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Advanced Battery Management System for Hybrid Electric Vehicle

Swathi Karike* **and D. Sudha Rani****

Abstract: Compared to fuel based engine vehicles HEV's not only produce less CO_2 emissions but also costs less fuel per km. It made Hybrid Electric Vehicles becoming popular and common. A hybrid electric vehicle support two propulsion systems consists of internal combustion engine and an electric motor with battery as storage unit. Unfortunately, batteries used in HEV's can be dangerous if not operated within their safety standards. Usually batteries used in HEV's are made up of long strings of cells in series and parallel, uneven charging and dis-charging of those individual cells increases the failure of battery. In this paper, advanced battery management system with cost effective cell balancing technique is implemented for hybrid electric vehicles to reduce the stress of cells in battery pack. As HEV requires higher operating voltages, it is not possible by single cell. Hence HEV's consists of multiple cells in a single battery pack. Due to the usage of multi cell batteries, overstressed individual cell leads to permanent failure of the battery. To reduce the failure of battery and to increase the battery life time, cost effective resistor based passive cell balancing technique is implemented. The analysis of proposed advanced battery management system is validated by using Matlab/Simulink.

Keywords: Hybrid Electric Vehicle, Advanced Battery Management System and Passive Cell Balancing.

1. LITERATURE SURVEY

Common problem to every multiple cell battery system with series cells is cell imbalance. Cell balancing is the method of designing safer battery solutions that extends battery run time as well as battery life. The latest battery protection and fuel gauging ICs from Texas Instruments (TI) – the bq2084, the bq20zxx family, the bq77PL900, and the bq78PL114 – present a wealthy lineup for cell-balancing needs [1].

The impact of cell imbalance on run-time performance and battery life in applications using series-connected cells is certainly undesirable. The fundamental solution of cell balancing equalizes the voltage and SOC among the cells when they are at full charge. Cell balancing is usually categorized into two types—passive and active [2], [3].

Another important avoidance action is to ensure at all times even temperature distribution across all cells in the battery. It is identified that in an EV or HEV passenger car application, the ambient temperature in the engine compartment, the passenger compartment and the boot or trunk can be significantly different and dispersing the cells throughout the vehicle to spread the mechanical load can give rise to unbalanced cell voltage conditions. Because Lead acid and NiMH cells can withstand a level of over-voltage without sustaining permanent damage, a degree of cell balancing or charge equalization can occur naturally with these technologies simply by prolonging the charging time since the fully charged cells will release energy by gassing until the weaker cells reach their full charge. This is not possible with Lithium cells which cannot tolerate over-voltages. Although the problem is reduced with Lead acid NiMH batteries and some other cell chemistries, it is not completely eliminated and solutions must be found for most multicell applications. [4]

* Phd Scholar, Department of EEE, KLU. *Email: swathi2710@gmail.com*
** Phd, Department of EEE, KLU. *Email: sudha179@kluniversity.in*

Even after all automotive company's implementing AUTOSAR, customer service complaints still increasing. This paper helps to overcome most of the battery balance problems HEV's experiencing with cost effective solution.

2. INTRODUCTION

Multicell batteries are commonly used in hybrid electric vehicles, this arrangement of cells in series is the cause of cell imbalance. Cell imbalance slowly reduces the capacity of battery. Overcharging and discharging of effected individual cells in battery are not identical. Cells from same manufacturer even does not consists of identical state of charge, capacity and nominal voltage ratings. These variations in individual cells leads to degrades the battery runtime and even the overall life time of battery pack. Most of the battery, chargers identify pack voltage to check maximum voltage point is reached [5]. The individual cells in the pack vary with different voltage levels. The voltage imbalances arise with some cells with high voltages and the other cell with low voltages. The weak cells and cells with degraded capacity usually have higher voltage compared to the cells at maximum charge. The effected cells will further degrade in continuous charge and discharge cycles. The over voltage of weak cells at full charge causes quick degradation of capacity. The effected cells have low voltage than other cells in pack, which is due to increased internal resistance or the increased rate of discharge from their lower capacity. Which causes the effected weak cells reach to cell under voltage limits same time the pack voltage is charge enough to power the vehicle, at the instant the full capacity of the battery pack cannot be consumed by the hybrid electric vehicle. Cell imbalance shows adverse effects on the performance and runtime of the battery pack.

The effects of cell imbalance can be reduced through cell selection. Battery pack should have made up of same rating cells, also from the same manufacturer. Testing can be done based on the analyses of the cells into groups which minimizes the variability within the group. Cell selection is not preferable for cell balancing technique as it requires most of manual interface. Other suggested solution for cell imbalance is to maintain high energy storage battery packs, which reduces the dependency of number of cells and their imbalance effects. Even in large capacity high power battery pack based hybrid electric vehicle have to connect cells in parallel to give high battery voltage. Using large cells keeps the interconnection between cells minimum, allowing simpler monitoring and control. Implementation of high battery packs results in high costs make costumer not to affordable of hybrid electric vehicles.

Once if the cell is failed, the whole battery pack has to be replaced and which is not cost effective. It is impossible to replace the individual failed cells due to the characteristics of the effected individual cell is different from the aged cells [6], [7]. The only solution to the cell imbalance is to dissipate the excess charged cells in the battery pack. The proposed advanced battery management system prevents the cells in battery pack from overstressed with the use of resistor based passive cell balancing technique.

3. CELL BALANCING

Passive cell balancing is the easiest technique to equalize cell voltages as show in Figure 1. The operation principle of this technique is to find the cells with highest voltage in the pack and remove the excess voltage through the series resistor until the charge or voltage matches to the minimum cell rating in the battery pack [8]. Some passive cell balancing techniques stop charging altogether when the first cell is fully charged, later discharge those cells to load until they reach the same charge level as the weaker cells. Other techniques are implemented to continue charging till the cells are fully charged but to limit the voltage which can be implemented to individual cell of the pack and to bypass the cells when this voltage has been reached. The proposed technique is much better to the conventional techniques in battery management system. The excess energy in the higher voltage cell is dissipated through resistor as heat makes passive cell balancing less preferable [9], [10]. But passive cell balancing is not much complex compared to active cell balancing which uses capacitive or inductive charge transfer between cells. This improve efficiency of active cell balancing need additional components of higher cost. The proposed passive cell balancing technique in this paper is however the lowest cost option of all the cell balancing techniques with less equalization time.

The cell balancing component in the BMS shall utilize an algorithm that identifies the excess/least charged cell(s) in the battery pack and when the cell voltage difference increases beyond 20mV then Cell balancing is initiated using Cell balancing Target signal (indicates the respective unit to balance it to the charge reference). While the difference in voltage of the cells falls below 20mV the cell balancing action is no more initiated as shown in Figure 2.

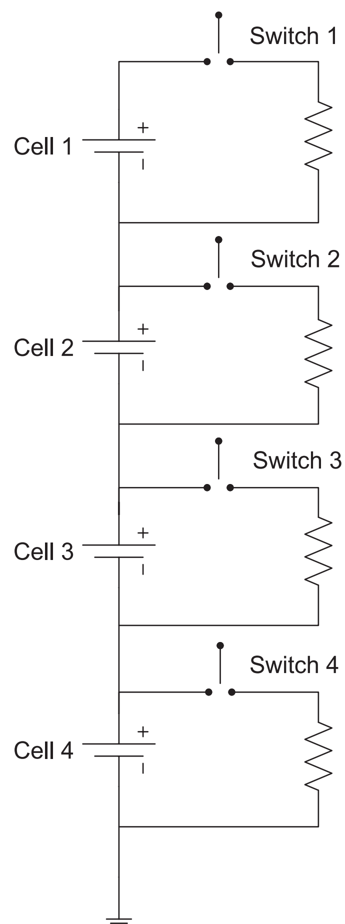

Figure 1: Resistor based Passive Cell balancing technique

The excess voltage in the higher voltage cell is dissipated through resistor

$$\mathbf{V_{terminal} = V_{cell} - IR} \quad (1)$$

This passive cell balancing technique is known for straight forward and simple balancing. Discharge cells that need to balance through a bypass resistor, this approach is favorable in Hybrid electric vehicle applications.

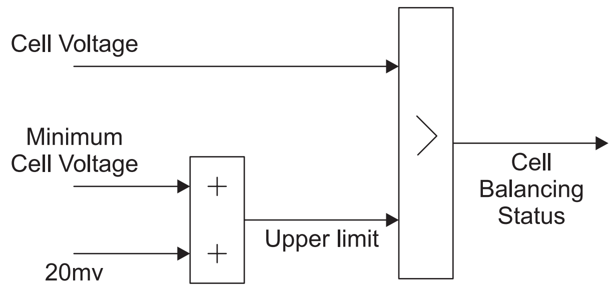

Figure 2: Cell balancing switching logic

This technique measures the voltage of each cell and identifies the cells to balanced, to avoid the identification of minor changes in cell voltages upper limit is considered as follows

Upper limit = 20 mv + minimum cell voltage of battery (2)

Any cell voltage greater than the upper limit is to be balanced, the difference in voltage of the cells falls below upper limit the cell balancing action is no more initiated

4. SIMULATION RESULTS

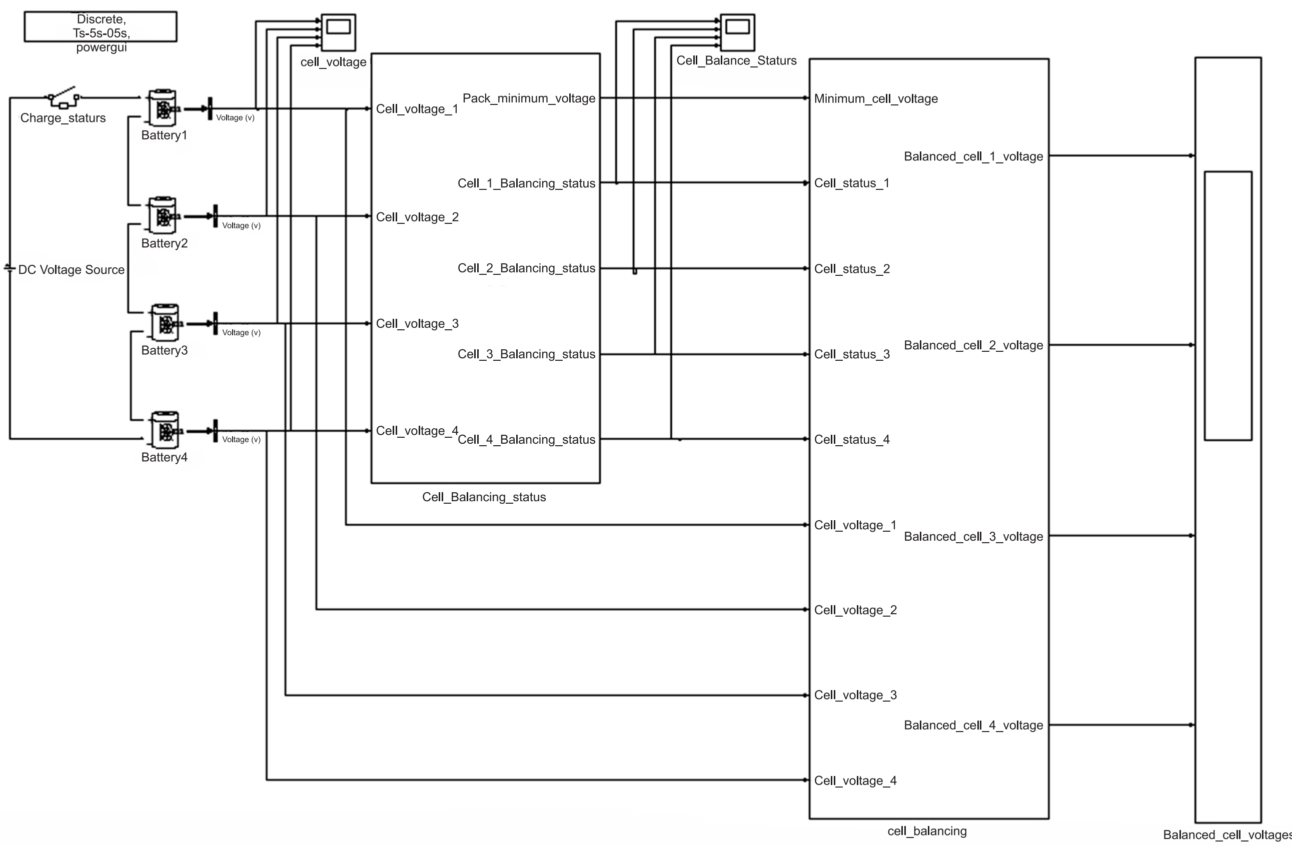

Figure 3: Simulink model of Cell balancing

From the measurement of cell voltages, it is identified that cell 1 = 4.6 V, cell 2 = 3.52 V, cell 3 = 3.53 V and cell 4 = 4 V. As per cell balancing cell 2 with 3.52 V is the minimum.

In the proposed cell balancing, cells with in the range of hysteresis band not required to balanced. The minimum of cell voltages is 3.52 volts, hysteresis upper limit is 3.54 volts. Cell 1 with 4.6 V and cell 4 with 4 V has to be balanced as these are not in hysteresis not in band. Cell 2 with 3.52 V and cell 3 with 3.53v not needed to balance as these cell voltages within the hysteresis band.

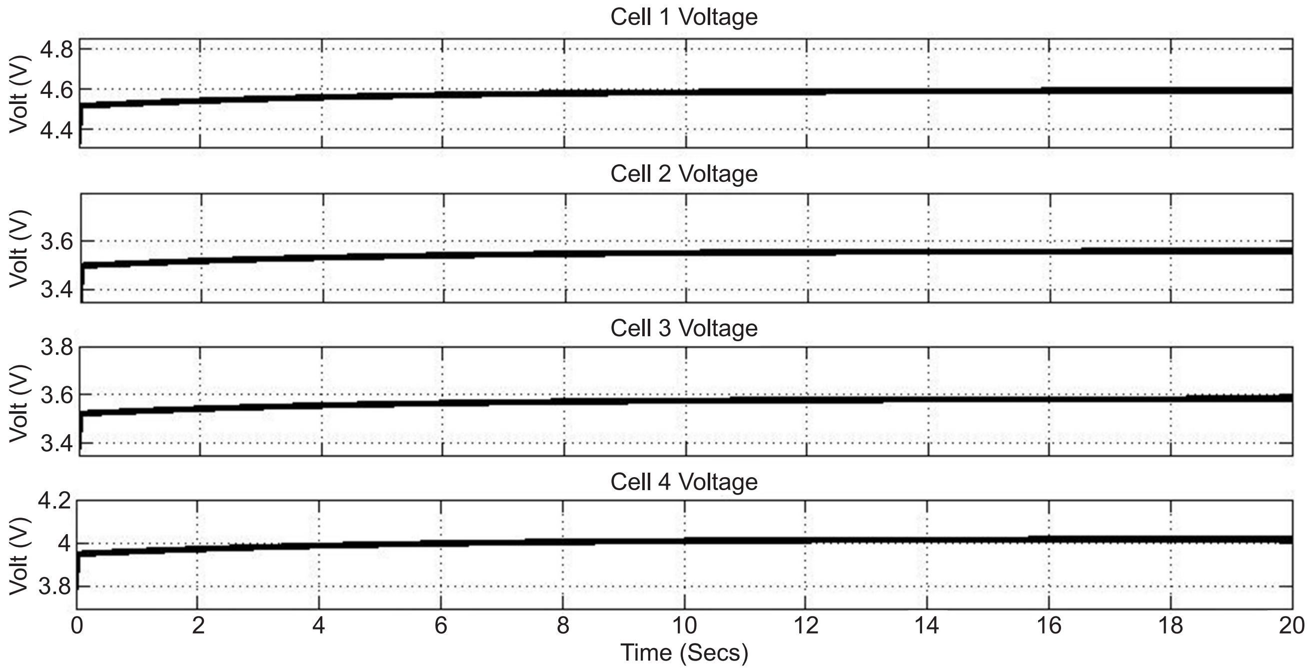

Figure 4: Simulated output waveform of cell voltages

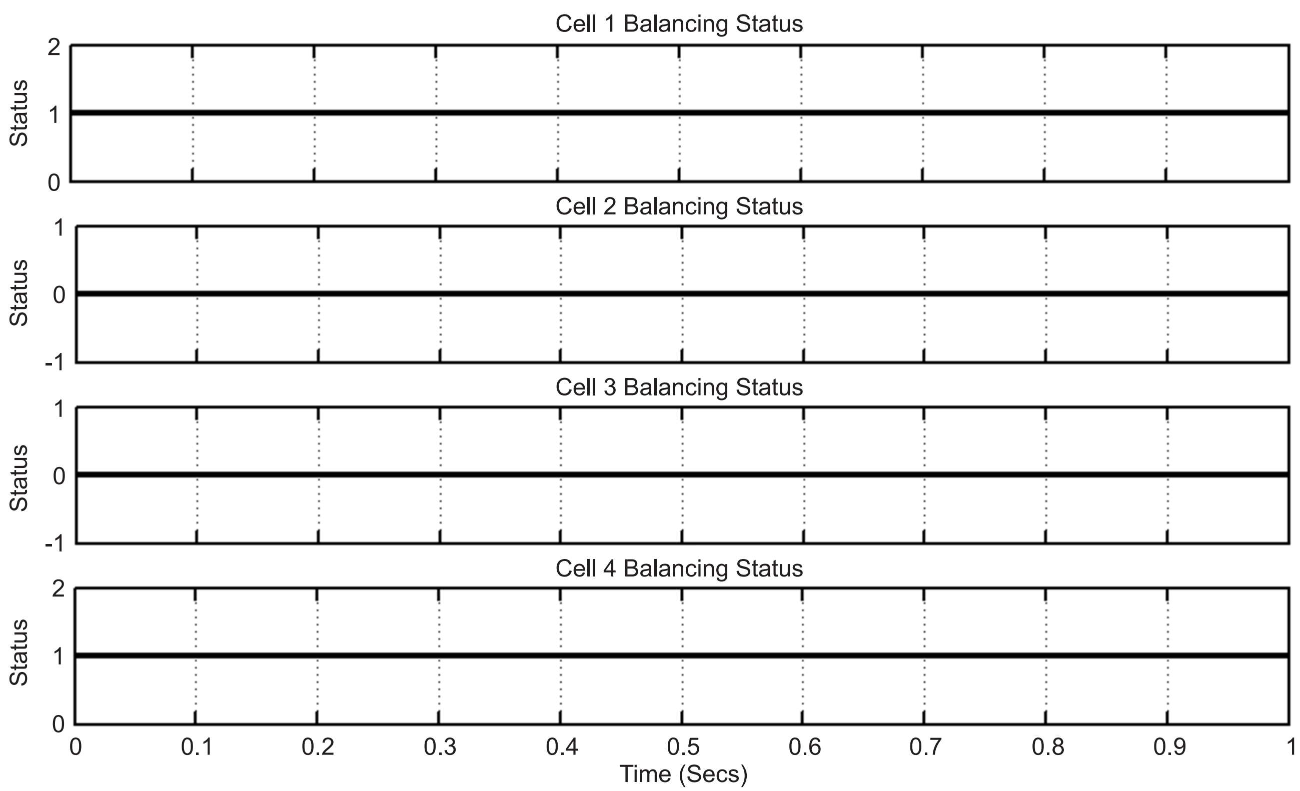

Figure 5: Simulated output waveform of cell balancing status

Cell 1 and cell 4 has to be balanced, in the proposed cell balancing the excessive cell voltage has to be passed from the resistor. For cell 1 1.08 volts has to be reduced, as it is a series circuit, current of 0.01 A is constant and the resistance is maintained as 30 Ω, for cell 4 0.48 volts has to be reduced resistance for it is maintained as 20 Ω.

After implementation of cell balancing all the cell are balanced to same voltage of 3.52 V as per equation (1).

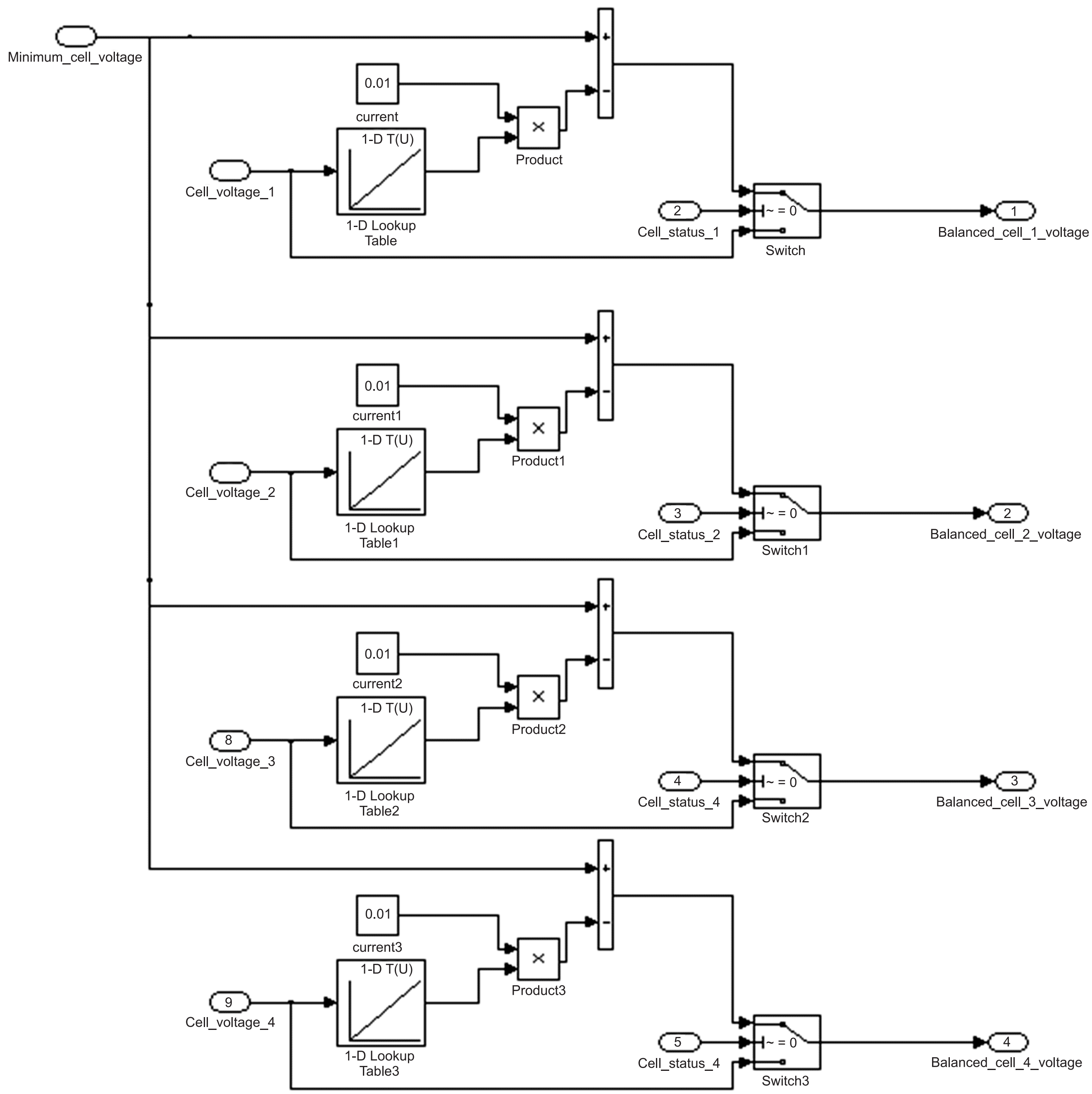

Figure 6: Simulink model of proposed cell balancing

5. CONCLUSION

One of the advanced battery management system technologies for improvement of battery safety and extending battery life is cell balancing. The proposed passive cell balancing estimates the amount of balancing need for individual cells, the overall life time of the battery safety is increased. The excess energy in the higher voltage cell is dissipated through resistor as heat makes passive cell balancing less preferable. But passive cell balancing is not much complex compared to active cell balancing which uses capacitive or inductive charge transfer between cells. This improve efficiency of active cell balancing need additional components of higher cost. From the simulation analysis, it is identified that proposed passive cell balancing technique is however the lowest cost option of all the cell balancing techniques with less equalization time. With passive cell balancing, battery run time can also extended which is suitable for hybrid electric vehicle.

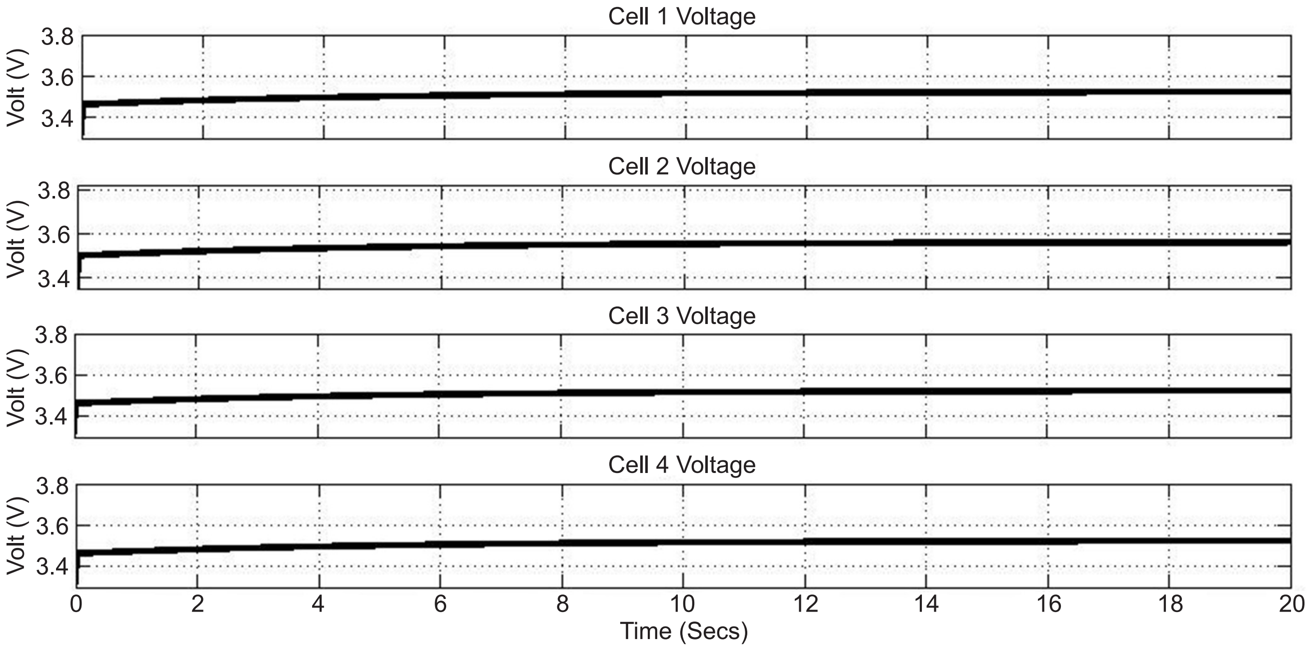

Figure 7: Cell voltages after implementation of cell balancing

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