Abstract #1222, 224th ECS Meeting, © 2013 The Electrochemical Society

# Modeling and characterization of different types of lithium-ion batteries under various conditions

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**Abstract**

Growing demand for energy storage systems in the wide range of applications such as electric hybrid vehicles, smart grids and various electronic and communication devices, as a backup or main source, persuade us to investigate and develop an accurate and comprehensive model for batteries, which covers all aspects and characteristics of that [1-3]. Similar to the other chemical systems, batteries have totally nonlinear characteristics and sometimes unpredictable. Therefore in order to have a precise model, different tests (like Hybrid Pulse Power Characterization (HPPC), Dynamic Discharge Performance (DDP) Open Circuit Voltage (OCV) and capacity test) under different conditions such as various temperatures, current levels and level of SoC should be performed. Then based on the statistical methods and using test results, an accurate model for the battery is presented [4, 5]. For having more reliable model, more tests with higher number of charge and discharge cycles are needed.

In this paper 5 different types of cells, NMC 4Ah & 11Ah LTO 10Ah, 13Ah and 60Ah are investigated and modeled. In case of parameter identification, HPPC test at different current levels, state of charge and operating tmperature have been performed and evaluation of estimated parameters is analyzed. Furthermore, HPPC test determines the battery charge and discharge current limitations, which these data are essential for designing an optimized battery management system. Using data extracted from DDP test, the Wh and Ah efficiency and also energy density of battery can be calculated. Capacity test specifies the Peukert constant and evaluates the discharge rate capability.

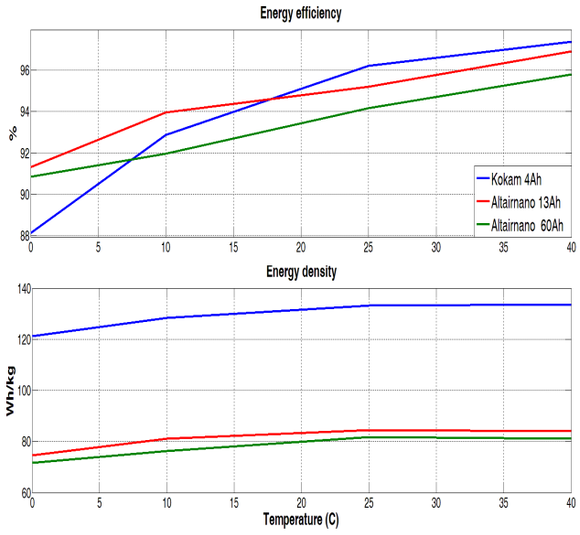


**Fig. 1. Calculated energy efficiency and density related to the NMC 4Ah, LTO 13 and 60 Ah cell at different temperature.**

For instance energy density and Wh efficiency extracted from DDP test related to the NMC 4Ah, LTO 13 and 60 Ah are indicated in figure 1. The test is done at 0°C, 10°C, 25°C and 40°C. These figures demonstrate that how the temperature variation can affect battery efficiency, which has to be taken into account in battery modeling and characterization.

Figure 2 shows evaluation of NMC 4Ah terminal voltage in function of discharge capacity at different temperatures, which are extracted from capacity tests. Those data are useful for state of charge estimation in function of operating temperature.

According to the intended application and using data gathered from all the tests that have been mentioned above and other tests that will be performed, a comprehensive dedicated model of battery will be developed that will cover all static and dynamic behaviors of battery.

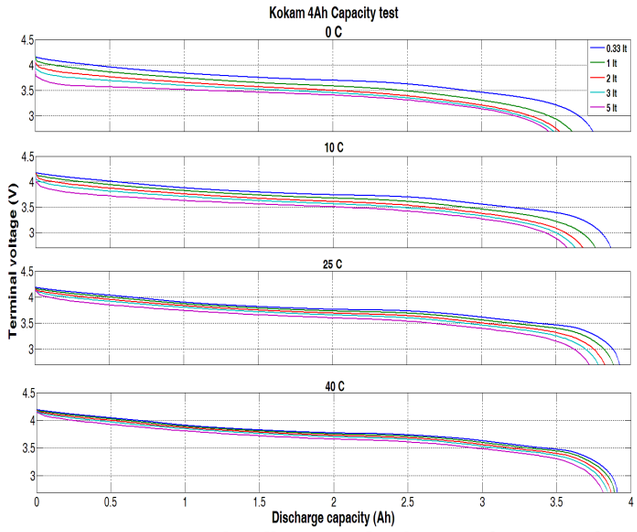


**Fig. 2. NMC 4Ah cell terminal voltage in function of discharge capacity at different temperatures**

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