Hysteresis Characterization Check of Lithium-Ion Battery Model under Dynamic Simulation Runs

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Abstract

Battery plays a key role in every industry starting from small scale battery application to large scale uninterrupted supply. Modeling and simulation of each sub system before going into real implementation decreases huge testing cost and time. At the same time accuracy of the model also important to consider. Accuracy of the model depends on number of parameters considered for characterization. Among that hysteresis effect of the battery is of great importance. In this paper we have tested the developed model for its dynamic response of hysteresis characterization. This model can be used as a sub system in industrial simulation for cost and time effective testing.

Keywords— *Battery, Lithium, Equivalent model, Hysteresis, BMS, SOC*

I. INTRODUCTION

Recent days the portability increases as the advancement in micro technology in every part of science and engineering. This leads to a development in portable power, batteries are major part this portable power [1]. Battery store chemical energy to give electrical energy. The forcible hold or release of electrons within the proper constructed structure cause for generation of voltage. This voltage depends on the property of the chemical material equilibrium voltage when it is reacted with other chemical material [2].There are different types of batteries are developed based on the size, type and chemistry usage. The recently advanced batteries are belonging to the lithium family these are due to their high energy and power density, high stability [1-3]. Some the chemistries belong to this family are Lithium manganese, Lithium cobalt, lithium manganese cobalt, lithium iron phosphate and lithium titanate [2]. Some of the chemical materials make harm to the user while they react with the normal environment around us.

The main application of the battery started from small industry like mobile phones, power tools, portable printers, scanners etc. to a large industry like industrial control divisions, electric hybrid vehicles, plug in hybrid electric vehicles, telecommunication transmit/receive stations etc [5] designers concentrating on protection circuit as a part of their design besides the main application design Proper characterization of the battery is an important to model the battery as a sub system. The battery can be modeled in electrochemical, mathematical, electrical methods [8-11]. Among all these models electrical models are sufficient accurate and advantageous [12-14]. Here we have developed the accurate battery model based on Chen and Mora [13] and model [14]. [13] Is parent model for all presently developing electrical equivalent of battery which consists most of the parameters that will affect the battery performance. Besides, based on the requirement the protection function can be implemented within the block of the battery. Remaining capacity calculation based on [15-16] considered for our future work.

In this work we are discussing the dynamic characrization of the battery modeled. The dynamic characteristics like hysteresis effect, capacity fade is observed. The capacity fade modeling is same as [14]. In our previous work [15] the hysteresis effect is modeled by analysis of research on hysteresis by many other previous works on batteries. Here we have checked the battery hysteresis characterization by providing the model with random signal. The hysteresis effect is due to the uneven intercalation of the ions in the cathode and anode material [14, 16]. Hysteresis effect conveys the information that what amount of power loosed between charging and discharging. Simply if we ignored the hysteresis then we are expecting the same power from the battery with which it is charged.

This paper is organized as follows. The section II describes the battery model considered. In section III gives the battery parameters modeled. Section IV shows the Simulink model and results. Finally concluded in section V.

II. LITHIUM BATTERY MODEL

The battery model developed here is based on our previous work [15] where the hysteresis effect is modeled by considering the diode, resistance as extra component. Fig (1) and Fig (2) shows the parent battery model and model developed by us respectively in our previous work [15] .

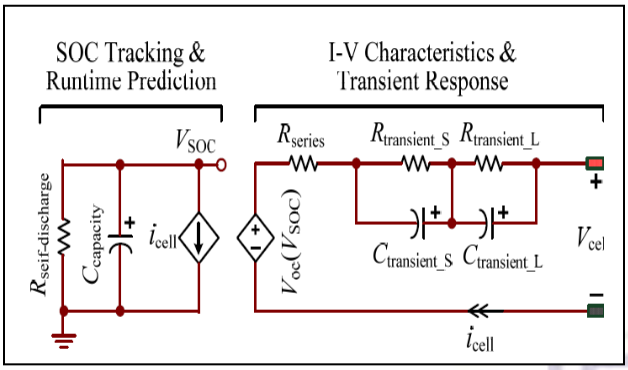


Fig.1 Parent model developed by Chen and Mora [13]

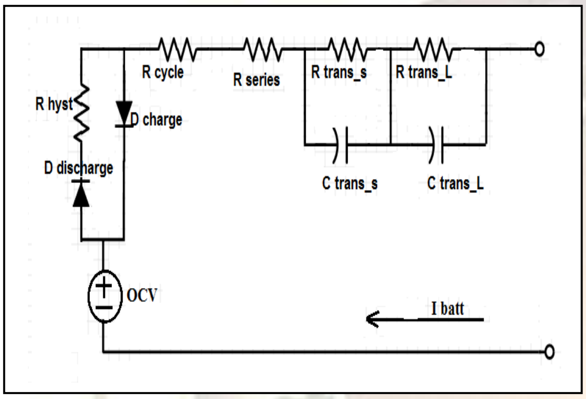


Fig.2 Battery Model from our previous work [15].

The left side (SOC Tracking) part of the parent model is unchanged in our previous work. So we have not provided the information regarding this part. Only the right part (Transient Response) which is different from the parent model is described here.

Here the diodes describes the path for battery charging and discharging and the resistance models the loss of power due to hysteresis, clear explanation of battery model can be understood by[14-15].

III. BATTERY CHARACTERIZATION

The battery hysteresis modeling increase the battery characterization accuracy. The battery hysteresis, temperature effect and other capacity fading is considered from several research work done previously [12-16]. The basic idea behind the hysteresis modeling is done in [15] through analytical analysis of the several lithium family research [12-16].

The cycle fade of the battery is modeled by using Equ (1) considered from [14, 17]

$$R_{cycle} = 1.5 \times 10^{-3} \times \sqrt{number\ of\ cycles} \quad (1)$$

The storage loss of the battery capacity is modeled based on the Arrhenius equation. It will give the relation between the temperature and reaction rate. When the battery is not used depending on the storage temperature the charge will get loss. This is the reason why the battery manufacturers will specify the storage temperature in their data sheet.

The battery terminal voltage is calculated based on the battery open circuit voltage, voltage drop due to its impedance and temperature correction factor [14]. Here in this work we have tried to observe the dynamic behaviour of the battery with hysteresis. The addition of hysteresis characterization to the battery model is advantageous to increase the accuracy as described in [16].

IV. SIMULINK MODEL AND RESULTS

The lithium battery model is developed in Simulink environment based on [14] and [15] is shown in fig (3). Here the complete battery model is masked as a sub system and this can be used as a single block in complete system simulation [15].

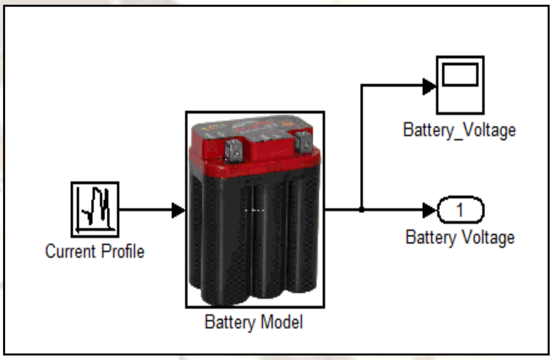
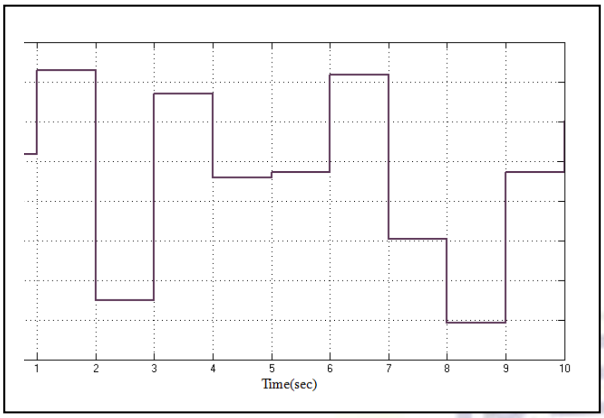


Fig.3 Simulink Battery Model with Mask from [15]

The battery model dynamic performance is tested by providing random current profile as an input. This random current profile is combination of the positive and negative currents describes the discharge and charge current. For analysis purpose we have assumed that the current out from the battery is positive. Other convection can also be considered. The current integration and voltage based methods are internally used for battery modeling.

The fig.4 (a) shows the current profile given to the battery model generated in Simulink environment. Here the current profile generated from the Random number block in Simulink environment. The fig.4 (b) shows the response of the battery model to the current profile. In general not even a single electron is ideal in its performance according to the theory. Battery also will not go into charge and discharge mode instantly as we think it will also have some transient response. This is modeled by RC combination in equivalent model. Number of RC blocks increases the accuracy of model but at the same time increase the complexity also.



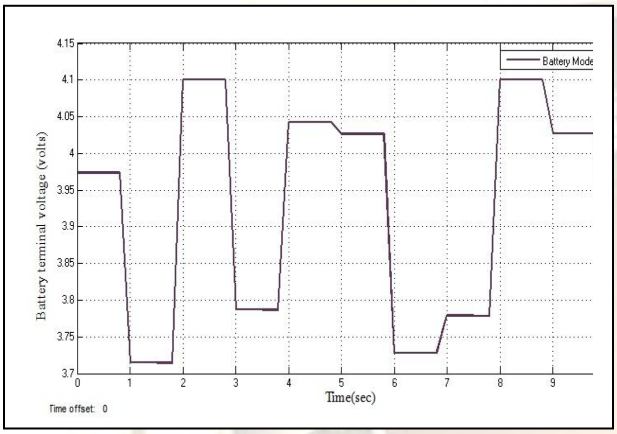


Fig.4 Simulation results (a) Current profile for dynamic response checking (b) battery terminal voltage.

The variation in the response of the battery model for the charge and discharge profile is in fig.4 (b).

As the current profile changing from positive to negative at the end of time 2 sec i.e. the battery changing the state from discharging to charging. In response the battery voltage has been increasing from lower value between 3.7 volts to 3.75 volts to a value higher than the 4.1. But due to the limiting function written in our battery model limits the battery voltage to 4.1Volts i.e. the battery maximum charge voltage for all lithium family batteries except some batteries with 3.7 volts.

In fig.4 (b) we can observe the accurate modeling of the hysteresis effect. Simulation time 1 sec corresponding to discharging and simulation time sec corresponding to charging both are with same current difference. But the voltage difference at first case is 0.25v and in the second case 0.27V indicates model responding with hysteresis characterization. Here the current or voltage difference is value at a particular instant (1sec or 4sec) compared with the previous value. The addition of hysteresis effect to the model is clearly explained in our previous work [15].

This results can be compared with the results obtained from the [13-14] in which the hysteresis effect has been ignored. In the case of simulating dynamic system like hybrid electric vehicles or plug in hybrid electric vehicles the current will not be completely for charging or discharging the battery pack at that case the consideration of hysteresis increase the accuracy of the complete model. This is more effective in the case of vehicles with regenerative braking.

This model can be used for any other chemistry by simply replacing the characteristic equations corresponding to that chemistry or to other type of battery. This accurate dynamic model makes it advantageous in simulation. Further analysis of the temperature, capacity fades and characterizing through experimental data instead of analytical data makes the battery model to represent a particular battery instead to a whole family.

V. Conclusion

The battery is important for each and every device in which portable or uninterrupted supply is required. Modelling and usage of the battery accurately decreases the huge test and development cost of industrial applications. The dynamic performance of the battery model is important in large dynamic system performance checking. Dynamic response of the battery with added hysteresis model is observed and it is compared with previous results to prove its accuracy. This battery can be used as a single block makes it ease of operation in many simulation runs.

Acknowledgment

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