iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: VII Month of publication: July 2020

DOI: https://doi.org/10.22214/ijraset.2020.30696

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue VII July 2020- Available at www.ijraset.com

Modeling of Lithium Ion Battery using OpenModelica

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Abstract: Modeling and simulation have multiple applications in the automotive industry such as the design of systems or the re-design of existing systems. Currently, automakers are turning to modeling and simulation to speed up the design process and achieve more successful approaches. The main objective of this project is to design the virtual electrochemical lithium battery that has similar properties as real batteries. The properties considered are SOC, OCV, Capacity, Temperature dependence of battery.
Keywords: Lithium ion battery, electrochemical cell, SOC, OCV, Capacity, Temperature.

I. INTRODUCTION

The smallest individual electrochemical unit is a cell which delivers a voltage depending on the combination of chemicals and compounds used in making of the cell. Primary cells are single-use cells whereas secondary cells are known as rechargeable cells. The most commonly used batteries in hybrid electric vehicle is lithium ion batteries. As li-ion batteries are able to be recharged hundreds of times and are more stable. It has higher energy density, voltage capacity and lower self-discharge rate which is advantageous over rechargeable batteries. Hence, better power efficiency as a single cell tend to have longer charge retention than other battery.

II. PROPOSED ALGORITHM

An electrochemical cell is a device that can generate electrical energy from the chemical reactions occurring in it, or use the electrical energy supplied to it to facilitate chemical reactions in it. These devices are competent to convert chemical energy into electrical energy, or vice versa.

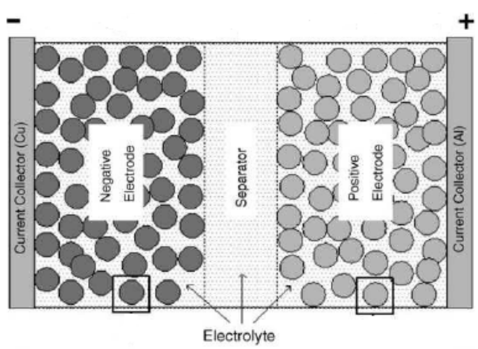


Figure 1. Electrochemical cell

On the basis of such considerations, the Lithium Iron Phosphate ($LiFePO_4$ or LFP) battery model is created based on the electrochemical cell. The model as shown in Figure 2 is created in the modeling perspective window by dragging and dropping of the required components and connecting them accordingly. It contains three solutions anode, cathode and electrolyte.
The redox reaction used for the designed battery is as follows:

$$LiFePO_4 \leftrightarrow FePO_4 + Li^+ + e^-$$
$$Li^+ + e^- + C_6 \leftrightarrow LiC_6$$

Where Anode is C_6 (graphitic carbon), Cathode is $LiFePO_4$, Electrolyte is $LiPF_6$. The substances are defined as record which consists of thermal quantizes such as enthalpy, Gibbs free energy and vacancy electron. After substances are defined it is connected based on the chemical equation and array of stoichiometric coefficients in reaction. These batteries can be connected to any electrical circuit that allows to understand discharging, charging OCV, Capacity and SOC characteristic curves.

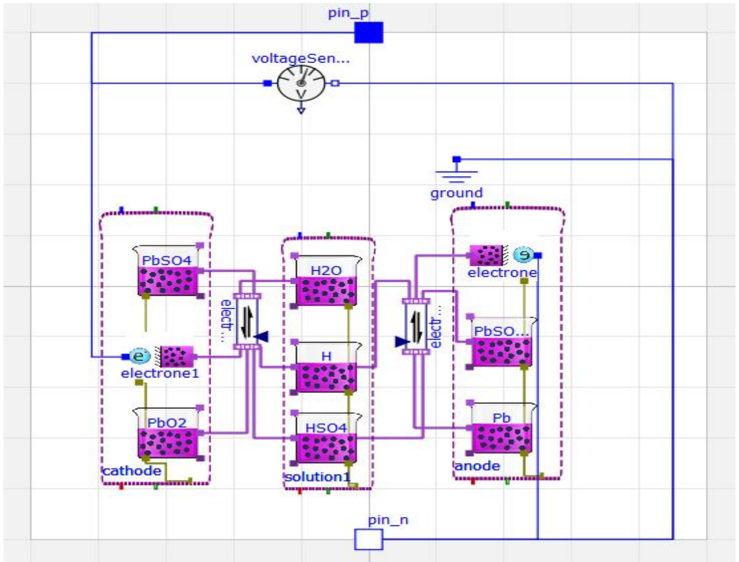


Figure 2. Lithium Iron Phosphate ($LiFePO_4$ or LFP) battery model

Further it is reduced to a component with a positive pin, negative pin and temperature port. The temperature port is connected to the temperature sensor. By making use of this component the temperature dependence of the battery is easily determined.

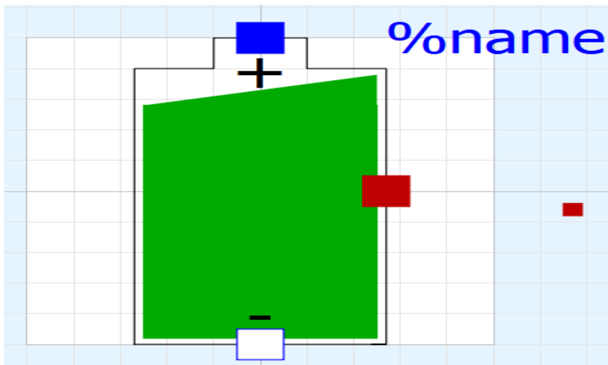
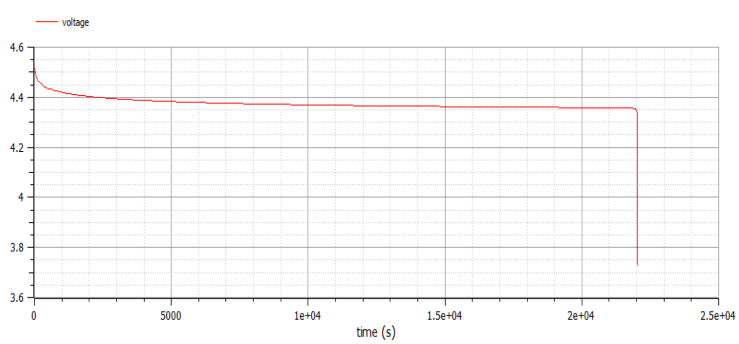


Figure 3. Component

III.EXPERIMENT AND RESULTS

The battery is tested by connecting to an external load or source based on the requirement whether to charge or discharge. OpenModelica 1.14 software platform is used to create and perform the experiment on battery. OpenModelica based on the Modelica modeling language is a free and open source platform widely used in optimizing, simulating, modeling and analyzing complex dynamic systems. A non-profit, non-governmental organization known as Open Source Modelica Consortium develops this software actively.



(a)

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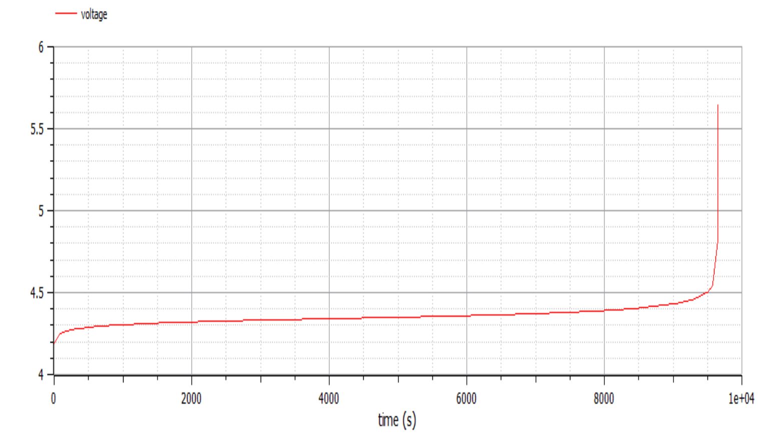
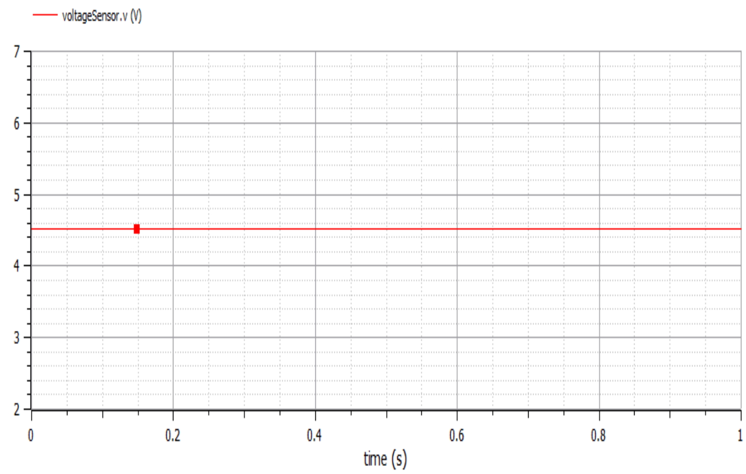


(b)

Figure 4. (a) Discharging the battery with 1 ohm resistor (b) Charging the battery with 10 amps of current source



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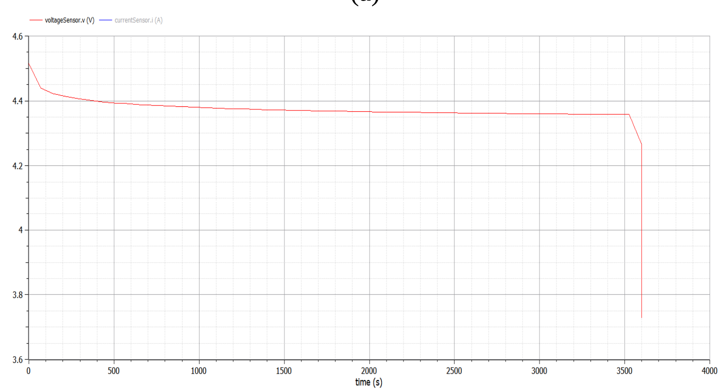
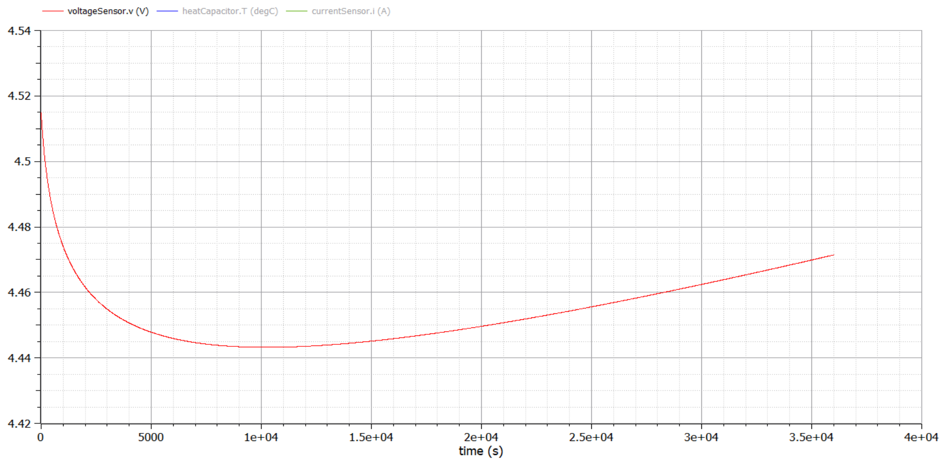


(b)

Figure 5. (a) OCV of 4.5 volts (b) SOC using coloumb counting method with respect to time



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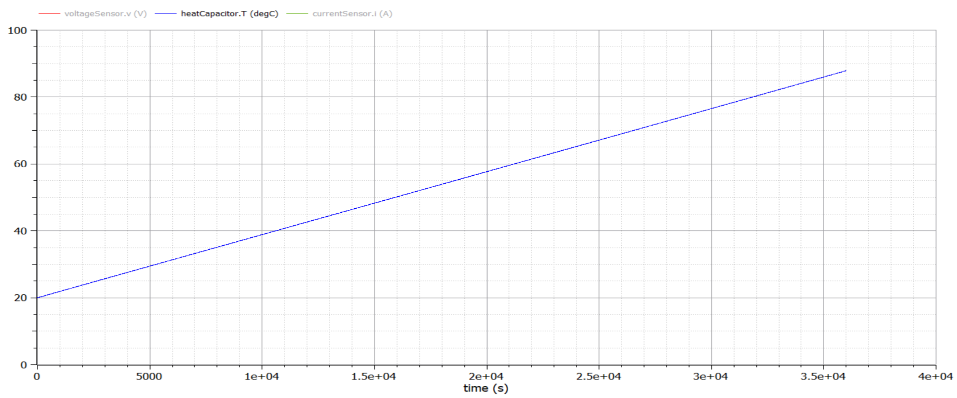

(b)

Figure 6. (a) Voltage raising graph (b) Temperature raising graph

The load of 10 ohm is connected to the battery is discharging, hence the voltage is decreasing to 4.47v from 4.52v. Temperature plays a crucial role in determining the chemical reaction speed, the resistance of the semiconductor, and the band gap. From −20 °C ~ 60 °C, Thermal energy tends to increase the reaction speed of the chemical processes (i.e,discharging) while at the same time also increasing the resistivity in conductors. Above 60 °C, The band gap, on the other hand, declines with increasing thermal energy and thus results in a lower circuit voltage. Generally, the acceptable temperature region for LIBs is −20 °C ~ 60 °C after which the thermal runaway takes place. Therefore, below or equal to 60 °C, voltage keeps decreasing after which it increases but in real life catches fire.

IV. CONCLUSIONS

Modelling and simulation process in OpenModelica tool need a lot of practice and knowledge. The tool allows easier creation of models in small time and also cost efficient. There are several other commercial software’s like COMSOL, MapleSim , etc with additional libraries and extra features. However, with OpenModelica tool one can design the required components and make use of it. The Lithium ion battery model is created by making use of the available components and is simulated. The simulation results shows that the proposed project work aims to create the virtual design of battery considering the parameters of OCV, SOC, capacity, temperature dependence of battery using the electrochemical model of the battery.

V. ACKNOWLEDGMENT

The authors would like to sincerely thank and acknowledge the staff of Department of Electronics and Communication, JSS Science and Technology University, Mysuru and all the fellow students for their timely assistance, guidance and valuable suggestion provided throughout the project.

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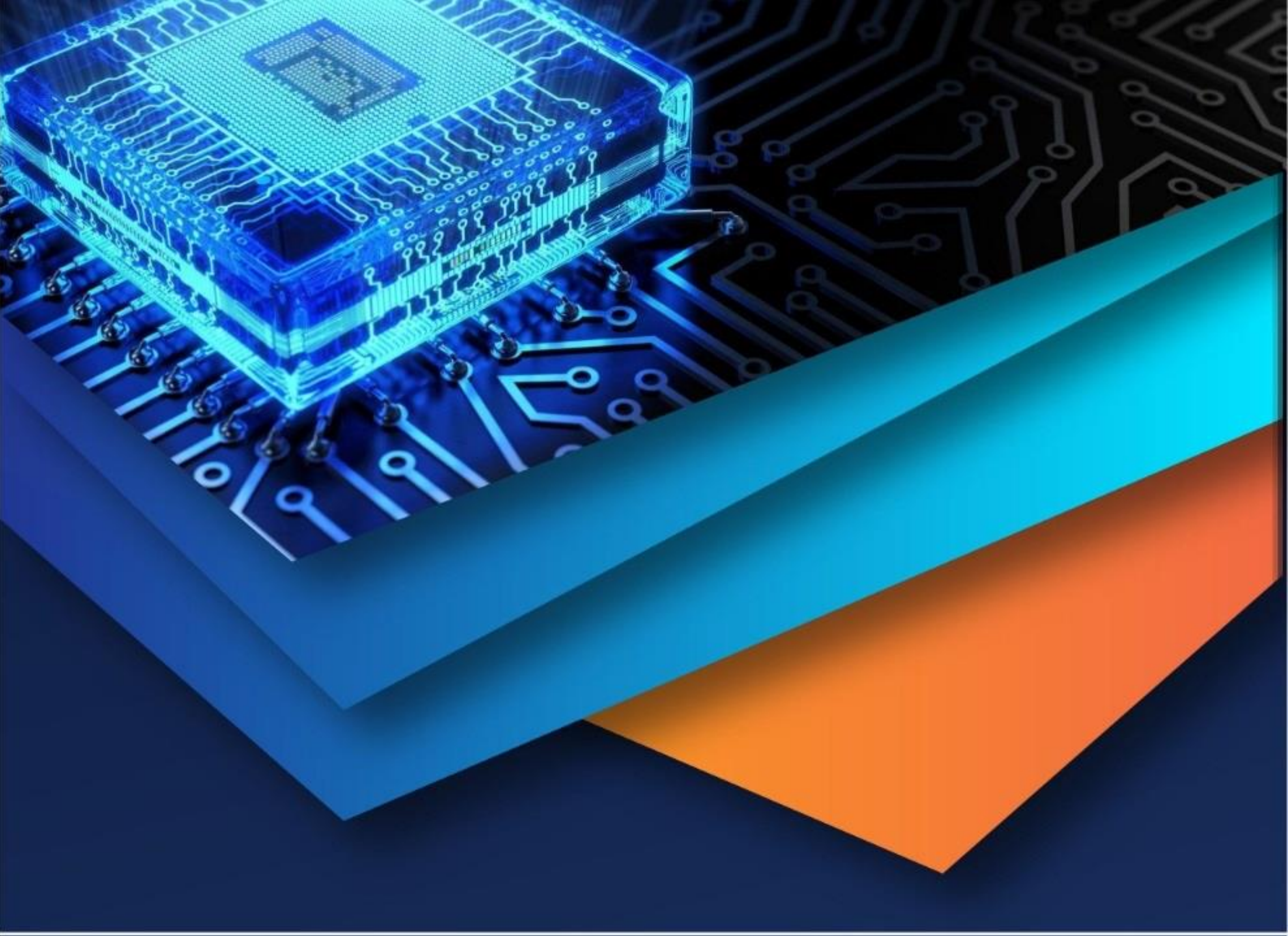

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