An Investigation for Meaningful Model of a Lithium-Ion Cell to Take into Account Electrochemical Behavior, Thermal Behavior and Degradation Using MapleSim

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ABSTRACT

This paper investigates to identify an optimal for analysis of battery behavior in system−level applications such as Battery Energy Storage Systems in Smart Grid infrastructures and Electrical vehicles. At system level applications, it is mandatory to check model for meaningful equivalency and practical ability for extension from unit cell to Battery stack. The investigation of current battery models in relation to their suitability for study and analysis of system level applications of battery helpful for identification of optimal model and it also provides an intuition and direction to develop the most suitable model, if such models are not available already

1. Introduction

Among various models available so far, some of them are not optimized even for characterization of battery, then how these models cannot be used in system level applications [1−2]. Some of the battery models which give a meaningful insight requires a number of mathematical equations to simulate a single cell. It seems impractical to use such models for system−level applications where hundreds of unit cells are configured in different ways [3]. A mathematical model developed by using MapleSim for Energy storage applications [4] have meaningful equivalency and available in iconic form (Figure 1) for ease of interconnection to develop packs and stacks. Similarly, the model developed in [5] used a Triple species element concept and developed a significant equivalent network model and validated against the realistic automotive drive cycle loads. The models in [4] and [5] will be elaborated further in coming sections.

2. Analysis of selected models

2.1 Maple−based Model

As a representative example, the iconic model was used to simulate the impact of different types of convection on temperature of the unit cell as shown in Figure 2. Based on this model, a battery pack was developed (Figure 4) to study the impact of "Temperature difference" (Figure 3) and "Temperature exchange" (Figure 4) between unit cells in a pack on the current distribution through the cell strings.

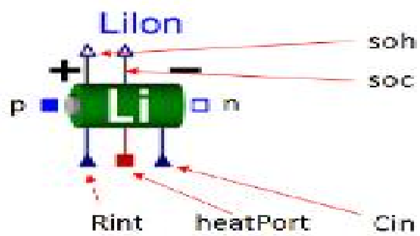

Figure 1 Iconic Model

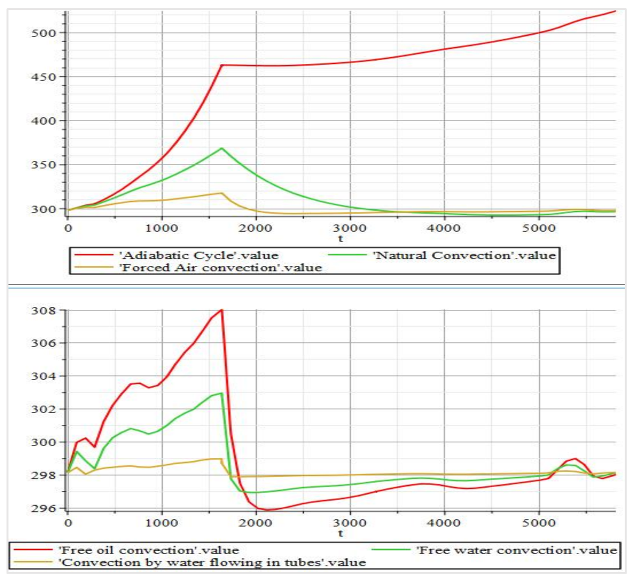

Figure 2 Study of different types of convection on unit cell temperature

Figure 3 Variation in currents due to imbalance in cell voltages

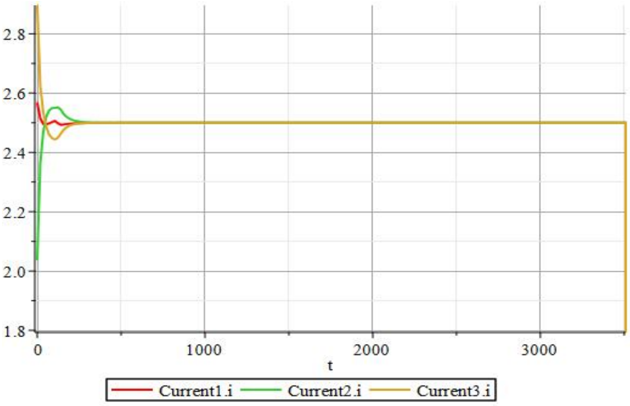

Figure 4 Balancing in current distribution through series strings

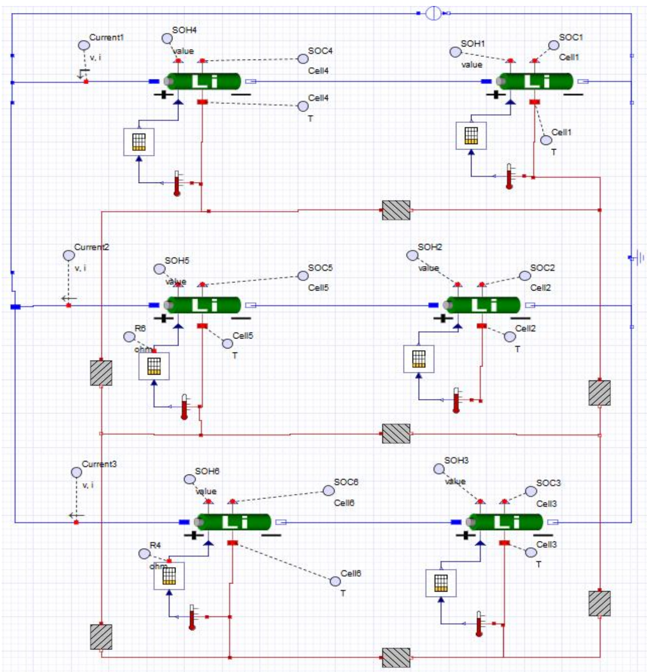

Figure 5 Battery Pack

2.1.1 Triple Species Element Model

Triple species element (TSE) model treats the intercalated Lithium, Li-ion and electrons as three species The activities of the electrons were modelled by simple resistors. In case of ions, by using analogy the chemical potential was converted into chemical capacitance and then chemical capacitance was converted into electrical capacitance by 1/nf conversion factor. The intercalated lithium was modelled in chemical domain by chemical capacitance.

The equivalent network shown in Figure 6 below.

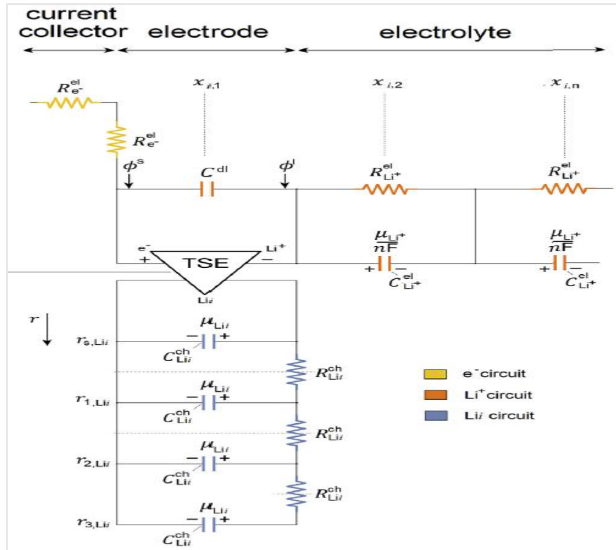

Figure 2 Triple species element model

3. Conclusion

It can be inferred that the equivalency of the TSE model is more precise that the maple-based model, but the iconic model by maple facilitates the study of battery stack and battery pack for system level applications. The overall analysis gives a direction for further research. The TSE model should be incorporated into maple, so that both precise equivalency and ease for modelling battery stack and pack can be achieved.

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