Battery Pack Modelling in MATLAB

Project synopsis submitted in partial fulfilment

for the Award of

CERTIFICATION

in

Electric Vehicle Course

by

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CHAPTER 1

List of Figures:

CHAPTER 2

PROJECT DESCRIPTION

Objective

The objective of this project is to develop a comprehensive Li-Ion battery pack model in MATLAB. This model will simulate the behaviour of a battery pack, providing insights into the state of charge (SOC), voltage, and current characteristics. The project will also involve simulating the battery pack's performance using different configurations and analysing the results.

Expected Results

The Outcomes of this project are discussed below:

- To configure the Li-ion battery pack model in MATLAB with the help of given data sheet.
- To Understand the role of each and every parameter and its significance in the Modelling.
- Simulate, Analyse and provide a detailed explanation of the simulation results, including SOC, voltage, and current trends.
- Modify the battery pack configuration to 4S3P (4 series and 3 parallel cells). Re-run the simulation to predict the battery pack's behaviour under the new configuration. Compare and contrast the simulation results of the different battery pack configurations.
- A comparison between the two battery pack configurations, highlighting the advantages, disadvantages, and trade-offs associated with each.

Pre-Requisites

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

- Simulink and MATLAB Environment.
- Simscape Library
- Basic Cell Nomenclature.

CHAPTER 3

REQUIRED INPUT PARAMETERS AND CALCULATIONS

Assumptions

The Assumption made for this project are:

- The Simulations on the cell parameters like SOC, Voltage and Current are done on the cell when it is in discharging.
- The SOC of the cell assumed to be 100%.

Input Parameters

Before modelling the Li-ion cell we must have a knowledge on the parameters of a cell and its significance in the function of the cell.

1. **Nominal Capacity:**

   It is the amount of charge that can be withdrawn from a fully charged battery. It specifies the quantity of charge. It was measured in Ampere Hour (Ah) or Milli Ampere Hour(mAh).

2. **Nominal Voltage:**

   It is the average operating voltage of a cell which depends on the active chemicals used in the cell while manufacturing. It lies between the maximum and minimum voltage of the cell. For example, if a Li-ion cell has a maximum voltage of 4.2 V then it has a nominal voltage of 3.7 V. Most of the Li-ion cells have the voltage range of 2.8-4.2 V.

3. **State of Charge:**

   It indicates the level of charge of the battery relative to its capacity. The SOC is used to know the percentage of charge in the Battery. It is measured in Percent (%).

4. **Cells connected in Series:**

   If the cells are connected in series, then the battery voltage is equal to the sum of individual voltage of each cell whereas the capacity is equal to the capacity of the individual cell. By connecting the cells series, we can get our required voltage for the battery.

   For Example, The Max Voltage of the Cell is given as 4.2 V. If the 4 cells are connected in series, then the total voltage will become as 4.2x4 = 16.8 volts.

5. **Cells connected in Parallel:**

   If the cells are connected in parallel, then the battery capacity is equal to the sum of the capacities of each cell whereas the voltage is equal to the voltage of the individual cell. By Arranging the cells in parallel we can get our required capacity of the battery.

   For Example, The Capacity of the Cell is given as 2.6 A. If the 3 cells are connected in parallel, then the total capacity will become as 2.6x3 = 7.8 Ampere.

6. **Charge Cut-off Voltage:**

   It can be defined as the Maximum voltage of the cell that can be obtained while charging the cell and there is no charging of cell takes place after reaching to that particular voltage.

7. **Discharge Cutt-off Voltage:**

   It can be defined as the Minimum Voltage of the cell that can be obtained while discharging the cell and there will be no discharging takes place after reaching to that particular voltage.

8. **Discharge Current:**

   It is defined as the amount of current used to discharge the battery from a fully charged state.

9. **Charge Current:**

   It is defined as the amount of current used to charge the battery.

10. **Internal Impedance:**

    It is defined as the internal resistance of the cell that opposes the flow of alternating current at a particular frequency, SOC and temperature.

The data sheet of the modelled lithium-ion battery is given in the below table:

Sl. No	CELL PARAMETERS	VALUE
1.	Nominal Capacity	2600 mAh
2.	Nominal Voltage	3.7 V
3.	Internal Impedance	0.07 ohm
4.	Discharge Cut-off Voltage	3.0 V
5.	Maximum Charge Voltage	4.2 V

6.	Standard Charge Current	0.52 V
7.	Rapid Charge Current	1.3 V
8.	Standard Discharge Current	0.52 V
9.	Rapid Discharge Current	1.3 V

Fig - 1

By using the above data sheet of the li-ion battery a battery pack is modelled with the configuration of 3 cells in series and 4 cells in parallel i.e. 3S4P as shown in the below figure:

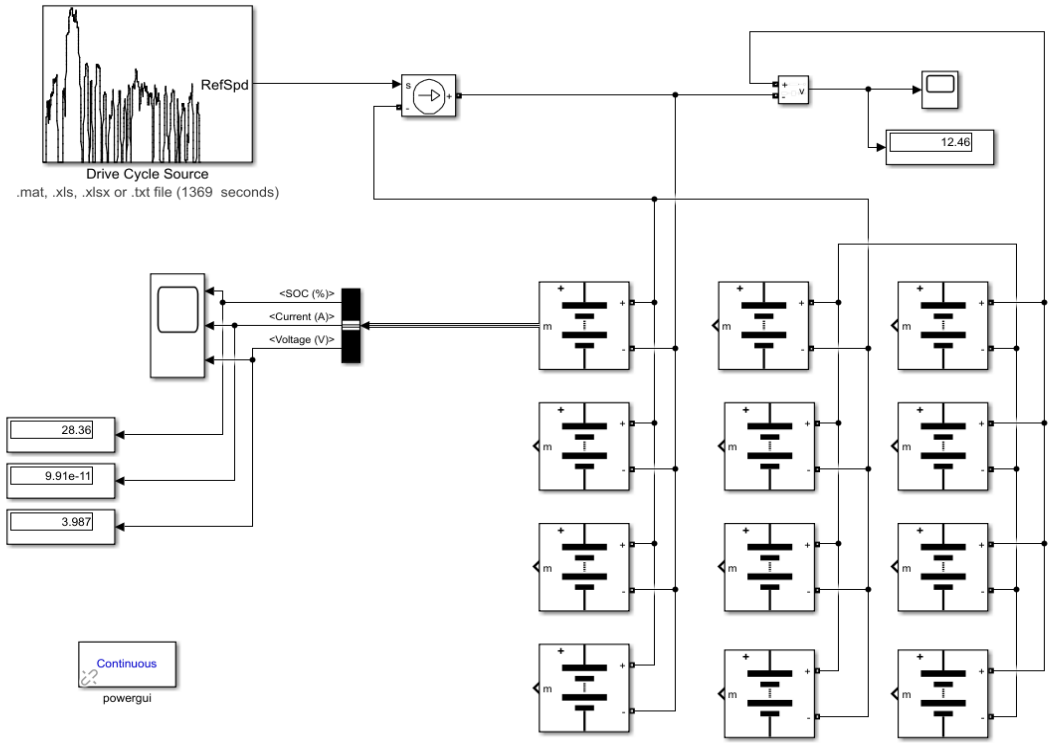

Fig – 2

After modelling the cell in 3S4P configuration the battery pack model is simulated for 1369 seconds as per the given drive cycle.

Now, the configuration is changed from 3S4P to 4S3P i.e. 4 Cells in series and 3 Cells in parallel as shown in below figure:

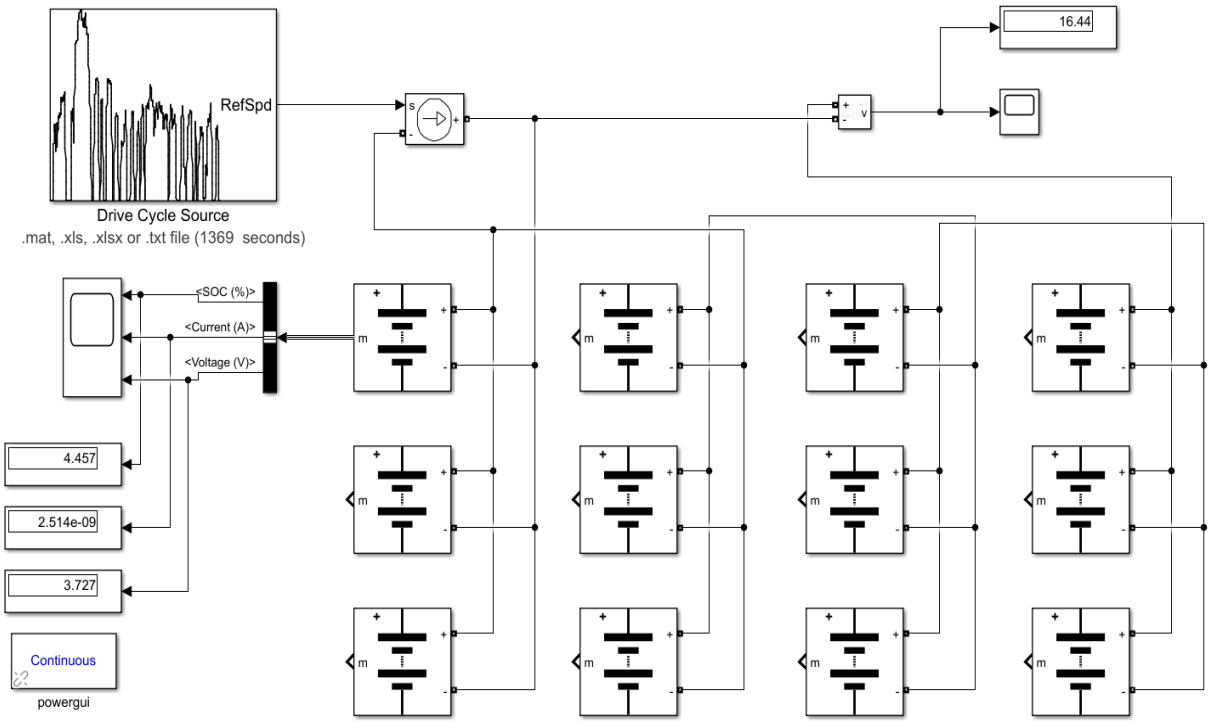

Fig – 3

After changing the battery pack configuration to 4S3P the model is again simulated for 1369 seconds as per the drive cycle to note the differences in both configurations.

CHAPTER 4

OUTPUT PARAMETERS

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

- A MATLAB script that implements the battery pack model according to the provided lithium-ion battery datasheet.
- Simulation results for the initial battery pack configuration, including graphs and tables showcasing the SOC, voltage, and current variations over time.
- A modified MATLAB script that reconfigures the battery pack to a 4S3P setup.
- Simulation results for the 4S3P battery pack configuration, including comprehensive explanations of the changes in SOC, voltage, and current behaviour compared to the initial configuration.

CHAPTER 5

RESULT

Since we have modelled a battery pack of two configurations with the given datasheet of a li-ion cell model and the results are discussed below:

Graphs of 3S4P configuration:

The Graphs for SOC, Current and Voltage are given below:

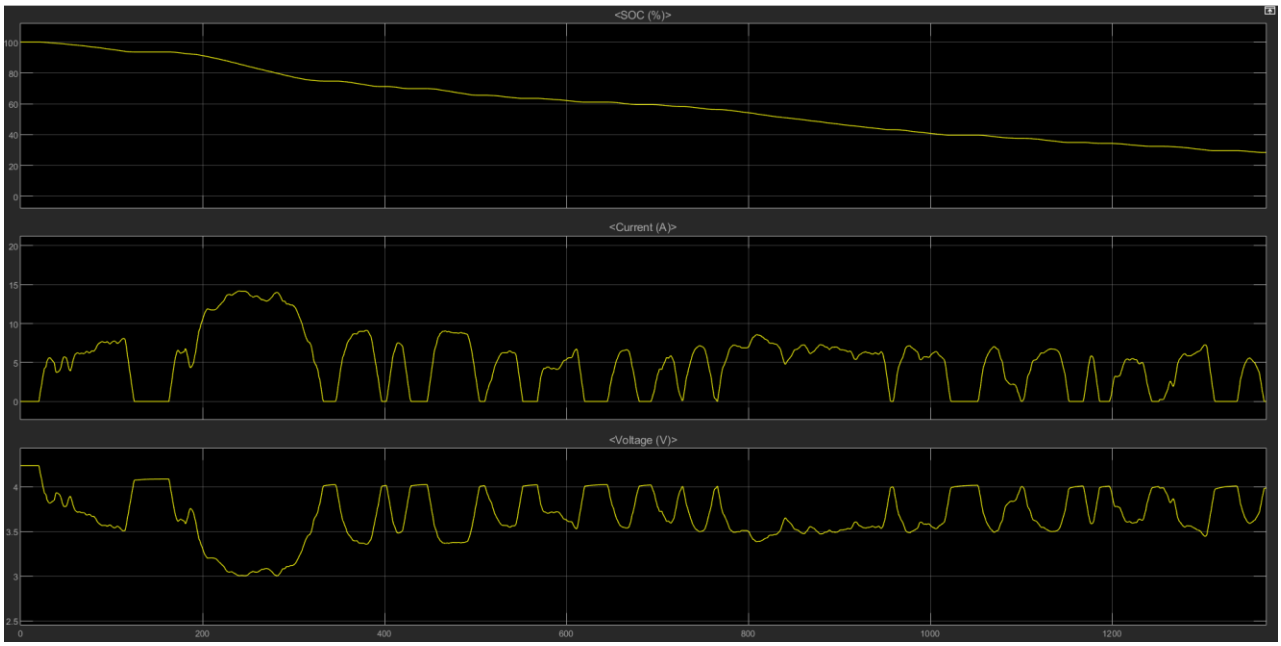

Fig – 4

From the above figure we can say that for first configuration i.e. 3S4P the SoC remained after the modelling is 28.36% as shown in the Fig- and by observing the above figure we can get the value of Max current during the discharge of the cell which is approximately 14 Ampere and the Minimum Voltage of the cell during the discharge is 3.0 V and Maximum Voltage is 4.2 V (Max Charge Voltage).

Graphs of 4S3P configuration:

The Graphs for SOC, Current and Voltage are given below:

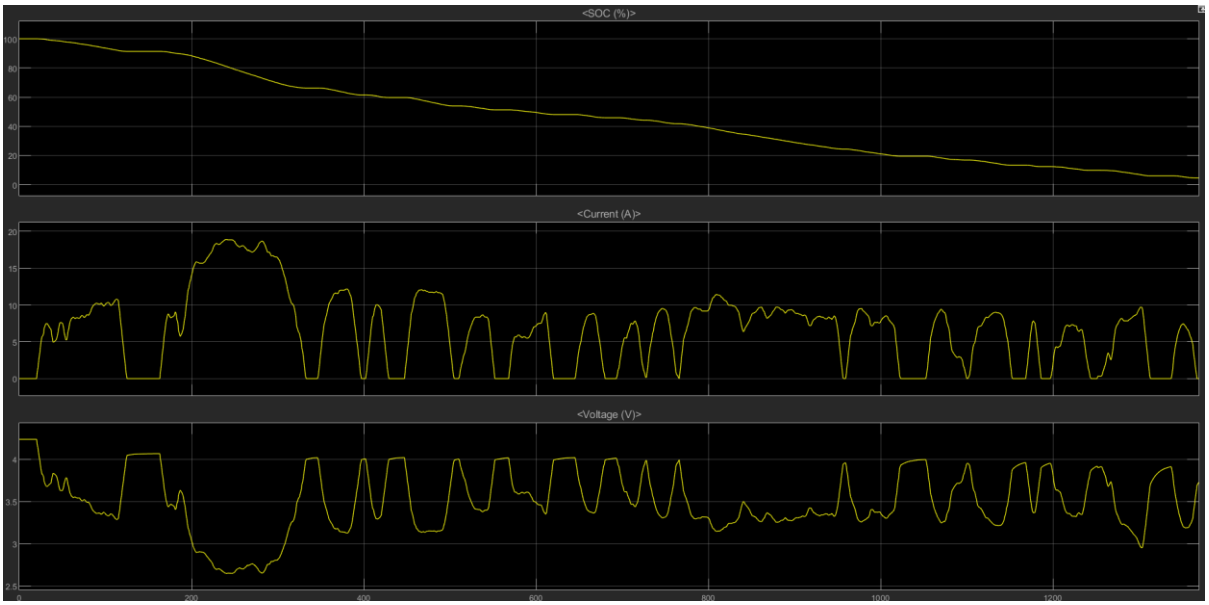

Fig – 5

From the above figure we can say that for Second configuration i.e. 4S3P the SoC remained after the modelling is 4.46% as shown in the Fig-3 and by observing the above figure we can get the value of Max current during the discharge of the cell which is approximately 18 Ampere and the Minimum Voltage of the cell during the discharge is below 3.0 V and Maximum Voltage is 4.2 V (Max Charge Voltage).

After modelling the both configurations in the MATLAB there are few differences in both models which are shown in the table below:

Sl. No	Parameter	3S4P Configuration	4S3P Configuration
1.	State of Charge	28.36%	4.46%
2.	MaxCurrent	14A(Approx.)	18A(Approx.)
3.	Voltage	3.0-4.2V	2.6-4.2V

Fig – 6

CHAPTER 6

OBSERVATIONS & CONCLISION

Since we have modelled a battery pack of configuration 3S4P and 4S3P with given li-ion cell data and Drive cycle data and simulated those models in Simulink and get the results which we discussed above.

By observing the above results, we can conclude that the SOC of the 3S4P battery is more than the SOC of 4S3P battery due to the reason of more current in 4S3P battery which increases the C-Rate of the battery. We can also see that the voltage has dropped below 3.0 V i.e. Cut-off voltage in the 4S3P battery whereas the voltage is in limit in the 3S4P battery. By completing this project, I have gained practical experience in battery modelling, simulation, and analysis using MATLAB.

References

Burzyński, D. and Kasprzyk, L., 2017. Modelling and simulation of lead-acid battery pack powering electric vehicle. In *E3S Web of Conferences* (Vol. 14, p. 01041). EDP Sciences.

https://www.youtube.com/watch?v=d7L_gv344lc

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