Battery Management System (BMS) Modelling and State of Charge (SoC) Estimation in MATLAB

Project synopsis submitted in partial fulfilment

for the Award of

CERTIFICATION

in

Electric Vehicle Course

by

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PROJECT DESCRIPTION

Objective

The objective of this project is to develop a comprehensive Battery Management System (BMS) model in MATLAB that includes the estimation of the State of Charge (SOC) for a given battery pack. For this we want to develop a detailed model of Lithium-ion cell and connect it to the BMS model. The BMS model should be capable of accurately tracking the SOC of the cell which we have modelled for the given cycle considering the cell's voltage, current and capacity.

Expected Results

The Outcomes of this project are discussed below:

- Modelling of the Lithium-ion cell model using MATLAB and Simulink.
- Developing a BMS model for the above cell model.
- Estimates the cell State of Charge (SOC) through the BMS Model.
- Understanding the role of Battery Management System (BMS) in the safe operation of the Battery.

Pre-requisites

To Complete this project, we have some basic knowledge on:

- Function of Battery Management System.
- Simulink and MATLAB Environment.
- Basic Cell Nomenclature.

CHAPTER 3

REQUIRED INPUT PARAMETERS AND CALCULATIONS

Assumptions

The Assumption made for this project are:

- The Cell used for modelling is KOKAM SLPB 70205130P cell of prismatic type.
- Let Cell be in fully charged condition and BMS is developed to monitor the cell during discharge Condition.
- The ambient temperature be 20 degrees Celsius or 273 Kelvin
- The Convective Heat transfer coefficient be 10 W/m^2.K
- The Specific heat of the cell (Cp) be 830 J/Kg. K

Input Parameters

Let us assume that the cell which is going to be modelled by using the Simulink be the KOKAM cell and its specifications are given below:

Capacity of the Cell = 12000 mAh

Nominal Voltage = 3.7 V

Thickness of Cell = 7 mm

Width of cell = 206 mm

Length of cell = 130 mm

Continuous current while discharging = 60 A

Temperature limits while discharging = 253 K and 333 K

Cut-off Voltage = 2.7 V

Maximum Voltage = 4.2 V

Mass of the Cell = 0.354 Kg

The Litium-ion cell is modelled by taking the above parameters is shown in below:

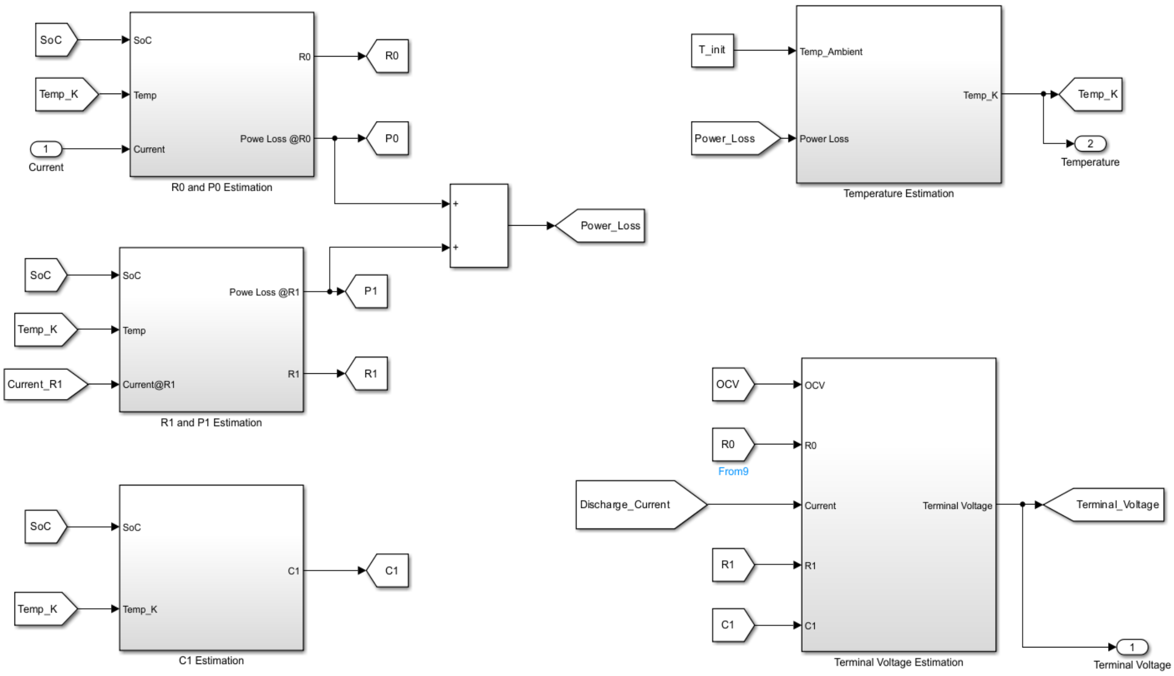

Fig – 1

The above figure is the Lithium-ion cell model which is consists of 5 blocks

1. R0 and P0 Estimation
2. R1 and P1 Estimation
3. C1 Estimation
4. Temperature Estimation
5. Terminal Voltage Estimation

R0 and P0 Estimation

This block is used to estimate the Internal Resistance and power loss of the cell. By expanding the block, we can see the following elements.

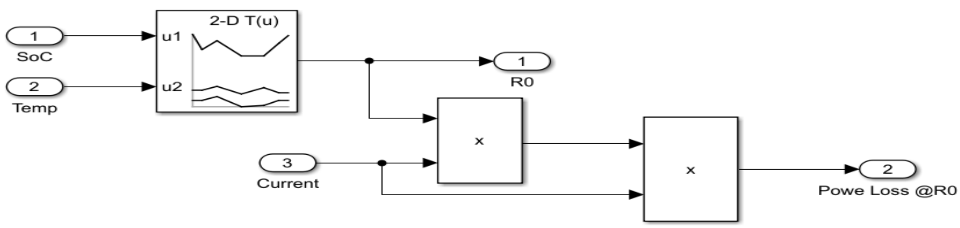

Fig - 2

To get the R0 and P0 we use the lookup table in which we pass the parameters like SoC, Temperature and Current which are obtained from the BMS model and the Temperature Estimation block we get the value of R0 and when we multiply the R0 with Current Cycle data we get the Voltage i.e. from ohms law V = I x R. To get the power loss the voltage is multiplied with the current cycle data.

R1 and P1 Estimation

This block is also used to estimate another internal resistance and the power loss of the cell by taking the same inputs as discussed above and the representation of the block is also same as the above.

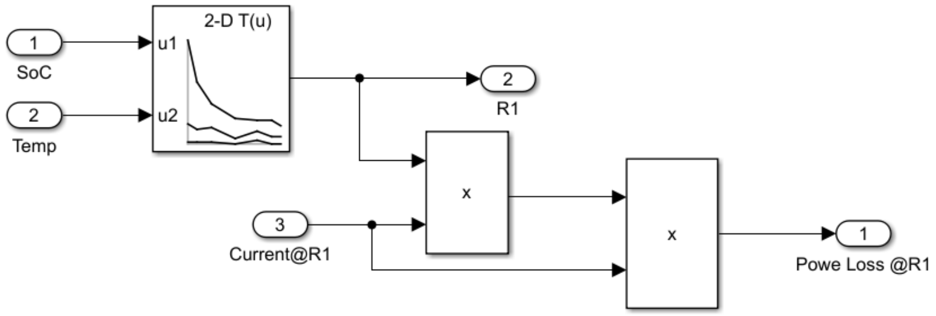

Fig - 3

We get the total power loss and total internal resistance by adding the outputs of the two blocks.

C1 Estimation

This block is used to estimate the internal capacitance of the cell. By expanding the block, we can see the following elements.

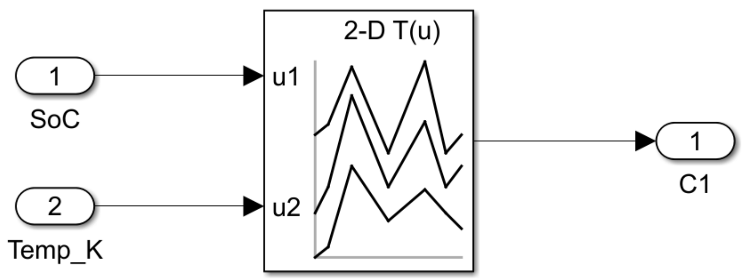

Fig – 4

To estimate the capacitance, we use a lookup table which takes input as SoC and Temperature as we discussed above and we get the value of the Internal Capacitance of the Cell.

Temperature Estimation

This block is used to estimate the Temperature of the cell. By expanding the block, we can see the following elements.

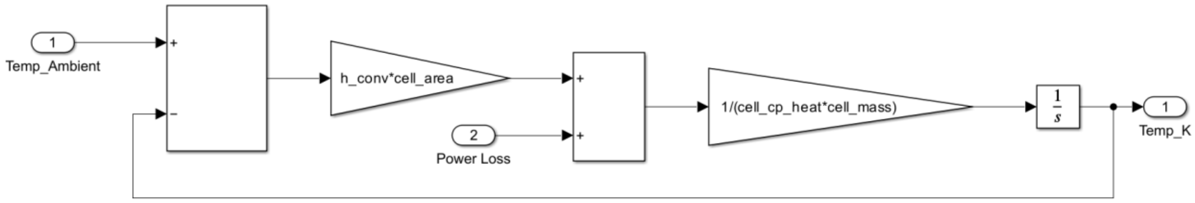

Fig – 5

This block takes Ambient Temperature and Power loss from the Cell as input and performs calculation as per the formulae shown below

$$Temp(cell) = Integral\ ((T_{amb} - T) * R_t + P\_loss)/C_t)$$

Were,

T_{amb} = ambient temperature

T = actual temperature

R_t = convective heat transfer Coeff x cell area

C_t = Specific heat capacity = Cp_cell x cell mass

By performing the above calculation, we get the Temperature of the Cell which is used to find the internal resistance, capacitance and power blocks as we discussed in the above blocks.

Terminal Voltage Estimation

This block is used to estimate the Terminal Voltage of the cell by taking the input of internal resistance, open circuit voltage, capacitance and the discharge current. By expanding the block, we can see the following elements. The internal resistance and the capacitance are taken from the R0 and P0, R1 and P1 estimation block and C1 estimation block respectively but the Open Circuit Voltage and the Discharge current should be taken from the BMS model.

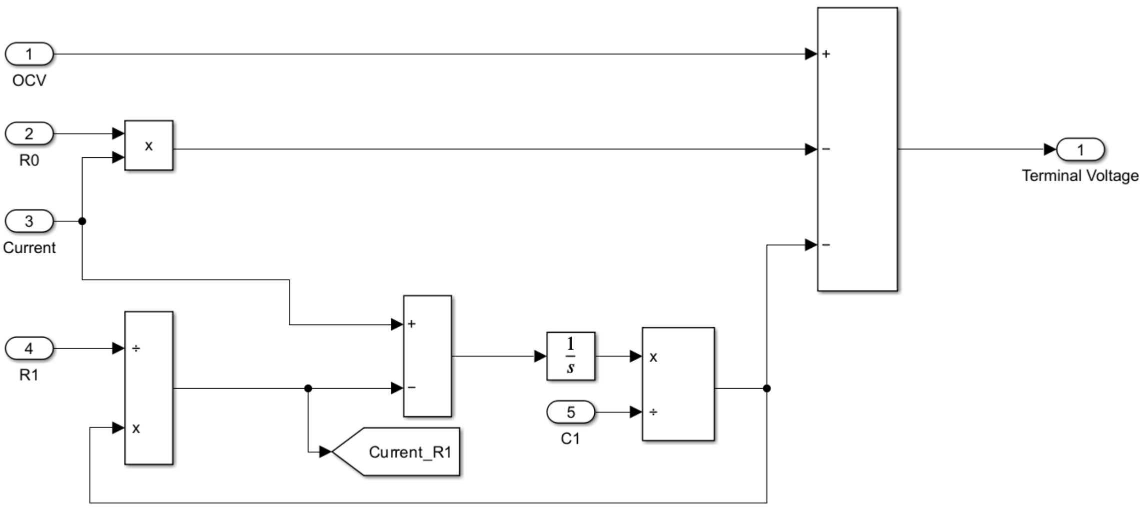

Fig – 6

By subtracting the Voltages of the Internal Resistances R0 and R1 and from the Open Circuit Voltage we get the value of Terminal Voltage. By this we completed the modelling of the Lithium-ion cell.

The Battery Management System (BMS) for the above cell model is shown below:

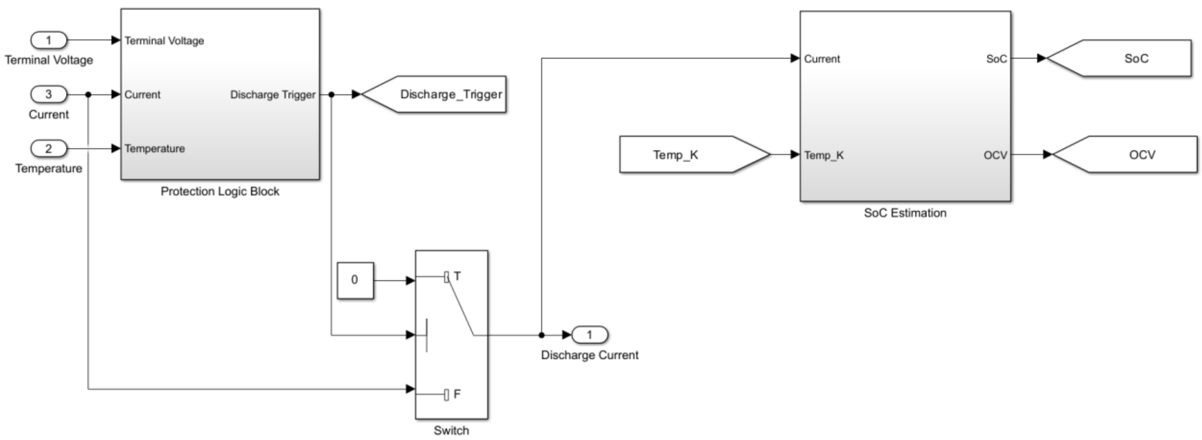

Fig – 7

The above BMS model consists of 2 main blocks. They are

1. Protection Logic Block
2. SoC and OCV Estimation Block

Protection Logic Block

This Block is used for the protection of the cell and mainly consists of the logic that protects the cell from under or over voltage, temperature and current. This block contains the following elements.

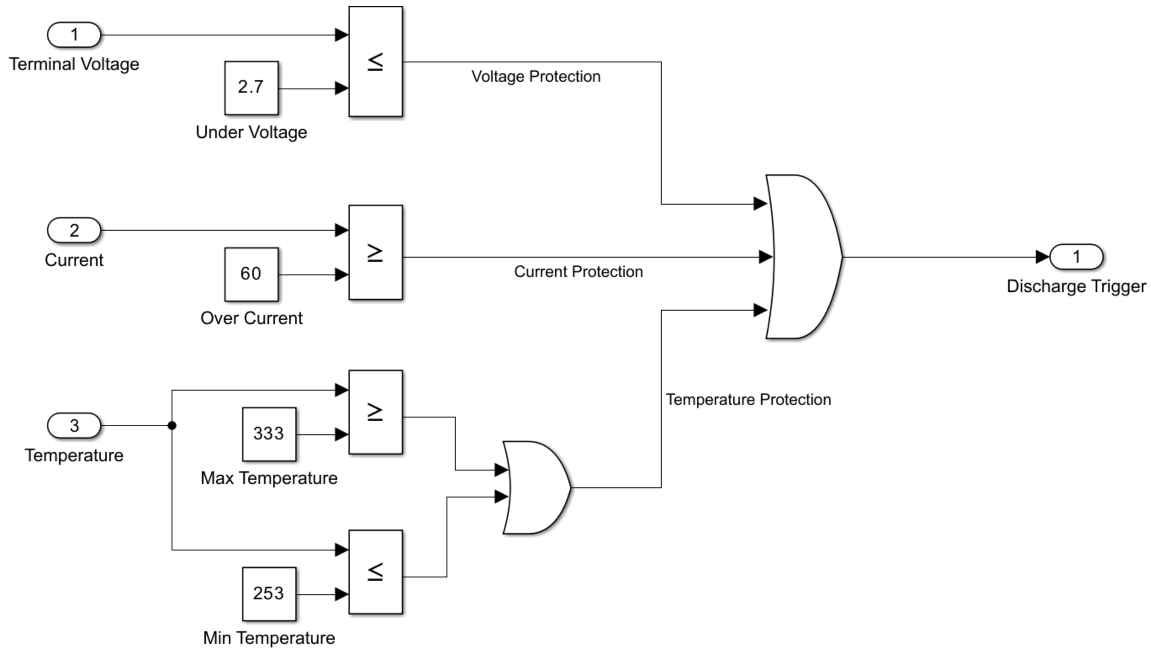

Fig – 8

This block takes the Terminal Voltage, Current and Temperature of the cell model as the input. If the values of the inputs are within the specified limits, then this block gives output as logical 0 through the OR block. If any of the input value exceeds the specified limits then this block gives output as logical 1 through the OR block.

This block gives output as Discharge Trigger and this is directly connected to the switch block as shown in the above Fig-7. The Switch Block is designed on such a way that it passes the current to the next block when the protection logic block returns logical 0. Then the discharge current from the switch block is given as input to the State of Charge (SoC) estimation block.

SoC and OCV Estimation Block

This Block is used to estimate the State of Charge of the cell which we have modelled by taking the input as Discharge Current and the Temperature of the cell. This Block Estimates the SoC based on the following formulae

SoC(t) = SoC(t-1) – Integral (I dt / C*3600)

Were,

SoC(t) = State of Charge at Current Time Step

SoC(t-1) = State of Charge at Previous Time Step

I = Current

C = capacity of the cell

This Block contains the following elements

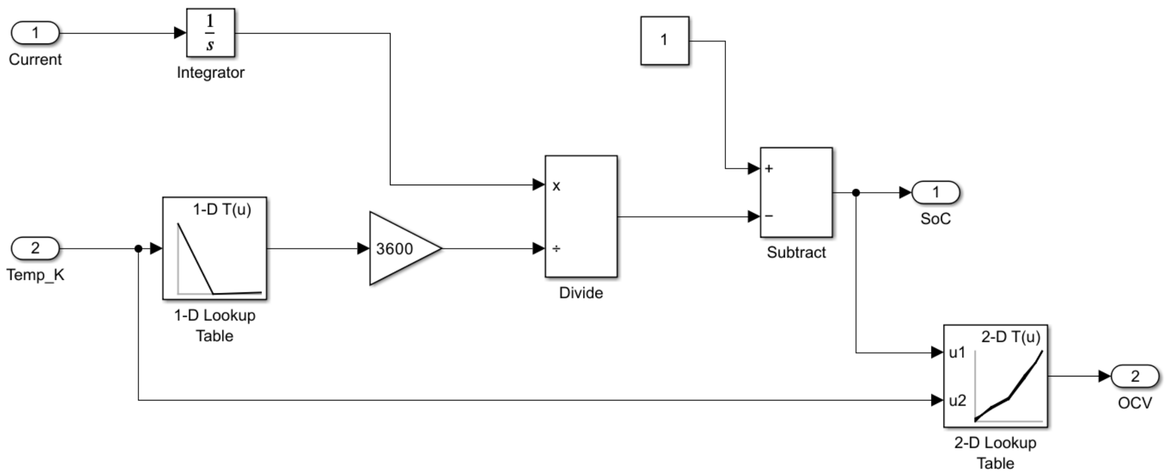

Fig – 9

To get the capacity of the cell the temperature is passed through the Lookup Table and the obtained capacity is multiplied with 3600. The Current is Passed through the integrator and divide with the capacity through divide block and the output from the divide block is subtracted from the previous SoC i.e. 100% by using subtract block then we get Current SoC. To estimate the OCV we use lookup table which takes input as SoC and Temperature. This Block gives the Output as State of Charge (SoC) and Open Circuit Voltage (OCV). By this we modelled the Battery Management System (BMS) for the Lithium – ion cell.

The Complete Model of the Cell with BMS is shown below.

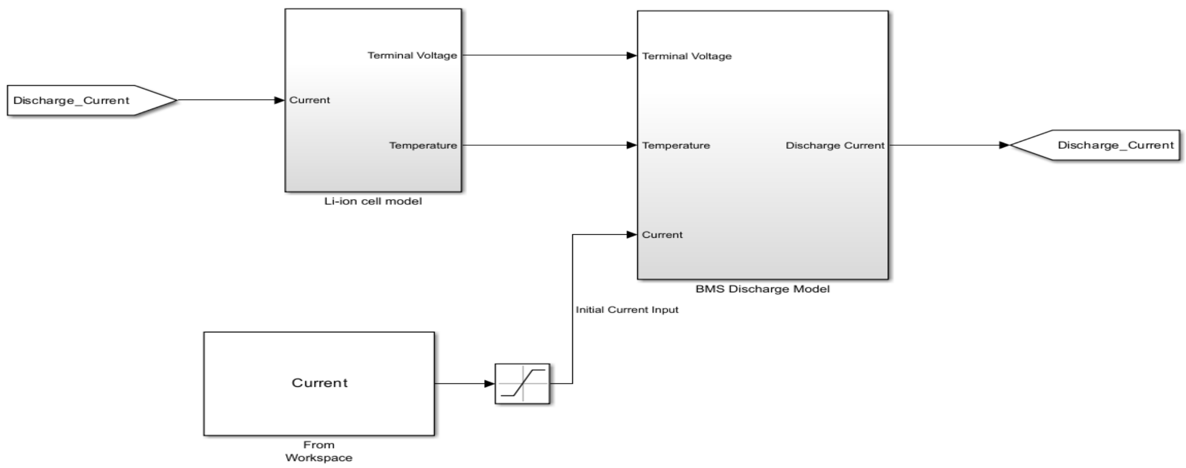

Fig – 10

CHAPTER 4

OUTPUT PARAMETERS

The Following are the output parameters that are retrieved from the project:

- **MATLAB Cell Model**

  A complete model of the cell designed in the MATLAB as shown in the Fig – 1 and a complete MATLAB Script that includes all relevant parameters.

- **SOC Estimation**

  Estimating State of Charge of the cell is done in this project by using the one of the SOC estimation methods called Coulomb Counting Method while modelling the Battery Management System for the Cell as shown in the Fig – 7 and detailed model of SOC estimation using Coulomb Counting Method is shown in Fig – 9.

- **Developing BMS Model**

  The BMS model for the Cell is developed in the MATLAB which estimates the SOC of the Cell by using Coulomb Counting Method. By this we also understand the function of Battery Management System in safe and secure operation of the Battery and its role in keeping the Cell healthy.

CHAPTER 5

RESULT

Since we have designed a model of KOKAM SLPB 70205130P cell with the specifications discussed above and we also developed a BMS Model for this cell to estimate the State of Charge of the cell while discharging by taking the input of drive cycle data and simulated about 1180 seconds.

After simulating the model for 1180 seconds as per the drive cycle data, we have plotted some curves to find SoC and Voltage of the cell as shown in below.

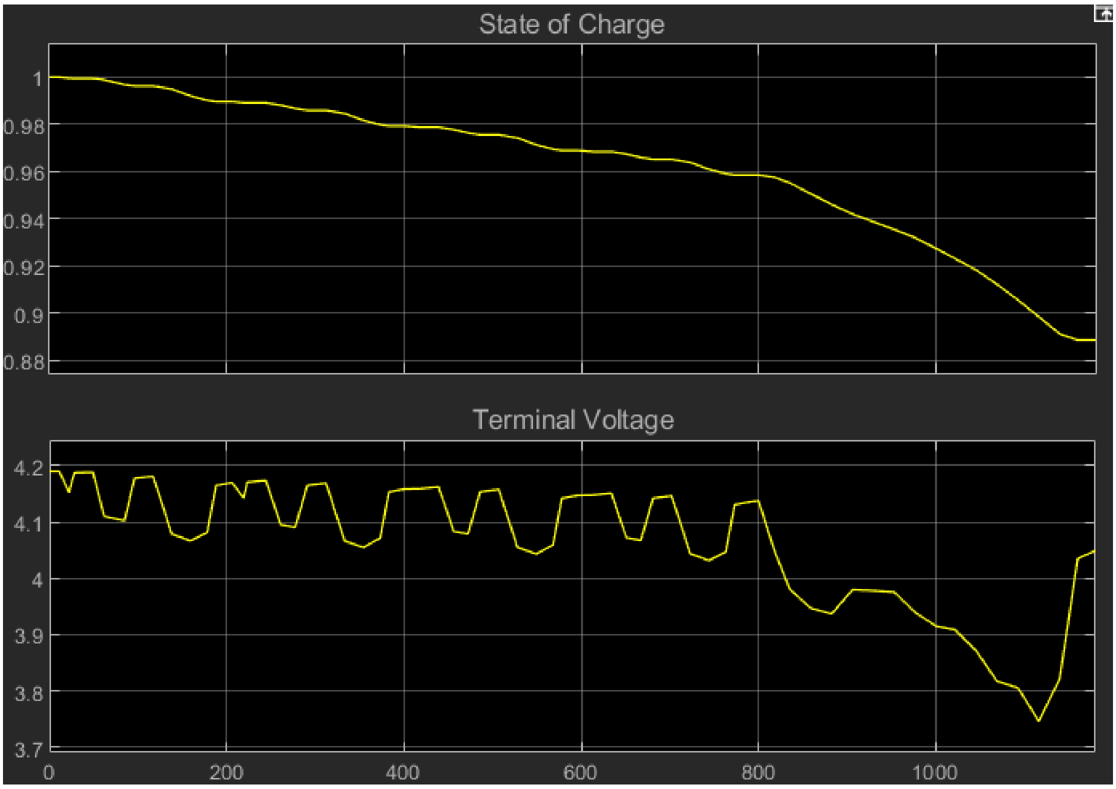

Fig – 11

From the above figure we can find the plots of the SoC and the Terminal Voltage of the Cell and we can see that the SoC is estimated in the BMS model of the cell as we discussed above. From the Terminal Voltage graph, we can say that the cell is operating within the voltage limits defined by the manufacturer 4.2 V as maximum voltage and 2.7 V as minimum cut-off voltage.

We also have plotted the curves for Temperature of the cell and the drive cycle data given for the cell as shown below.

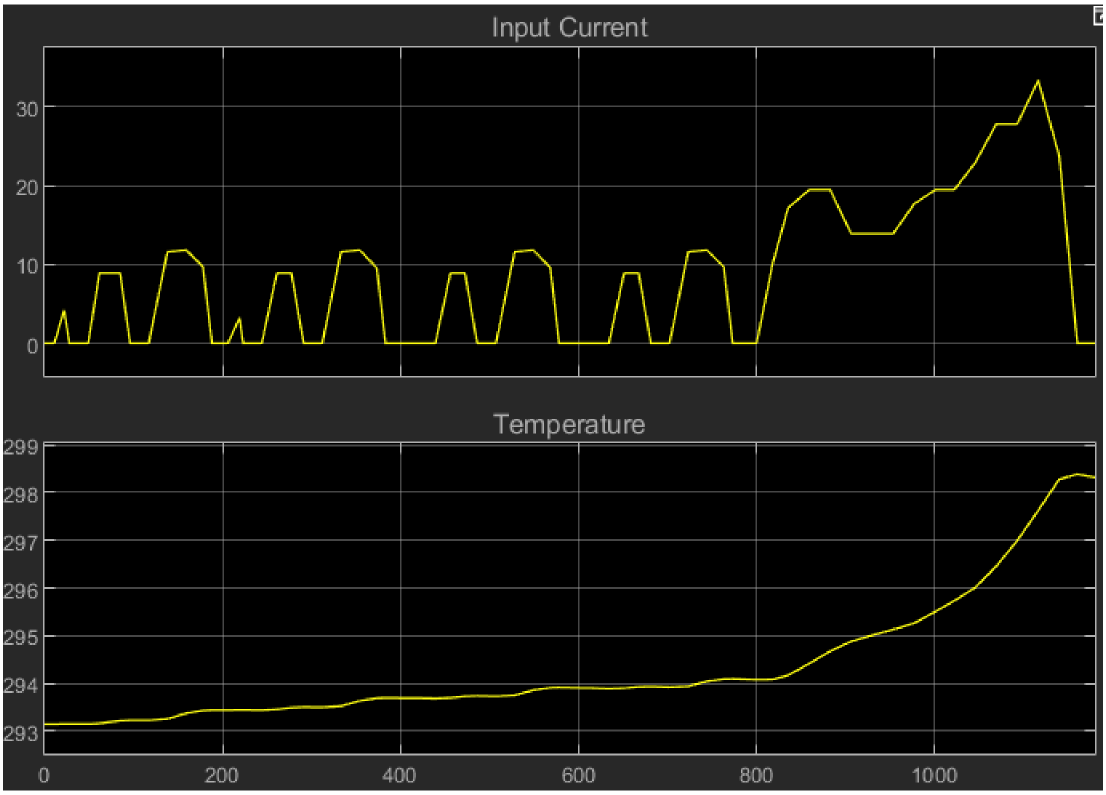

Fig – 12

From the above figure we can see that the plots of the drive cycle (input current) and the temperature of the cell. The first one is the input drive cycle data which is given for a time of 1180 seconds. From the temperature graph we can say that the cell is operating with in the temperature limits defined by the manufacturer -20^{0} C to 60^{0} C i.e. 253 K to 333 K.

CHAPTER 6

OBSERVATIONS & CONCLISION

From the Observation of the above results, we can say that we have developed a Battery Management System (BMS) model for the Lithium – ion cell called as KOKAM SLPB 70205130P with capacity of 12 Ah and we have determined the cell State of Charge (SoC) by using the Coulomb Counting Method as we discussed above. We also get the Terminal Voltage of the cell and the Temperature of the cell within the operating limits specified by the manufacturer.

By this we can conclude that that the BMS model for the cell KOKAM SLPB 70205130P is designed using the MATLAB and Simulink with the specifications provided by the cell manufacturer and simulation is done as per the given cycle time (Current.xslx) i.e. for 1180 seconds to obtain the results like Soc of the cell, Temperature of the cell and voltage of the cell and the obtained results are within the limits specified by the manufacturer.

NOTE: Cell_Data_Script.m, Current.xslx, Simulink files of the cell and BMS model are attached to this document.

References

Bhovi, R., K. Ranjith, B. Sachin, and S. Kariyappa. "Modeling and Simulation of Battery Management System (BMS) for Electric Vehicles." *Journal of University of Shanghai for Science and Technology* 23, no. 06 (2021): 805-815.

Cheng, Ka Wai Eric, B. P. Divakar, Hongjie Wu, Kai Ding, and Ho Fai Ho. "Battery-management system (BMS) and SOC development for electrical vehicles." *IEEE transactions on vehicular technology* 60, no. 1 (2010): 76-88.

https://www.yumpu.com/en/document/read/30113500/slpb-70205130p-li-ion-bms

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