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Modelling of Cell Balancing and Battery Aging of Battery Management System for Electric Vehicle Application

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ABSTRACT

The Battery Management System (BMS) ensures safe and cost effective utilization of battery. The Battery Management System must include something called cell balancing, which is the most crucial components for dealing with cell imbalance. To compute individual cell voltage and balance a Li-ion battery pack, connect external discharge resistors parallel to the cells control the relevant IGBTs. It depends on the discharge resistor that is being utilized, the bypass current may vary from a few milliamperes to amperes. The paper focuses on mainly battery cell balance and battery aging monitoring. It also shows a simulation that explain aspects of a lithium-ion cell such a battery aging. The recommended subsystem produces positive results and provides useful information for further study and comprehension of lithium-ion behaviour.

Key Words: *BMS, Cell balancing, Battery aging, Lithium -ion Cell.*

INTRODUCTION

Lithium-ion batteries are commonly utilized for energy storage, electric vehicles, and other applications due to their high performance. The nominal voltage of a lithium cell is 4.2V, but applications like EVs, portable gadgets, laptops, and power banks demand greater voltages. This is why designers combine many cells together. To create a more powerful battery pack, connect them in series. When combining cells to produce a pack of batteries, it's important to ensure their chemistry and voltage ratings matching.

When battery connected in series or parallel, inconsistent characteristics might result in inconsistent internal resistance and condition of charge(SOC) among single cells. These consist of the battery's starting state, its rate of aging, the connection type, and environmental factors. Moreover, the parameters Overtime,

cell inconsistencies can lead to poor performance and a reduced battery life. Changes in voltage levels can induce cell unbalance, leading to difficulties including thermal runaway, cell degradation, insufficient pack charging, inefficient use of pack energy, and safety concerns like explosions. In order to improve battery pack protection, life cycle, and energy efficiency, balancing methods are essential.

Cell balancing makes ensuring that every cell in a battery pack has the same voltage level, which produces the best power. cells are linked in series to create battery packs, which provide constant voltage ranges. But as the battery pack is operated, temperature changes, internal resistance variation, and SOC imbalance cause the cells to become unbalanced.

Cell balancing equalizes the charge of all cells in the chain, compensating for weaker cells and increasing battery life overall. In multi-cell battery chains, slight differences between cells are exaggerated. Each charge-discharge interval is influenced by production tolerances or operating conditions. Overcharging weak cells can lead to premature battery breakdown.

PROPOSED METHODOLOGY

Battery Management System consists of control algorithm which helps the battery to operate safely, efficiently and cell balancing. Battery Management system classified into two part's -

A. Modelling of Passive cell Balancing
B. Modelling of Battery Aging

A. Modelling of Passive cell Balancing

A circuit for passive cell balancing is shown in Fig.3. The battery stack seems to have the same capacity in all cell's due to passive balancing. During the charging cycle, it draws a small amount of energy from cells with significant soc and consumes a relatively low current. This causes every cell to charge to its maximum SoC. To achieve the same soc in every battery cell, an insulated gate bipolar Transistor(IGBT)is utilized in parallel with each battery cell as a switch and bleed resistor.

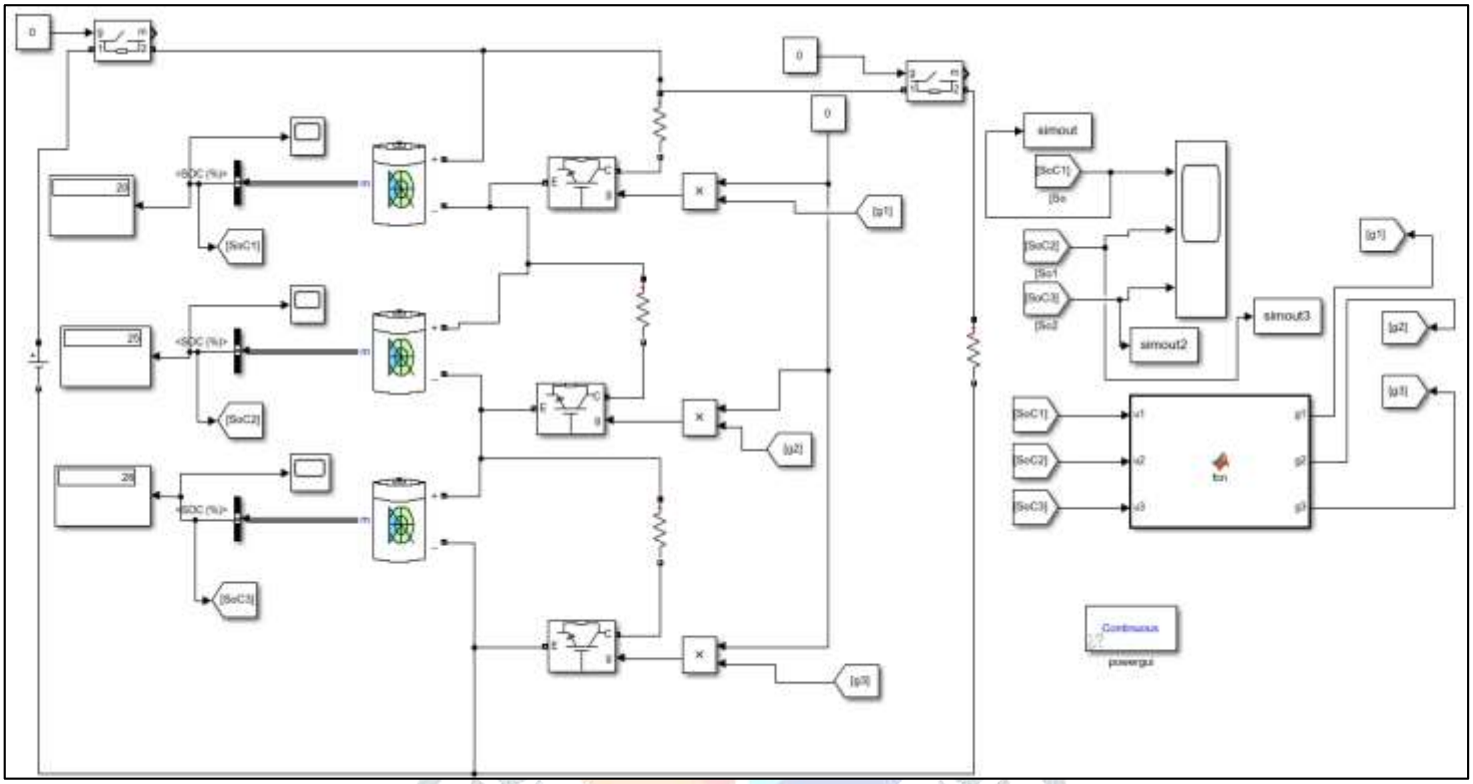

Fig. 1: Layout of Passive Cell Balancing

MATLAB is used to design the cell balancing circuit shown in figure 3. It consists of three cells connected in series and cell combination within a battery pack. One resistor is connected to the IGBT's collector terminal in each cell. One of the key issues that will lead to a lower lithium-ion cell's quality of life is an uneven distribution of charge or substantial fluctuations in the soc of the cells in a lithium-ion battery pack. By utilizing effective devices like IGBT, which assist in establishing appropriate voltage balancing with the least amount of components.

Since the IGBT is a unidirectional device, it will conduct in the direction of the collector to the emitter if the input at the gate terminal is high. The input of the gate (S1) only rises when one of the other cells' SoC is lower than the firsts. When S1 rises, the IGBT will operate and it transfer excess charge from one cell to the other cell. Also the attached resistor is bleeder resistor which discharge excess charge in the circuit when the IGBT turn off.

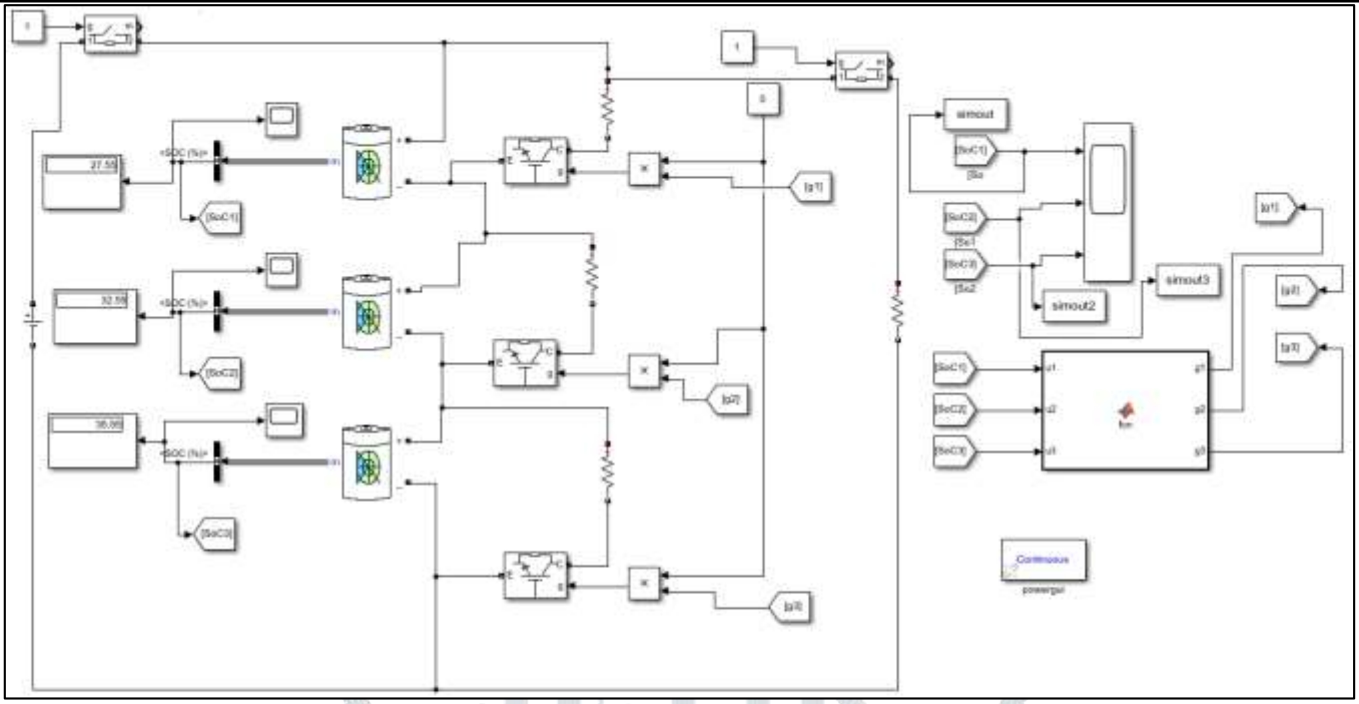

Fig. 2: Initial Stage of Cell Balancing

Fig. 2 Show the Initial stage of a passive cell balancing circuit simulation in MATLAB, where each cell's SoC differs. This means the dispersion of charge in all cells are uneven and not balanced.

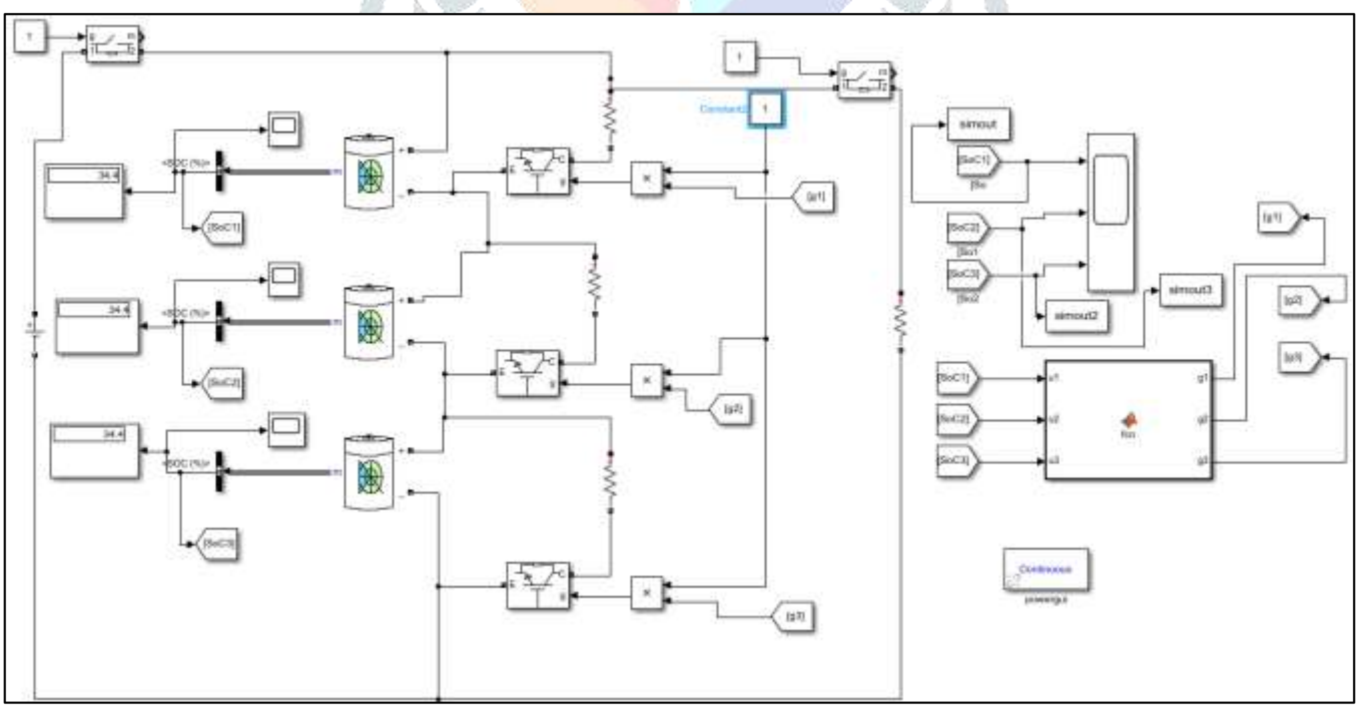

Fig. 3: MATLAB / Simulink of Cell Balancing

After running the simulation in MATLAB, the final stage (Fig. 3) shows that all cells have an equal and balanced SoC of 34.4%. In this cell balancing method, the charges is uniformly distributed among all the cells. Below figure shows a graphical illustration of the passive cell balancing.

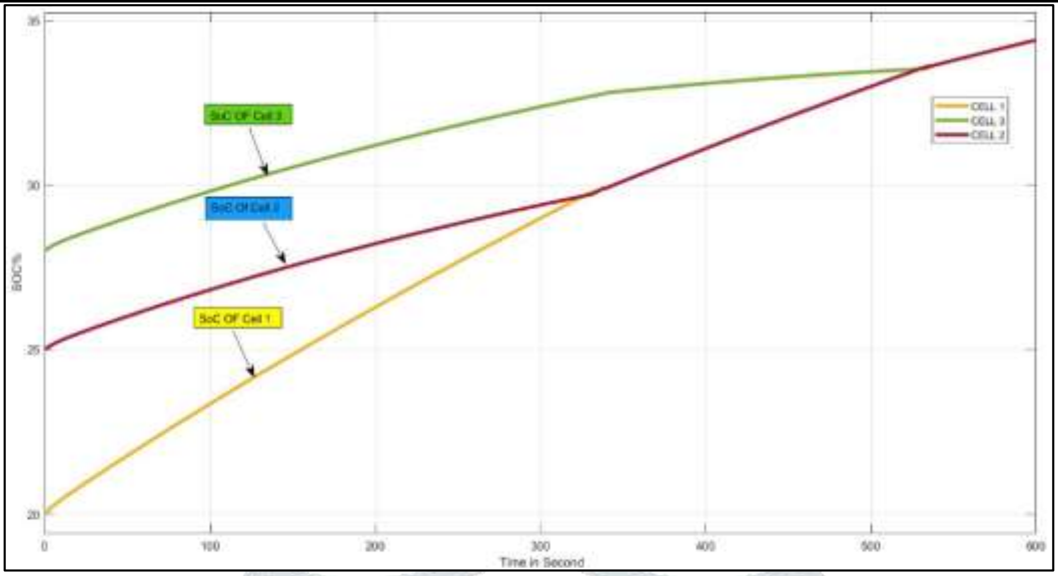

Fig. 4: Graphical Result of Passive Cell Balancing

Modelling of Electric vehicle Passive cell Balancing

Electric vehicle have a higher energy conversion efficiency than traditional vehicles.The battery will be an efficient source of power .The model simulation will show how batteries behave, and we can also see how breaking charges the battery and cell balancing.Cell balancing is the process of ensuring that all cells in a battery pack have an equal state of charge (soc) or voltage.cell balancing prevent from overcharing or discharging , overcurrent and improve efficiency of battery.

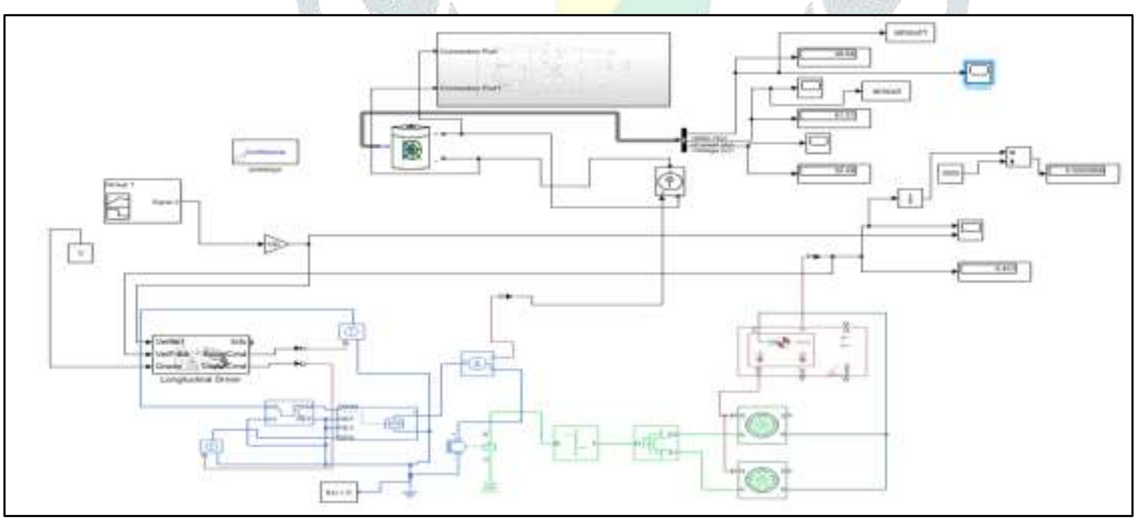

Fig. 5: MATLAB / Simulink Model of Electric vehicle passive cell balancing

The complete simulation system is separated into four subsystems. The first vehicle's body is located in the first subsystem. The motor and controller circuit reside in the second subsystem. The third subsystem consists of driver input, while the fourth subsystem contains the battery pack.

RESULT

The below output shows the state of charge and current of Electric Vehicle.

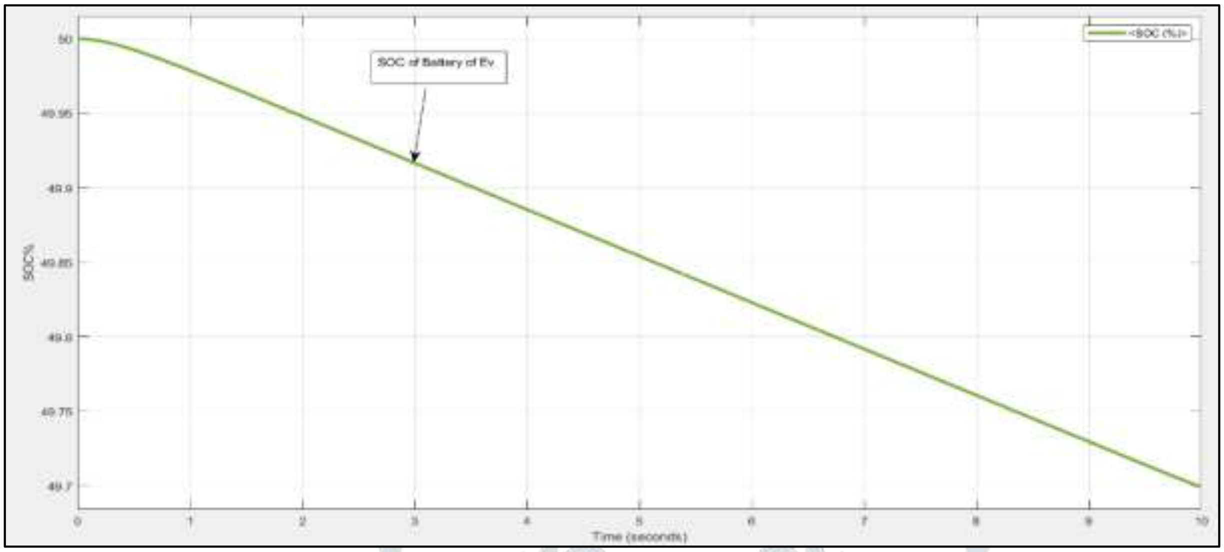

Fig. 6: Output of Electric Vehicle SOC

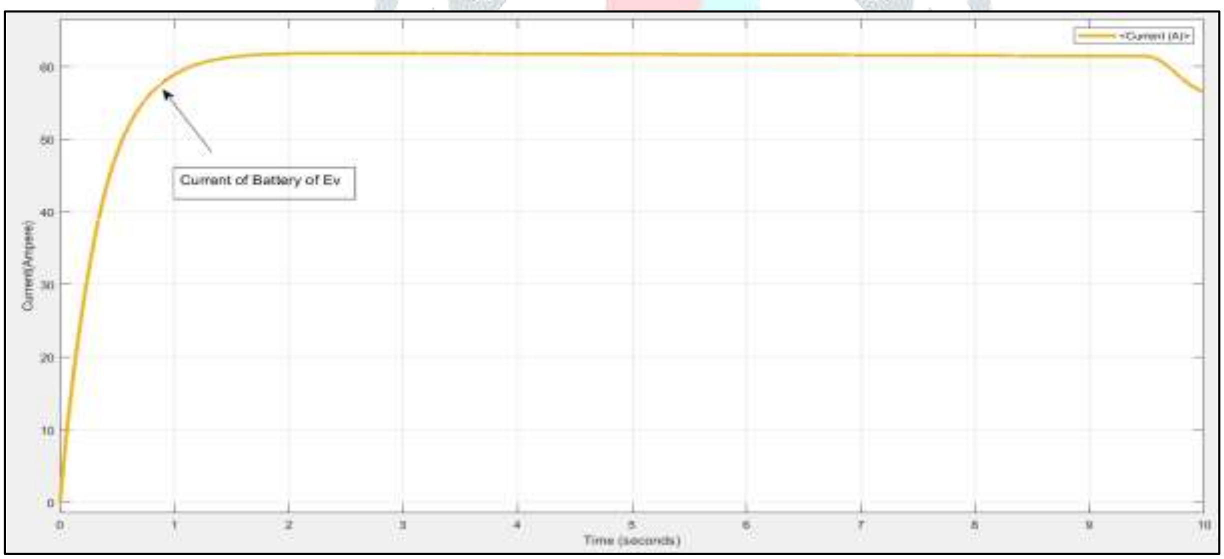

Fig. 7: Output of EV Battery current

B. Modelling of Battery Aging

Fig. 8 shows the aging model of a Lithium-Ion battery and the relationship between it's properties. The graph displays voltage, current, state of charge, cell temperature, age, and maximum capacity. This model simulates the aging of a Lithium-ion battery pack over charge-discharge cycles. Basic parameters, such as initial SoC of 100% in cell. Temperature is set to 25 degrees Celsius. The ambient temperature is at 25 degrees Celsius, and the central block generates charge-discharge cycles.

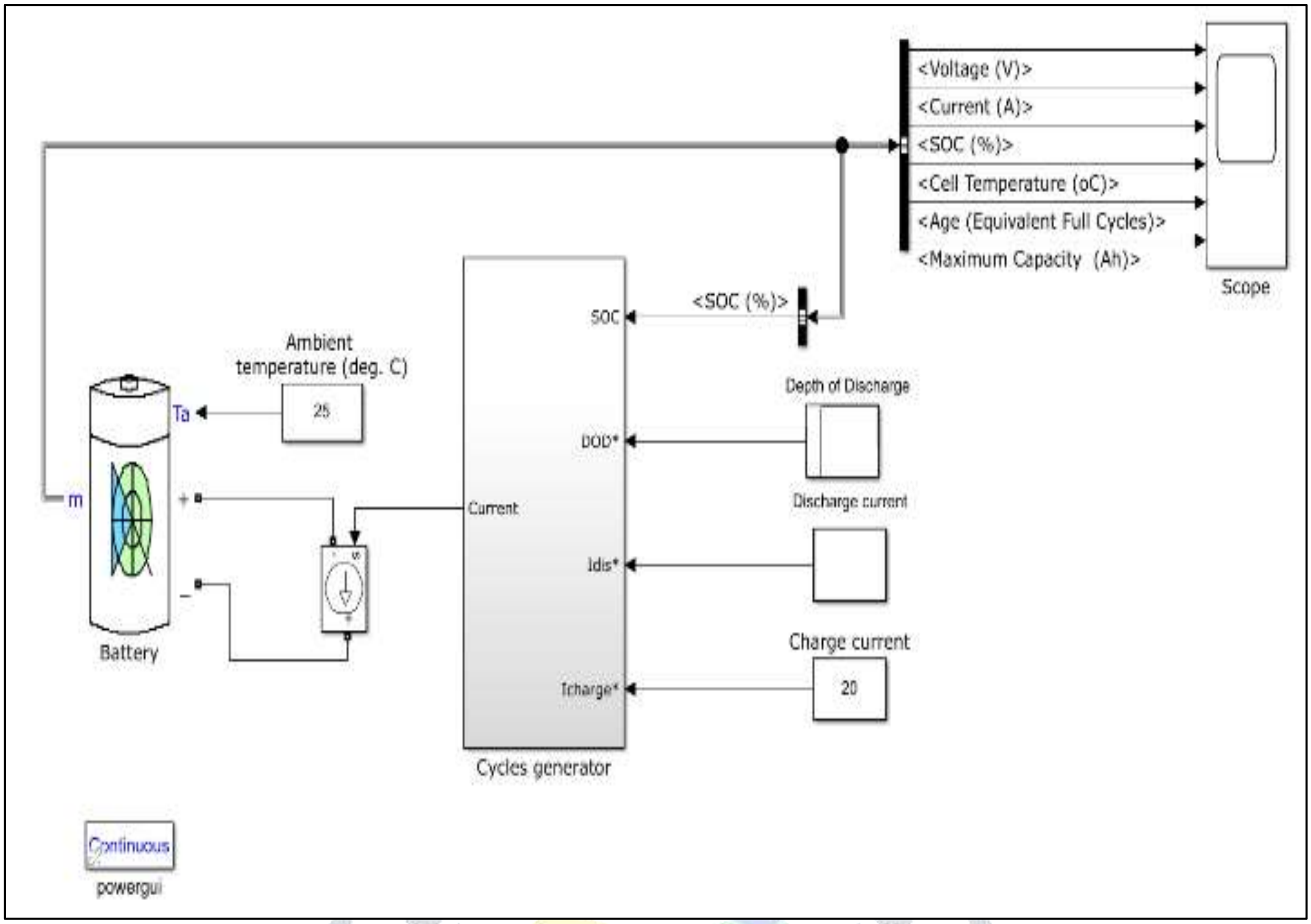

Fig. 8: MATLAB / Simulink Model of Battery Aging

To mimic perfect charge-discharge cycles, some characteristics are derived directly from the battery while others are provided as independent inputs. The impact of aging on these cells. The output includes metrics such as voltage, current, and SoC. The battery is subjected to 1000 hours of charge-discharge cycles with varying depths of discharge (DoD) and discharge rate.

RESULT

The below output shows the voltage ,current, state of charge(soc),cell temperature ,age and maximum capacity of battery.

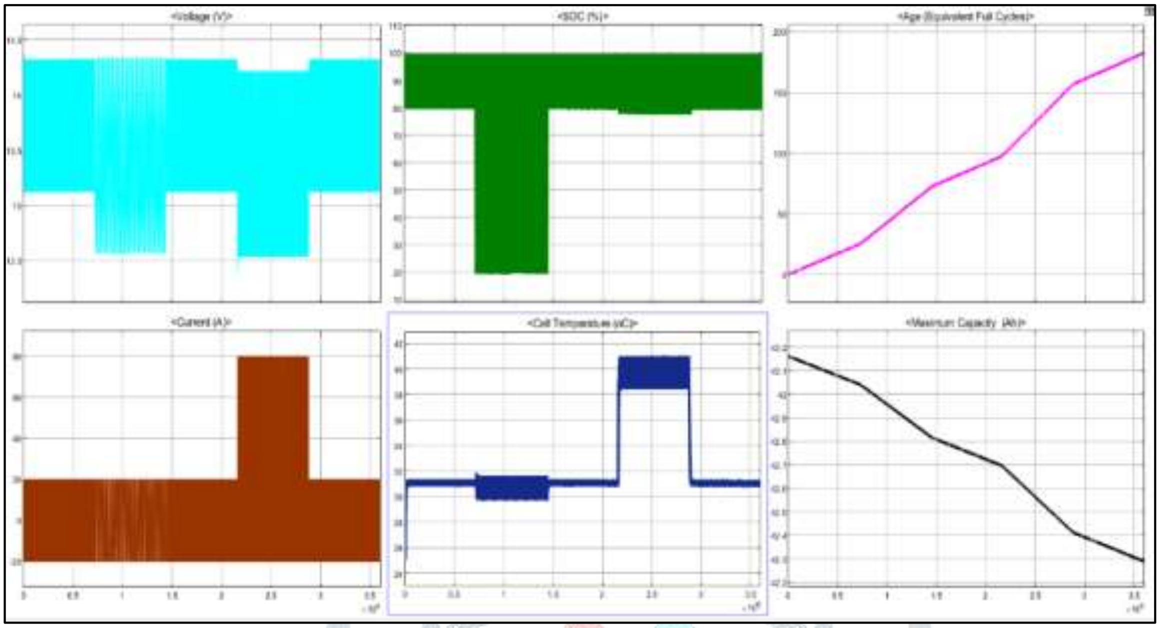

Fig. 9: Output of Battery Aging Model

The battery is cycled to a 20% DOD at a 0.5C Discharge rate, as depicted in the graphs in figure 7.The DoD is increasing at a rate of 80%.

The battery cycles with a discharge current of 20A(0.5) at t=0s.The original SOC is 100% At a constant temperature 25°C .The discharge keeps going until the SOC reaches to 80% or the DoD reaches to 20% with a charging current of 20A,the battery is fully charged to 100% SoC, Battery aging and capacity reduction occur as the cycle continues. The temperature within the cell rise from 25 to 33 degree Celsius.

The battery is charged to 100% SoC after being drained to 20% SoC and (80% DoD) at t=200 hours.This cycle continue for 200 hours more, at which point the battery starts to age more quikly.

The cycling DoD is reset to 20% for an additional 200 hours at t=400 hours. This delays the aging process for batteries.

The discharge current is raised to 80A at t=600h,Which corresponds to a 2C discharge rate.The temperature within the cell rise from 33 to 43 degrees Celsius.

The battery ages quickly as the cycle goes on, decreasing its capacity. The discharge current slows down the battery's aging process by returning to 0.5C (20A) for an additional 200 hours at t = 800 hours.

Figure 9 above illustrates how battery capacity decrease with age.

Therefore, after a certain amount of age, we need to change the battery to increase better performance and efficiency .It also assists the user in ascertaining the battery's age.

CONCLUSION

We carried out a through market study on electric two-wheelers which included Lithium-ion battery packs specification including current rating and system voltage and battery type. This paper demonstrates the design of key subsystems of a BMS, including cell balance as well as battery aging. We have simulated the aging model for time period of 1000 hours, and hence it has been studied for most of possible cases of functioning resulting in better accuracy. These model are applicable for implementation in a BMS for a Lithium-Ion battery packs in various applications, including electric vehicles and energy storage systems.

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