Simulation study on battery management System for lithium ion batteries

Pallavi Raj 1 , Paulami Majumder 2 , Shobha T 3 , Sanjana Patil 4 , Gurushant Koulagi 5

1,2,3,4,5 Department of Electrical and Electronics Engineering, Acharya Institute of Technology, Bangalore.

Abstract : With the advent of Electric vehicles (EV), high voltage battery packs have gained considerable significance. The primary energy source in EV is the battery. Improper use of battery packs could be hazardous. Thus, control and monitoring of batteries play key role in electric vehicle existence. Often the purpose is served by dedicated electronic circuitry called Battery Management System (BMS). The work presents simulation as a tool in realizing BMS. Simulation helps the designers in recognizing errors and modifies them as required. The simulation was carried out in MATLAB/SIMULINK as simulation tools to validate the results.

IndexTerms: **Battery Management System, MATLAB/SIMULINK, Electric vehicles.**

I. Introduction

Battery management system (BMS) is a regulatory technique, which helps in monitoring and controlling the different parameters of rechargeable batteries. BMS can be categorised into both: simple and complicated. A simple BMS measures the amount of voltage and restricts the flow, when desired limit is reached. Whereas, a more complex BMS monitors different parameters of the battery, to effectively increase its battery life and also increase its efficiency. The simulation is carried out using MATLAB/SIMULINK to control and monitor different aspects of lithium ion batteries.

1.1 Cell alignment

The alignment of cells, while designing a BMS is very important. The different cell alignments can be categorised as

- Series alignment- Series connection is preferred for portable equipments that require high voltage rating.

Fig 1: The above figure shows 4 cells connected in series.

The conductor size required for high voltage batteries are small. Electronic bikes or e-bikes generally come with a voltage rating of 36 V or 48V. Mild hybrid cars normally work with a cell rating of 48V and uses a DC-DC convertor for the electrical system. When high voltage batteries are operated in cold temperatures or for drawing heavy loads, precautions are taken for cell matching, as there is always a possibility of a cell falling when a number of cells are connected in series.

- Parallel alignment- Parallel connection is preferred when large current rating is desired but large cells are not available or do not fit in the designed model.

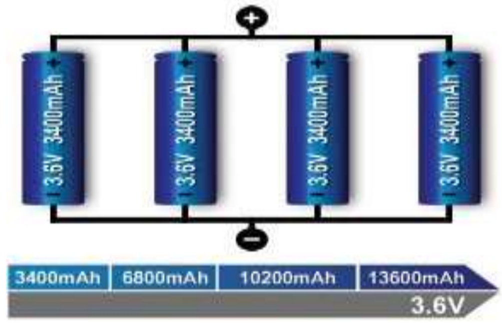

Fig 2: The above figure shows 4 cells connected in parallel.

If a cell has less resistance and opens up, then it will be less critical to arrange it in parallel than in series. For cells in parallel connection, the capacity and runtime gradually increases but the voltage remains constant.

- Combination of Series and Parallel alignments- By combining series and parallel alignments, the BMS design acquires flexibility and also attains the desired voltage and current ratings with a standard cell size.
  Lithium-ion tends to have better efficiency and performance when the cells are arranged in a combination of both series and parallel alignments, but constant monitoring is also required for keeping the various parameters of the battery within acceptable limits.

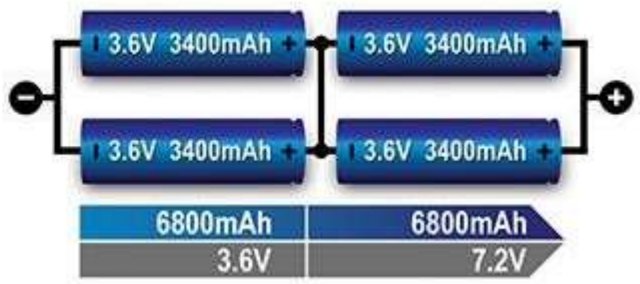

Fig 3: The above figure shows 4 cells arranged in series-parallel alignment.

II. Cell parameters

Cell parameters are the different features of the battery that are monitored to restrict them within acceptable limits. The different parameters monitored are:

- State of Charge (SOC) : SOC of a battery is a measure of the amount of charge available in the battery with respect to its original capacity. SOC is calculated in percentage points.
  The different methods of calculating soc are:
  a. Direct measurement- In direct measurement techniques, parameters like terminal voltage and impedance of the battery are directly noted.
  b. Open circuit voltage method- In this method, the linear relationship between the SOC of the battery and the OCV (Open Circuit Voltage) of the battery is given as,

$$Voc(t) = a1 \times SOC(t) + a0$$

Where, SOC(*t*) refers to the SOC of the battery at the time interval 't'.
a0 refers to the terminal voltage of the battery when SOC is equal to 0%
a1 refers to the terminal voltage of the battery when SOC is equal to 100%
Unlike lead acid batteries, lithium ion batteries do not have a linear relationship between SOC and OCV. A typical graph depicting relationship between OCV and SOC for lithium ion batteries is given below.

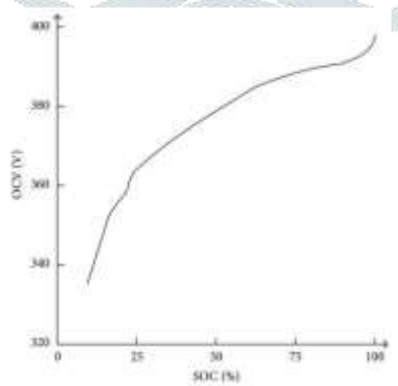

Fig 4: the above graph shows the non linear relationship between OCV and SOC for a lithium ion battery.

c. Coulomb counting method- This method helps in measuring the amount of discharging current in a battery. It performs integration of discharging current over time, in order to estimate the SOC. The equation used in this method is given by,

$$SOC(t)= SOC(t-1) + (I(t)/Qn) \times delta (t)$$

Some of the factors that affect the coulomb counting method are: temperature, battery history, discharge current and life cycle.

- Charging and Discharging of the battery cells : The charging of the battery is done in two modes,
    a. Constant current.
    b. Constant voltage.

The maximum allowable current is 22A for both constant current and constant voltage measurements. These both measurements are done at 80% of SOC level. A different control algorithm is required to charge 80% of the battery to 100%

During the discharge mode, our reference is 48V and thus, we will use PI Controller in this mode. When the battery is in discharging mode, the SOC decreases but the battery current stays positive and the load voltage is about 48V. The system is separately working in two stages, but we incorporate a switch, so as to combine both the stages. The switch depends on the voltage source for determining its operation.

When the voltage source is enabled, battery is charging and the load is supplied from the source.

When the voltage source is disabled, battery is discharging and the load is supplied from the battery.

- Voltage : In order to show the voltage based control effect up to 80% , we require a PI Controller for determining reference battery current. The reference current is 22A, because the battery voltage is less than 25.98V. Using the PI voltage controller, it is reduced and the battery starts charging at 25.98V and 16A. While the battery is charging, the voltage increases and the current decreases.

III. SIMULATION MODEL

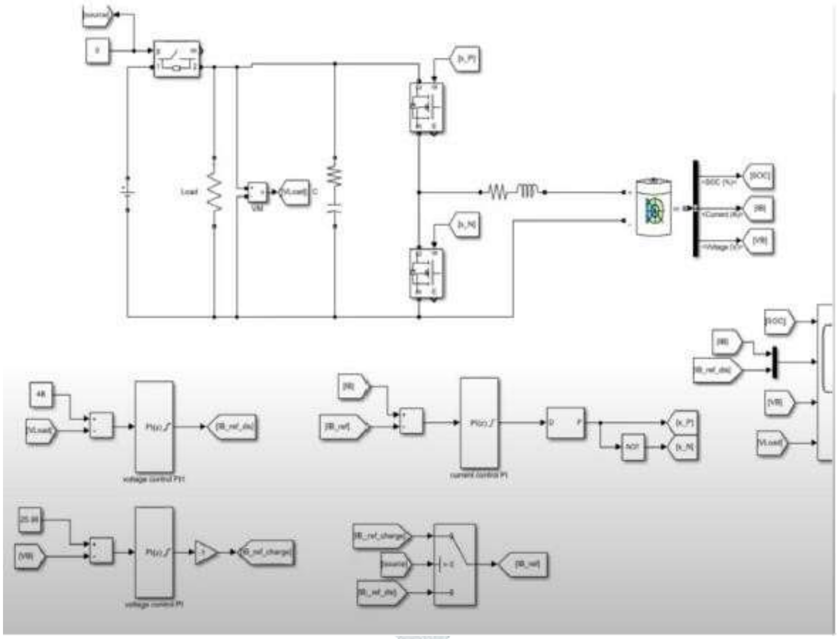

Fig 5: The above figure depicts the simulation model of the BMS designed.

The components that were used to design the above simulation model were:

a) Battery
b) DC voltage source
c) Bidirectional DC-DC convertor
d) Common load for two sources.

When the voltage source is disabled, the battery will supply the load. When the voltage source is enabled, the battery will charge and the load will be supplied from the voltage source.

IV. RESULTS

The charging mode output of the BMS model gives proper and desired output.

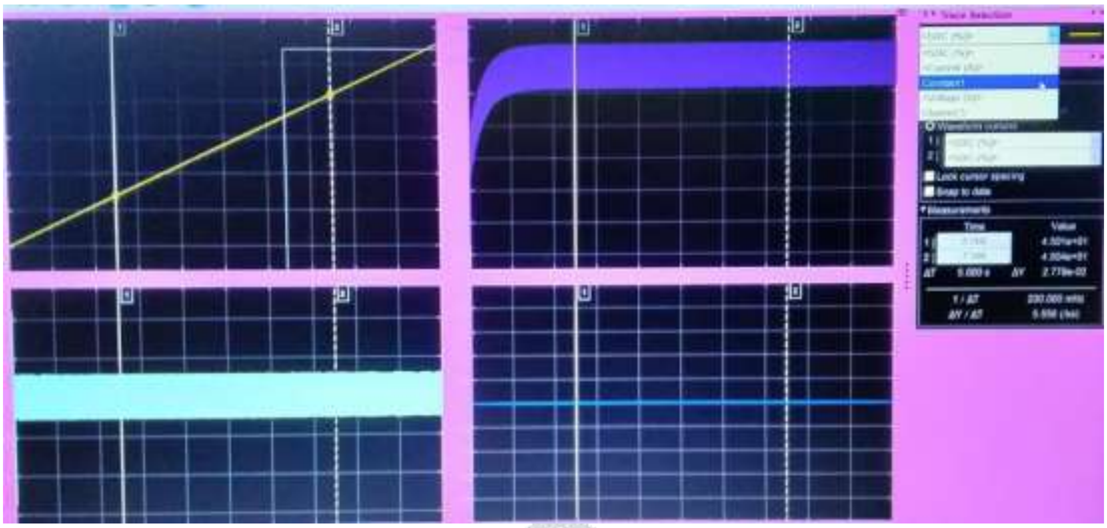

Fig 6: The above graph shows the output obtained during charging mode.

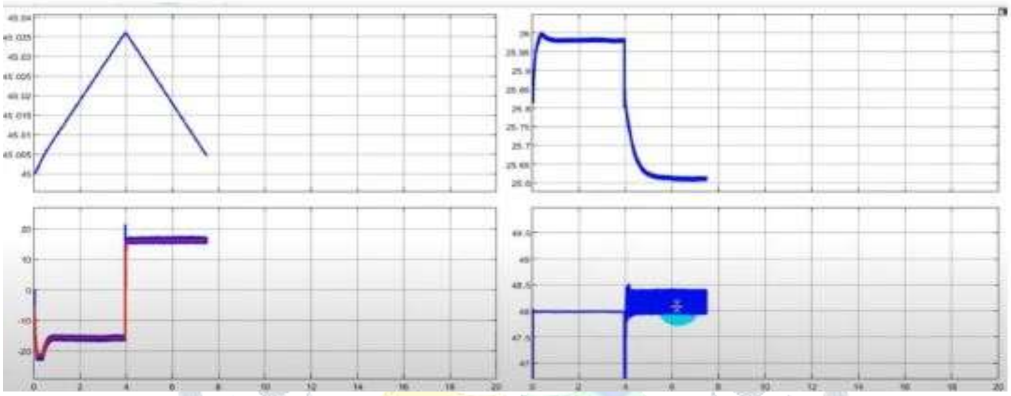

Fig 7: The above graph represents the output obtained when the source is disabled.

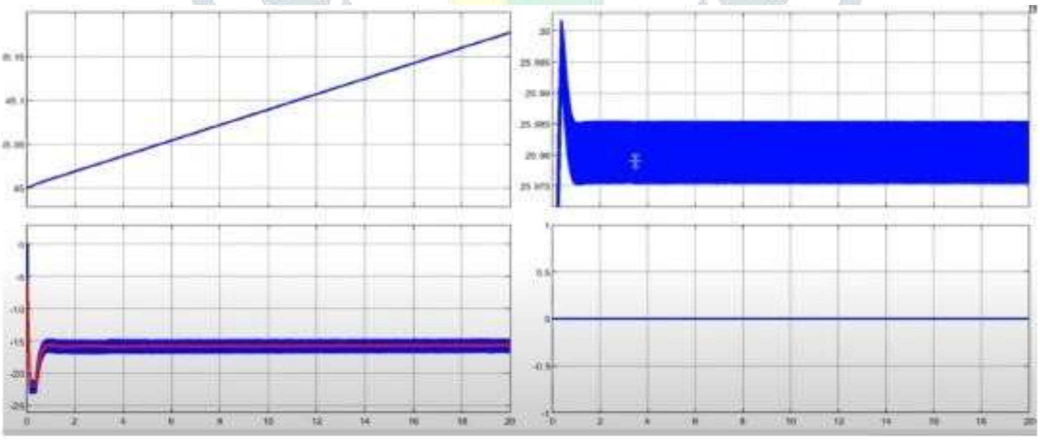

Fig 8: The above graph represents that the battery is in discharging mode.

V. CONCLUSION

First, we designed the simulation model and then made the cell arrangements; consequently our BMS model was completed. Using the simulation model of our BMS, we were able to monitor the different parameters such as SOC, charging, discharging and voltage. The similar procedure can be implemented for the hardware part of the project. The various advantages of designing the simulation model prior to the hardware are:

a) It will save time
b) It will be cost effective
c) It helps in identifying errors.

The various applications of BMS are :

a) Electric vehicles (EV)

b) Electronic Devices (ED)
c) Stationary Battery Energy storage
d) Used in Aviation, drones, power tools.

VI. ACKNOWLEDGEMENT

For the completion of this paper , we would like to thank our guide, Mr. Gurushant koulagi, for always supporting us and helping us to clear the doubts. We would also like to thank our project coordinator, Mr. Sunil, for helping us with whatever was needed to complete our project.

VII. REFERENCES

1. Active cell balancing in battery packs' by Stanislav Arendarik and Radhoštem.(2018)
2. Review on key issues for lithium-ion battery management in electric vehicles' byRaghavendra Arunachala, Sabine Arnold. (2016)
3. Real time battery monitoring system' by Abin Robinson, Aravind S, Ashna Felix, Hrithu OA. (2016)
4. Methods for state of charge determination and their applications' by Meng Di Yin, Jiae Youn, Jeonghun Cho .(2018)
5. Development of battery management system for cell monitoring and protection' by , Irsyad Nashirul Haq, Muhammad Iqbal, Nugroho Soelami, Nugraha, Deddy Kurniadi, Brian Yuliarto/ (2017)
6. Battery prognostics at different operating and condition' by Dong Wang a , Jin- zhen Kong (2016)
7. A Review on Battery Charging and Discharging Control Strategies' by Irsyad Nashirul Haq, Edi Leksono, Muhammad Iqbal, Nugroho Soelami , Nugraha, Deddy Kurniadi, Brian Yuliarto. (2017)
8. The Optimal Charging Method Research for Lithium-ion Batteries Used in Electric Vehicles _by makus lie thomas braun, makus knil. (2016)
9. Modelling of Lithium-ion Battery for Charging/Discharging Characteristics Based on Circuit Model' by Lu a, Xuebing Han , Jianqiu Li , Jianfeng Hua , Minggao Ouyang ,a State Key Laboratory of Automotive Safety and Energy, Tsinghua University.(2016)
10. Battery Management System Hardware Concepts' by Makinejad, Raghavendra Arunachala , Sabine Arnold , Hassen Ennifar Han Zhou , Andreas Jossen, Wen Changyun. (2017)