is given in this research paper. BMS plays a vital role in the detection of malfunction happening due to various reasons. Battery life performance degrades after some time during use, due to chemical reactions, charging-discharging cycles, etc. BMS has the capability to monitor and safely control the operation of the battery’s charge-discharge cycles [3]. Temperature is also one of the most serious problems arising from battery life. Battery degradation is a very severe problem to deal with nowadays.

Functions of BMS include cell balancing, charging-discharging control, and determination of SoC, SoH, and communications. Cell balancing is a type of method that counter balance weak cells by distributing charge equally in all cells of the chain.Cell balancing is of two types i.e. Active cell balancing and Passive cell balancing. In active cell balancing charge from higher SoC cells is transmitted to lower SoC cells. In the passive cell balancing technique charge of higher cells is removed until the charge from the lower cell matches.

As it increases the cost of maintenance, the capacity of the battery decreases, and the life span of the battery becomes less. Even though manufacturers of batteries say that the battery life is about six to ten years but in fact the battery is assumed to be at the end of service when its capacity falls to 80% of the battery’ s original life [5]. This paper reviews current information and advanced techniques in areas related to battery degradation and battery management system (BMS). This work emphasizes the research on battery life enhancement, how to increase battery life span, and what measures could be done to do it. All the reviews regarding this topic are given in the below sections followed by the simulation and conclusion.

2. Cell Balancing

None of the two battery cells are alike and a battery pack is a grouping of such cells with different capacities. This capacity varies with continuous charging and discharging. The state of charge of each cell keeps on dropping with time. When all cells are at the same SOC, the battery pack is balanced [9]. Cell balancing is a must for a secure, consistent, reliable battery operation system [10].

Battery performance reduces with cell imbalance [11]. Unbalancing in the cell can be caused by internal cell resistance, variation temperature of the cell, type of connection, and SoC imbalance throughout the charging and discharging cycle. [25] Cell balancing is a technique for keeping the voltage state of each cell connected in series to make a battery pack equal to achieve optimal battery pack efficacy.

Cell Balancing Techniques-

Active cell balance

Passive cell balance

1) Active cell balance:

Making each cell's voltage status and SoC equal without wasting energy is what active cell balancing is all about and is often referred to as non-dissipative cell balancing. The active cell balancing approach transfers superfluous charge from a single cell to other cells with a lower charge to equate all cells. It is done by employing charge-storage devices such as capacitors and inductors [10].

However, with this balancing approach, energy is moved from one cell to another, resulting in less energy destruction and a shorter period for balance. The state of charge of a battery pack is equal to the mean of all individual cells SoC. As a result, active cell balance is used at a greater extent since its effective than passive cell balance. But the drawback of this method is that this method has complex construction and needed the extra cost of electronics.

Active cell balancing is further classified and grounded on active rudiments similar to a capacitor, converter, inductor, and transformer [12]. The charging and discharging in active cell balancing is shown in fig 1.

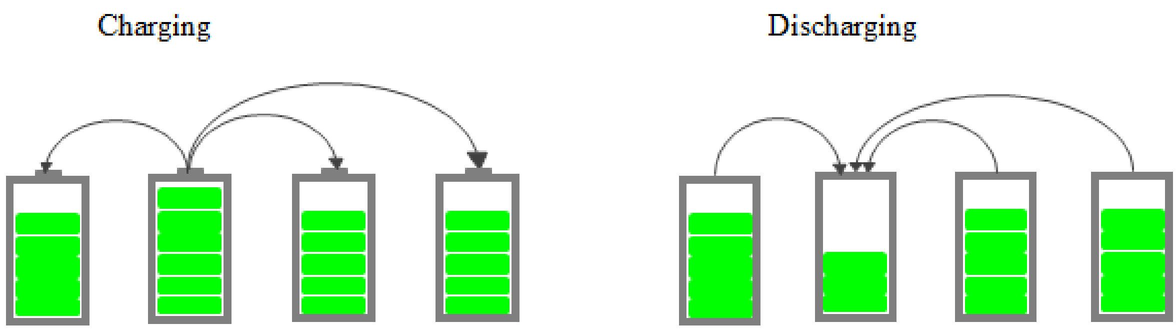

Fig.1 Active Cell Balancing

2) Passive cell balance:

Passive cell balancing entails squandering energy through a resistor to equalize the charge and voltage status of each cell. It is sometimes referred to as dissipative cell balancing. A resistor is employed in the passive cell balancing method to drain the redundant voltage and equate it with remaining cells. These are referred to as bypass resistors. All cells in a battery pack are connected in series, with the bypass resistor connected via the switch.

However, this balancing method is cost-effective, small in size, and has a simple construction. The disadvantage of this method is that the capacity of a battery pack is limited by the weakest cell, i.e. the lowest SoC, and the battery pack's energy consumed as heat is essentially excessive because an additional coolant method is required owing to heat. Another problem is that the passive cell balancing mechanism is not used when discharging because this mode lacks rare direction switching, resulting in unbalance in every cycle [11]. Two types of passive cell balancing resistors are i) Fixed Shunting Resistor which has a fast reactive time and improves overall system effectiveness ii) Switching Resistor is widely used in cell equalizing. [12] Passive cell balancing is as shown in fig 2.

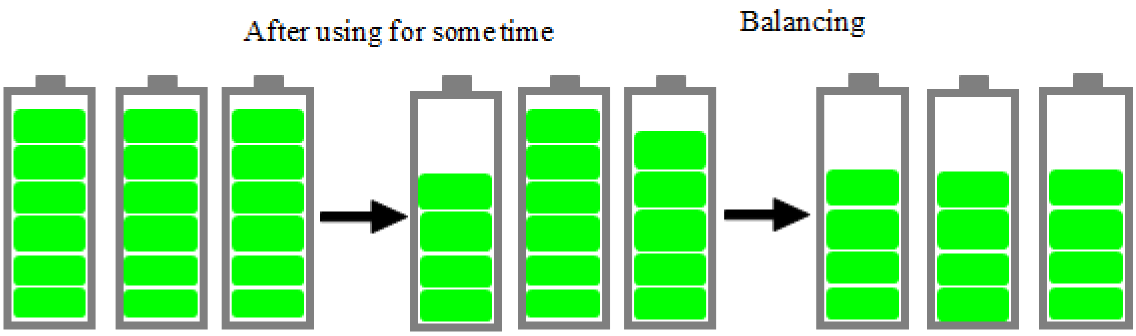

Fig. 2 Passive Cell Balancing

3. SoC & SoH

Simply said, SoC is the state of charge of the battery. It is the current capacity of the battery, measured in Ah. Another word for batteries that simply defines their status is a state of health, or SoH [15][17]. It is the ability of the battery to transmit and store electric energy. It's also important to assess the battery’ s health.

3.2. SoC Calculation.

The SoC must be correctly evaluated to maximize system performance, which improves battery life. This lessens unpredictable system outages and protects the battery from being overcharged or discharged, which could irreversibly damage the battery's internals. The SoC of a battery is difficult to determine because it relies on the type of battery and the application for which it is used. According to different methodologies, SoC computation differs. One can use either the voltage approach, the coulomb count (ampere hour counting), or a combination of both to determine a battery's SoC [16].

3.3. Coulomb Counting Method

So many things can affect a battery's SoC, properly measuring SOC for rechargeable batteries is never straightforward. Coulomb counting is one of the most popular and established techniques among all the approaches for SoC estimate that have been created [18]. This is the most likely approach for determining battery SoC. The method involves a mathematical computation of the built-in battery's current value over the course of operation. SoC values come from

$$SoC = SoC(t0) + (1 \div Crate) \int_{t0}^{t0+\tau} (Ib - Iloss)\, dt$$

Where,

Initial SoC = SoC(t0)

Rated capacity=Crate

Battery current=Ib

Current consumed per loss reaction = Iloss

The residual battery capacity is obtained by adding the incoming and outgoing battery charges using Coulomb counting. With the previously established battery capacity, the initial SoC may be precisely calculated. By bringing the cell's voltage to its maximum, you may determine the reset point. By taking several things into account, the SoC must be estimated with more precision [19][22]. Frequent SoC reanalyses are necessary for addition to taking the loss of reuse ability into account for more precise estimates. Firstly, the charging current rapidly decreases and slowly increases while charging at a constant voltage [20]. The initial SoC can be calculated using the constant current-constant voltage curve.

SoC can be determined using the coulomb counting approach if the battery's initial charge is known [21] [23]. Suppose a battery will charge up to 6 Ah if it receives a 2 A of input current for three hours. If the battery has a 24 Ah capacity, the SoC will rise by 6 / 24 = 25%. That's 25% greater than it was at the start, but we don't know the last SoC since we don't know what the initial SoC was.

4. Simulation Setup

4.1. Design Specifications

Table 1 displays battery data such as cell type, number of cells considered, voltage capacity, nominal voltage, charging current, balancing methodology, and charging method of the lead-acid. The MATLAB/Simulink environment is used to create the simulation for the specifications provided in Table 1.

Table 1: Design Specifications of Lead-Acid Battery.

Parameter	Detail
Type	Lead-Acid
Nominal Voltage	12V
Capacity	42Ah
Max. Charge Current	12,0A
Balancing technique	Passive Balancing

Charge Method	Constant Voltage Charge

4.2. Simulation

A passive device (resistor) is employed in this model to dissipate the excess charge in the battery. Here, each cell is connected to a resistor that consumes charge when any of the given cells in the battery is excessively charged. An ideal switch is used in the circuit. Only when the capacitor is overcharged in comparison to the other cells does the switch close. The gate signal in the circuit is solely determined by the charge state. A Simulink program is created wherein a circuit is created using a lead-acid cell. The SoC is set to 60%. Two more such cells are connected to the first cell. An ideal switch is connected to the 3 cells. The gate signal is configured for the switch. In MATLAB, a function is defined. The program is programmed so that if one of the cells is overcharged in comparison to the other two, that cell is discharged via the discharge resistor (also known as the bleeding resistor). MATLAB/Simulink is used to conduct passive cell balancing in this manner. Fig 3 shows the simulation layout of passive cell balancing.

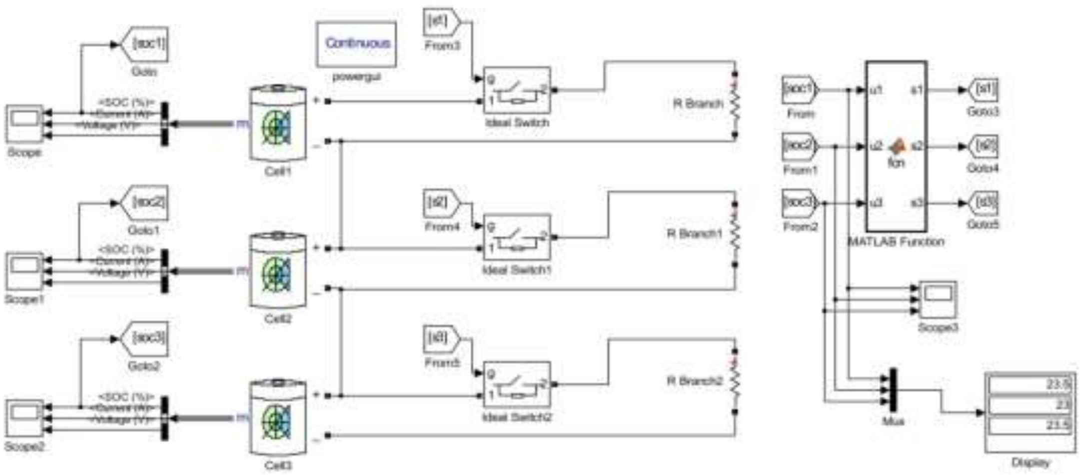

Fig.3 Simulation Layout

Fig.4 shows flowchart of the code used for passive cell balancing in MATLAB Function. First, battery specifications are inputted according to Table.1. Cells are assigned variables for calling in the program.

If else conditions are coded to compare each cell with each other and discharge the cell with most SoC.

Accordingly 1 or 0 is generated which is passed to ideal switch for turn ON/Off action.

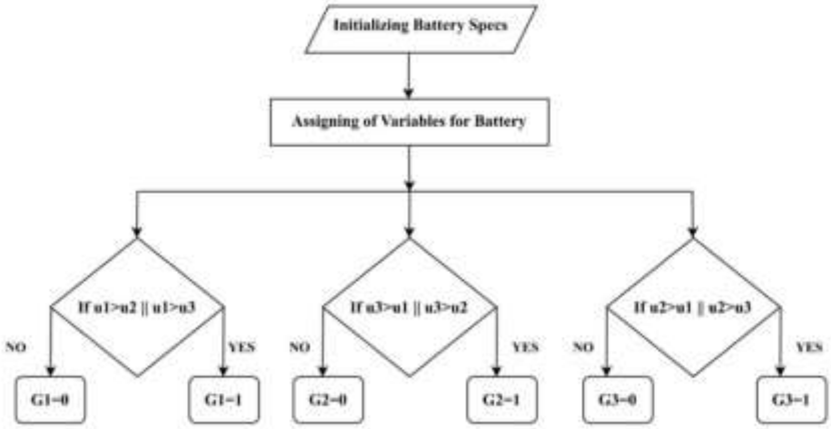

Fig.4 MATLAB Program Flowchart

Fig.5 displays simulation results acquired during simulation. Cell1, Cell2 and Cell3 have Socs 26, 23 & 24 respectively. MATLAB Function compares each cell with one another and discharges cells to equalize with lowest SoC cell. Cell1 and Cell3 SoC is discharged to 23.5 to equal with Cell2.

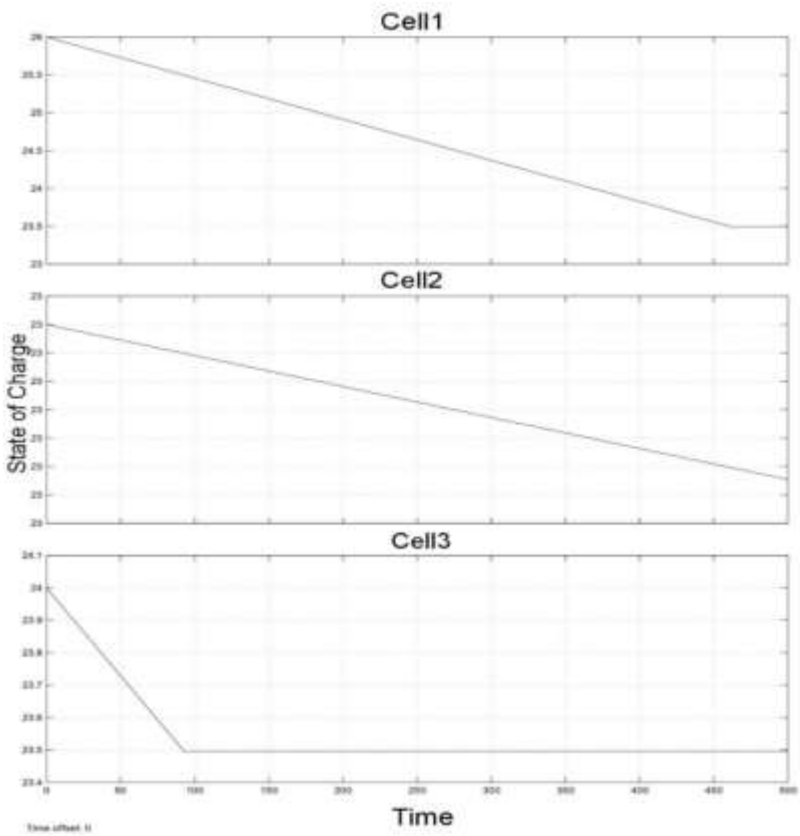

Fig.5 Simulation Graphs of each Cell

Table 2 shows a straight forward results of output of simulation for SoC of cells before and after simulation. It is clear from the table that passive cell balancing works very effectively for balancing the battery voltages as per the specified values.

Table 2 SoC Before and After Simulation

Name	Before	After
Cell1	26 V	23.5 V
Cell2	23 V	23 V
Cell3	24 V	23.5 V

5. Conclusion

In this study, we aimed to create a cell-balancing approach that would extend the lifetime of a lead-acid battery while decreasing its size. In this proposed work, the voltage of one cell of a lead-acid battery is compared to the voltage of another cell, and all cells of the battery are balanced using the appropriate technique, i.e. active or passive cell balancing, based on the requirement. A cell balancing approach is used to govern the charging and discharging of the battery. Temperature, voltage, current, and other parameters are taken into account in the control scheme. The total proposed method can increase the life of the lead-acid battery while also reducing its size and expense. We obtained an appropriate battery management system from this study, which can improve battery life and minimize battery size at a reasonable cost. The suggested system is developed and validated using the MATLAB/Simulink platform.

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