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Lithium-ion Batteries – Extended Analysis of Parameter Change and Development of a New Battery Model

N. Omar[1], Y. Firouz[1], M. Abdel Monem[1], A. Samba[1,2], J. Smekens[1], H. Gualous[2], P. Van den Bossche[1], J. Van Mierlo[1]

[1]Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium

[2]LUSAC, université de Caen Basse Normandie Rue Louis Aragon - BP 78 50130 Cherbourg-Octeville, France

As the global economy begins to strain under the pressure of rising petroleum prices and environmental concerns, research have spurred into the development of various types of clean energy transportation systems such as Hybrid Electric Vehicles (HEVs), Battery Electric Vehicles (BEVs) and Plug-In Hybrid Electric Vehicles (PHEVs). Especially PHEVs acquire the most attention due to the combination of an electrical source and a conventional engine. This type of vehicle provides the user a considerable pure electrical range and also an extended range, which can be performed by a conventional Internal Combustion Engine (ICE). The establishment of a Rechargeable Energy Storage System (RESS) that can support the output power during acceleration, efficiently use the regenerative energy and perform for a considerable cycle life are the critical aspects to be met by battery technologies [1-3].

In the field of battery electric vehicles and hybrid electric vehicles, accurate models can be considered of high importance. In this area quite significant research work has been executed [4,5]. However, the performed works were mostly related to some specific battery chemistries and the developed models were only suitable in narrow operating conditions.

This paper represents the assessment of the changing parameters of 3 lithium-ion battery types (nickel manganese cobalt oxide 40Ah, lithium iron phosphate 14Ah and lithium titanate oxide 15Ah) at different operating conditions (temperature, state of charge, current rates, pulse width and cycle life). Based on the proposed analysis, the main varying parameters based on a advanced second order FreedomCar battery model have been mapped out and further related to the state of health. Then, the study has been extended to the impedance spectroscopy measurements, whereby a general battery model has been derived. The proposed model has been integrated into the advanced second order FreedomCar model for evaluation of the battery behaviour in wide operating conditions.

In order to estimate the battery model parameters as accurate as possible, the Levenberg-Marquardt estimation tool has been enhanced and used.

From the performed analysis, we can observe that the increase of the ohmic resistance is significant compared to the polarization resistance as demonstrated in figures 1 and 2. This evolution has been recognized for the three investigated lithium-ion battery chemistries.

Moreover, this evolution has been figured out during cycle life, which indicates that the SoH prediction can be related to the increase of ohmic resistance and capacity fade.

However, the battery model parameters indicate that the increase of the internal resistance is more significant compared to the capacity fade.

Finally, in the framework of this study a number of thermal characterization tests have been carried out at the mentioned operating conditions for evaluation of the thermal parameters such as thermal resistance, thermal convection and thermal capacitance. The obtained parameters have been used for development of a thermal model and integrated in the electrical model for having an accurate prediction of the battery behaviour.

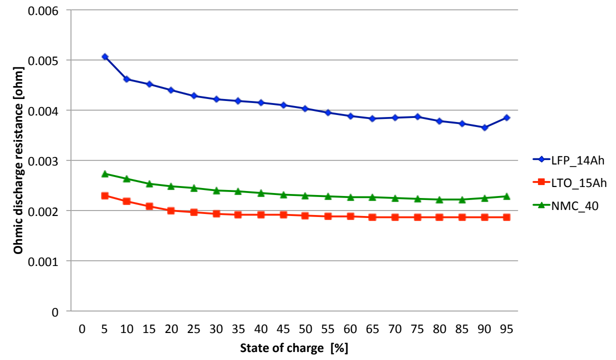

Fig. 1. Evolution of ohmic discharge resistance for the investigated lithium-ion batteries based on second order FreedomCar battery model at 25°C & 10s pulse

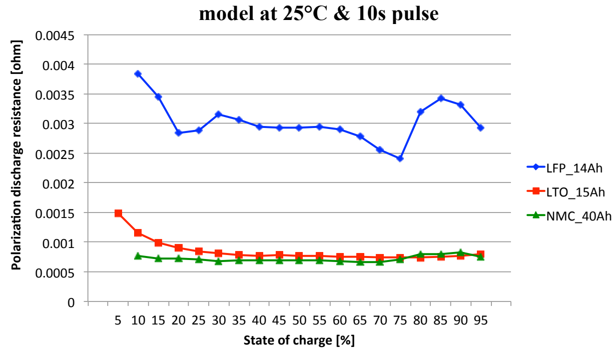

Fig. 2. Evolution of polarization discharge resistance for the investigated lithium-ion batteries based on second order FreedomCar battery model at 25°C & 10s pulse

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