A Study of Passive Cell Balancing and State of Charge Assessment Using Coulomb Counting Method

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Abstract.

Cell balancing and State Of Charge (SOC) assessment are important aspects of electric vehicle (EV) battery management systems. Cell balancing makes sure that all of the cells in a battery pack are at the same level of charge, which contributes to the battery packs overall longevity and performance. SOC estimation, on the other hand, is the process of determining the current state of charge of the battery pack. This information is used to predict the remaining range of the EV and to prevent overcharging or over-discharging of the battery pack. Both cell balancing and SOC estimation are typically accomplished through the use of sophisticated software algorithms and hardware sensors. These algorithms and sensors must be able to accurately measure the temperature, current, and voltage of each cell in the battery pack to provide accurate and reliable cell balancing and SOC estimates.

1. INTRODUCTION

Renewable energy system development has increased as a result of rising crude oil prices and greater environmental consciousness around the world. Because of their superior performance and low environmental impact, batteries are among the most alluring energy storage technologies. The industry currently uses several different battery kinds. Li-ion batteries provide the benefits of high cell voltage, low pollution, low discharge rate, and high-power density. Batteries are frequently utilized in industrial applications, hybrid electric cars, and mobile gadgets [1-12].

1.1 SOC Estimation

The Coulomb counting method is a technique for estimating the State of Charge (SOC) of a battery. It is based on measuring the charge flowing into and out of the battery and integrating this overtime to give the total charge that has been stored or discharged. The basic idea is that the net charge that has flowed into the battery since it was last fully charged is equal to the SOC of the battery.

To implement Coulomb counting, a current sensor is needed to measure the current flowing into and out of the battery, and a discrete-time integrator is used to perform

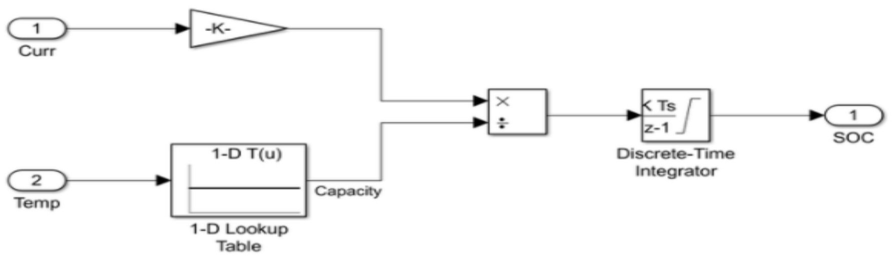


Figure 1.1

the integration of the current over time. The battery is connected in series with the current sensor, which periodically detects the current going into or out of the battery. The integrator then integrates this current overtime to give the total charge that has been stored or discharged. The SOC is then calculated as the total charge stored divided by the total capacity of the battery.

1.2 Cell balancing

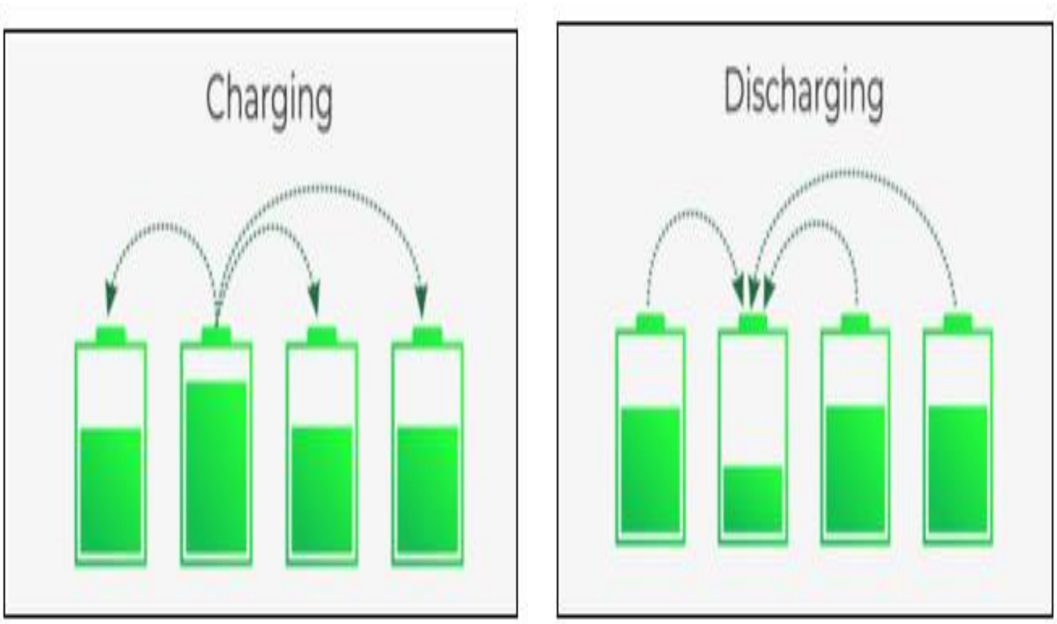
It is nearly impossible to produce two identical cells with the exact same capacity, and this results in a variation in the battery's terminal voltage. When consistent current is given to or removed from all of the cells, this also results in overcharging of cells with higher SOC during the charging cycle and complete discharge of cells with lower SOC during the discharge cycle. Cell balance is the method we employ to get rid of this issue.

Cell balancing's primary goals are to maintain a constant voltage across the battery, achieve higher rates of discharge from cells with higher SOC than other cells during the discharge cycle, and achieve higher rates of charging from cells with lower SOC than other cells during the charging cycle. In other words, to achieve the same voltage level, cells with greater SOC should charge cells with lower SOC.

In parallel operation, the voltage across the parallel combination of batteries remains constant, while current is distributed among the batteries in proportion to their capacity. This concept is used to balance the cells, so the cells in the battery are arranged in parallel.

Implementing cell balancing allows us to provide a longer battery life while also increasing battery efficiency.

Figure 1.2



2. SIMULATION ANALYSIS

2.1 Simulation of SOC Estimation

Table 2.1 shows the specifications of the lithium-ion battery used in simulation 2.1.

Parameter	Value	Unit
Nominal Voltage	48	Volts
Rated Capacity	50	Ah
Capacity at Nominal Voltage	45.21	Ah
Cut-off Voltage	36	Volts
Fully Charged Voltage	55.87	Volts
Nominal Discharge Current	21.73	Amp
Internal Resistance	0.0096	Ohms

The following figure 2.1 shows the Simulink model of SOC estimation in a simulated vehicle.

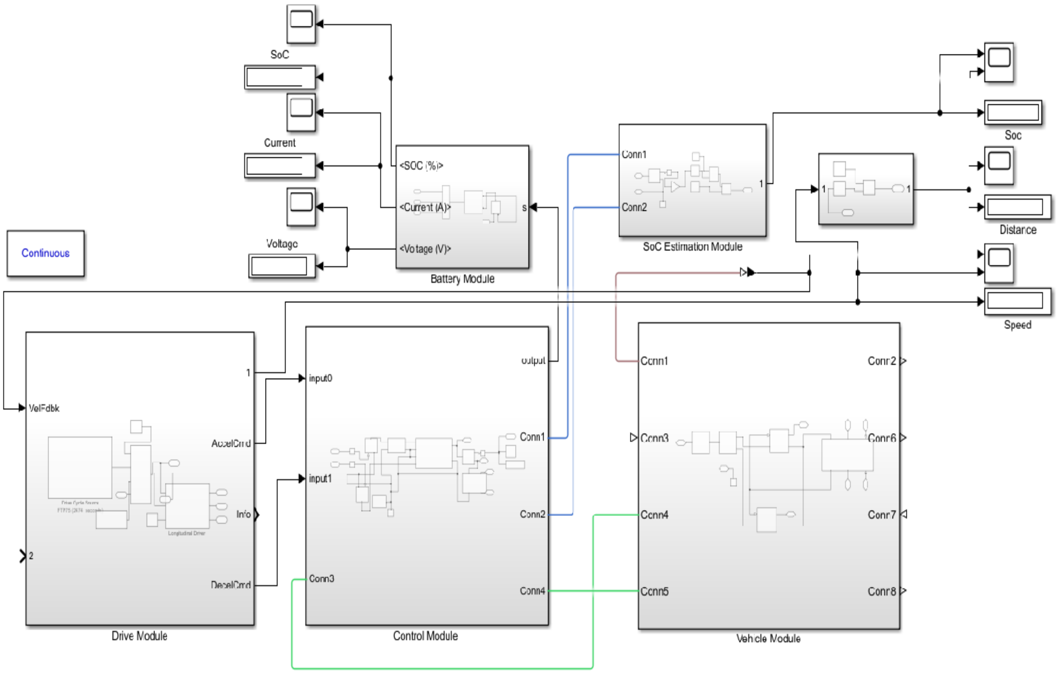


Figure 2.1

SOC estimation using the Coulomb counting method is discussed in this simulation. A virtual vehicle has been simulated using a built-in drive cycle function from Matlab. The initial SOC is assumed to be 90%.

2.1.1 Sub-systems

Drive Module

The drive module (figure 2.1.1) consists of a simulated driver with a built-in drive cycle source which creates a system to show the real-time variation in velocity and how it affects the SOC of the battery.

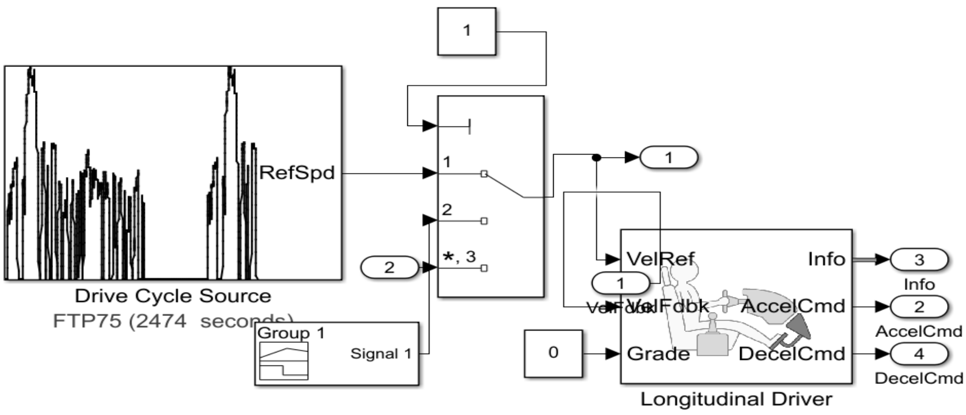


Figure 2.1.1

Control Module

This system consists of a PWM generator and H-bridge which helps in generating a pulse waveform from the velocity variation in the drive module, to help us analyze the electrical part of the circuit.

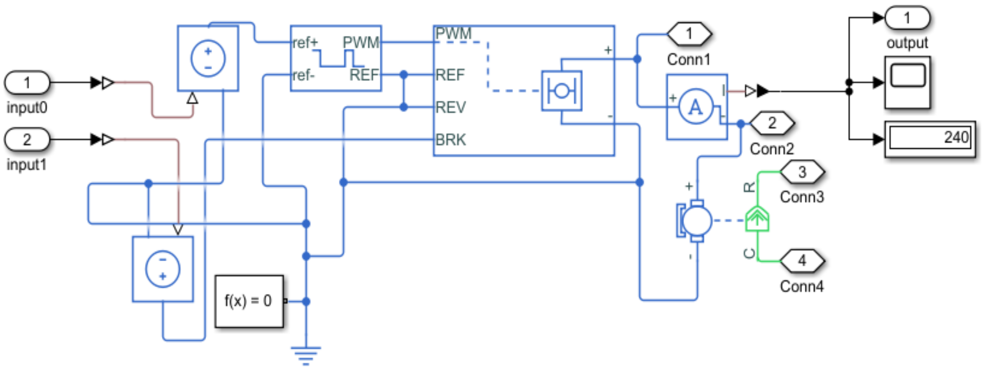


Figure 2.1.2

Vehicle Module

This system shows the layout of the vehicle consisting of a gear system, wheels, and the vehicle body.

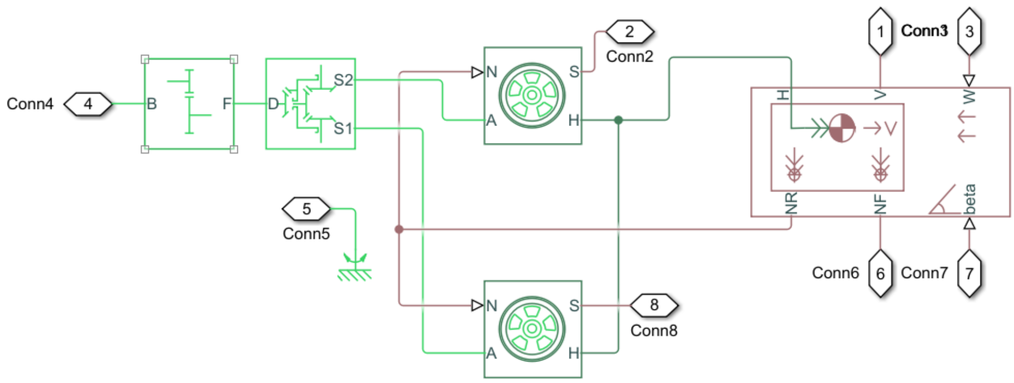


Figure 2.1.3

Battery Module

Figure 2.1.4 shows the connections to the battery and the measurement of SOC from it.

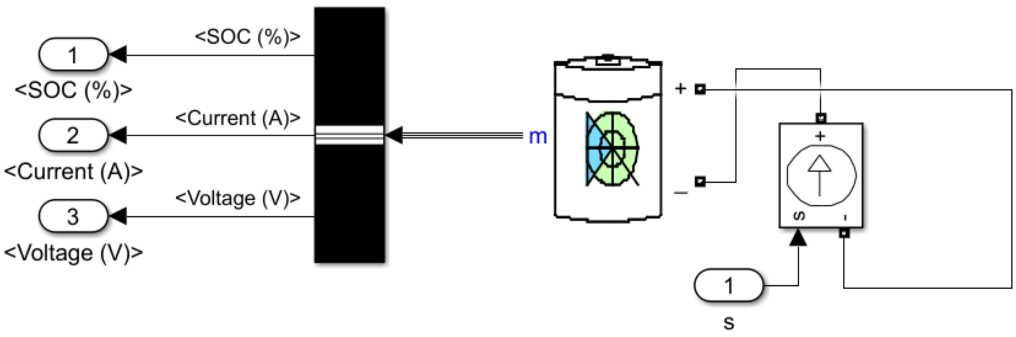


Figure 2.1.4

2.1.2 Result and Analysis

This division converses the simulation outcomes obtained in MATLAB. Here, in figure 2.1.5 the variation of SOC through the ideal method and the SOC using Coulomb counting method is observed. The difference in the plots is due to the lack of inaccuracy reduction methods which is to be addressed.

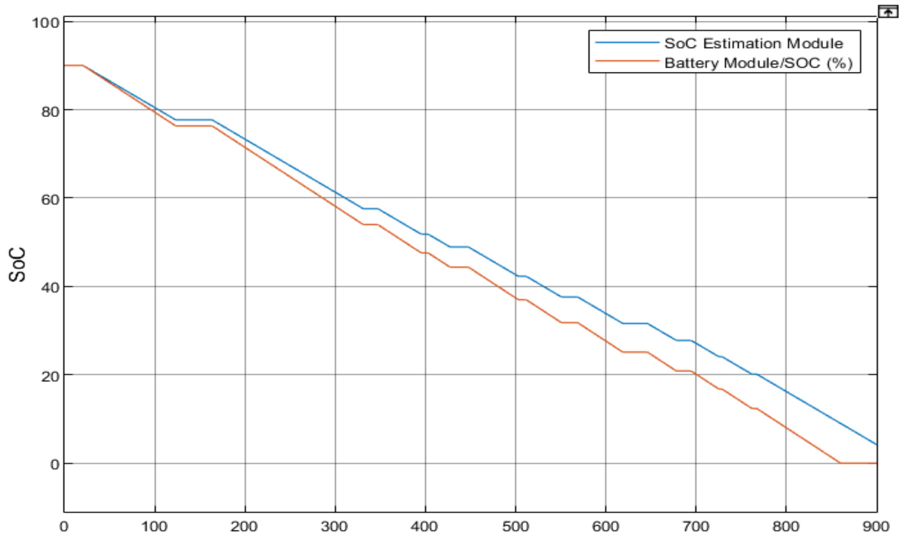


Figure 2.1.5

The graph for current and voltage variation is shown in figure 2.1.6

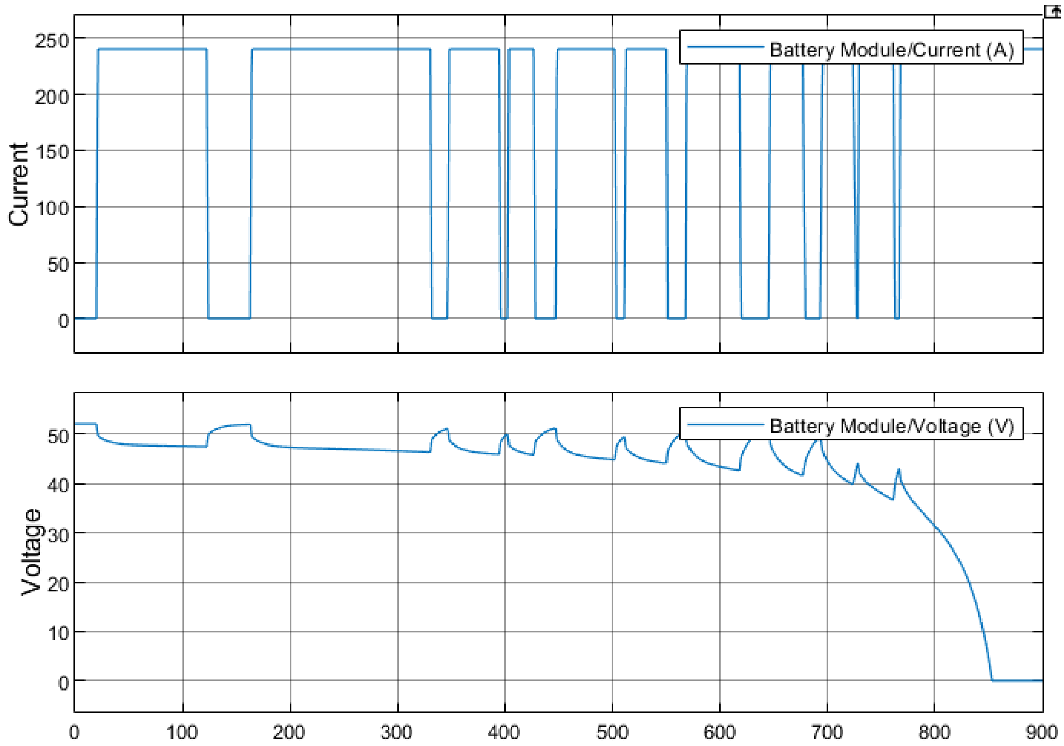


Figure 2.1.6

2.2 Simulation of Cell Balancing

A simulation was carried out for cell balancing of three lithium-ion cells. Figure 2.2.1 shows the Simulink model for passive cell balancing technique. Three lithium-ion cells are connected in series wherein each cell is connected to an IGBT switch along with series resistor.

For simulation, imbalance in SOC is taken as 85%, 80% and 75% for cell 1, cell 2 and cell 3 respectively. The SOC of each cell is given as input to the controller. Controller compares the SOC of cells, and based on the algorithm, output is generated. This output from the controller is given as input to IGBT gate signal.

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Table 2.2.1

Parameter	Value	Unit
Nominal Voltage	48	Volts
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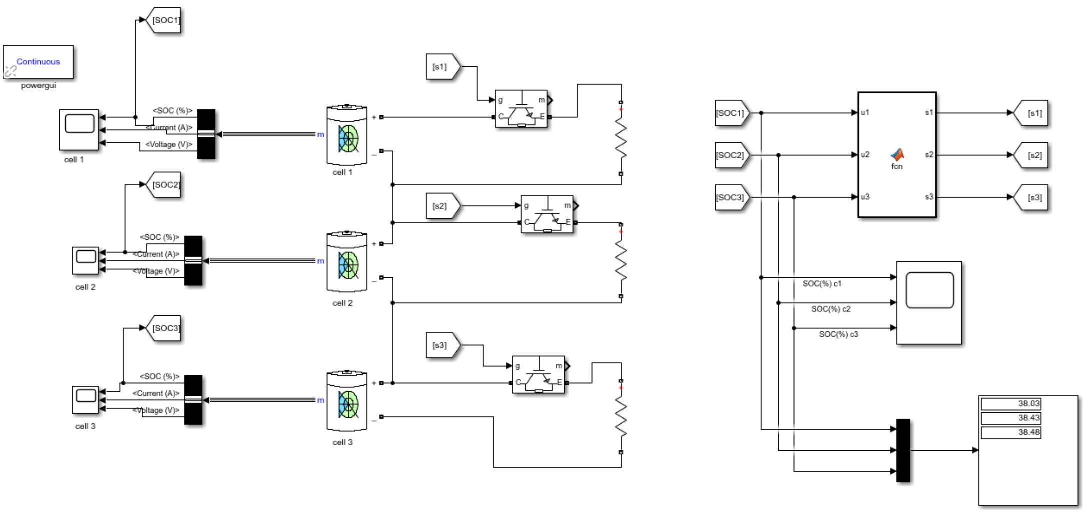
Figure 2.2.1



and Analysis

Figure 2.2.2 shows graph of SOC of three cells vs time. It has been observed that cells with higher SOC dissipate energy through series resistor and after certain time, SOC of cells will be equal, that is cells are balanced.

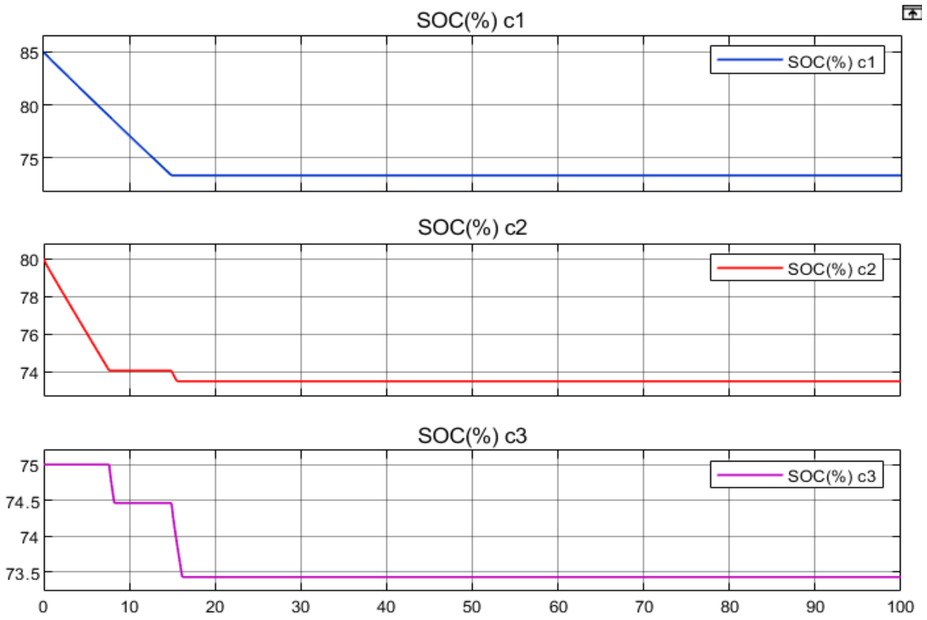


Figure 2.2.2

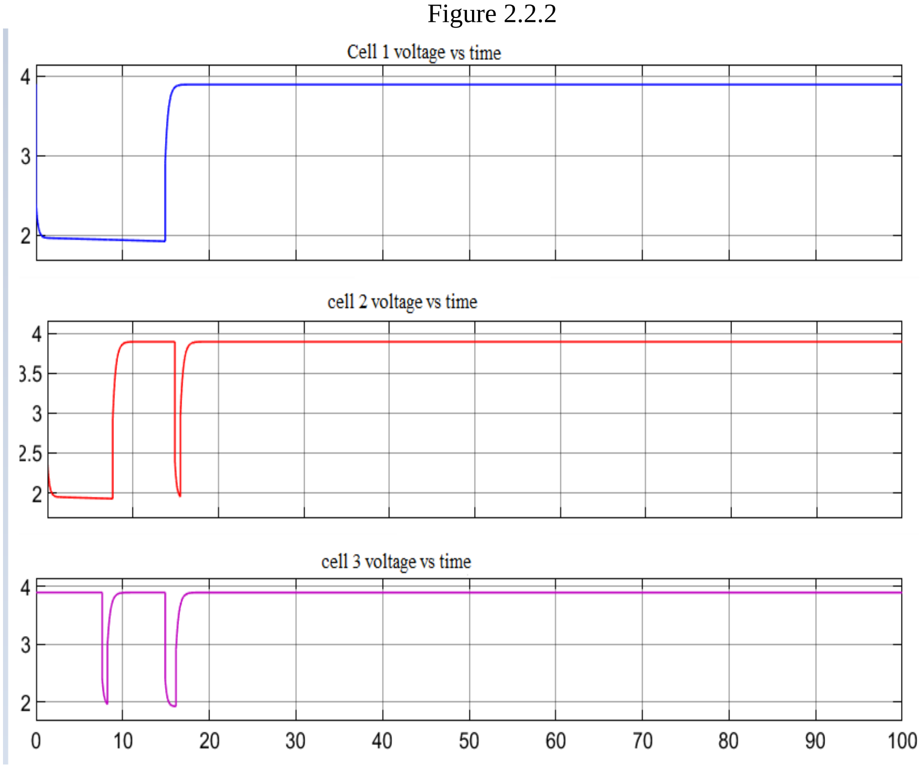


Figure 2.2.3

Figure 2.2.3 shows the graph voltage of three cells vs time. It has been observed that voltage of all the three cells is equal when cells are balanced.

3. CONCLUSIONS

Cell balancing and State of Charge (SOC) estimation are critical components of electric vehicle battery management systems. Cell balancing confirms that all cells in a battery pack are in the same state of charge, which helps to extend the battery pack's overall lifespan and performance. SOC estimation refers to the process of determining the current state of charge of the battery pack, which is used to predict the EV's remaining range and prevent overcharging or over-discharging of the battery pack.

Overall, cell balancing and SOC estimation are critical to EV battery performance and longevity. Additional research is required to increase the accuracy, reliability, and effectiveness of these techniques, as well as to optimize their integration into an EV's overall battery management system.

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