Application of the PNGV Lumped Parameter Battery Model

Jeffrey R. Belt, Senior Engineer
Idaho National Engineering and Environmental Laboratory
PO Box 1625, Idaho Falls, ID 83415-3830
Phone: 208-526-3813
Fax: 208-529-0969
Email: beltjr@inel.gov

Chester G. Motloch, Jon Christophersen, Chinh D. Ho
Idaho National Engineering & Environmental Laboratory
Ira Bloom, Vince Battaglia, Argonne National Laboratory
Raymond A. Sutula, U.S. Department of Energy
Ted Miller, Ford Motor Company

The U.S. Department of Energy (DOE) initiated the Advanced Technology Development (ATD) Program in 1998 to address barriers that limit the commercialization of high-power lithium-ion batteries in hybrid electric vehicle applications. As part of the ATD program, standardized calendar- and cycle-life tests age 18650-size cells at Idaho National Engineering and Envirionmental Laboratory and Argonne National Laboratory. Every four weeks, hybrid pulse power characterization tests (HPPC) quantify capacity and power fade rates of these cells.

The PNGV Lumped Parameter Battery Model correlates battery data to a simplified electrical circuit. The model estimates parameters that are difficult or impossible to determine from available test data. The estimated parameters include open circuit battery voltage, internal ohmic resistance, internal polarization resistance, polarization time constant and capacitance. The Lumped Parameter Model predicts ATD Gen 2 HPPC resistances extremely well.

An HPPC pulse consists of a discharge pulse (Rdis) and a regen pulse (Rreg), from which resistances can be directly calculated. The Lumped Parameter Model estimates the overall ohmic (Ro) and polarization (Rp) resistances for an HPPC pulse without differentiating between discharge and regen pulses. The sum of Ro and Rp is essentially equal to the average of Rdis and Rreg for ATD cells aged at 45°C at 60% SOC at INEEL. See Figure 1.

Equally important is the time dependence of the ohmic and polarization resistances estimated by the Lumped Parameter Model. Fig. 2 shows the percent change in Ro and Rp versus time. Figure 3 shows the linear fit for the Rp data and a square-root of time fit for the Ro data for the same cell. Figs. 2 and 3 are typical for cells tested at 45°C at INEEL. The time dependence of the ohmic resistance is linear with the square root of time, which is consistent with diffusion mechanisms. The polarization resistance shows a simple linear time dependence.

The results of the Lumped Parameter Model agree with the results from an independent HPPC test analysis. Moreover, Rp increases linearly with time and Ro increases with the square root of time.

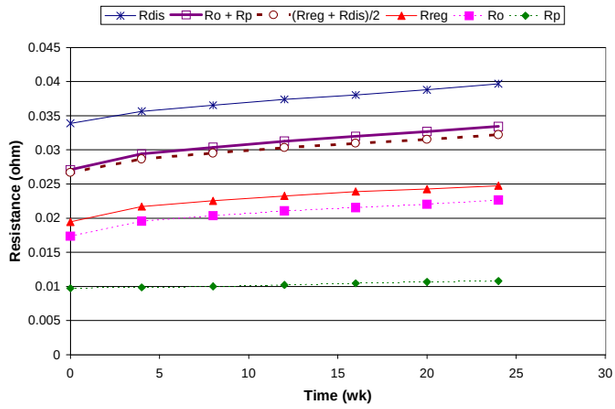

Fig. 1: Comparison of Lumped Parameter Model Ro and Rp with HPPC Rdis and Rreg for an ATD Gen 2 Cell at 45°C and 60% SOC.

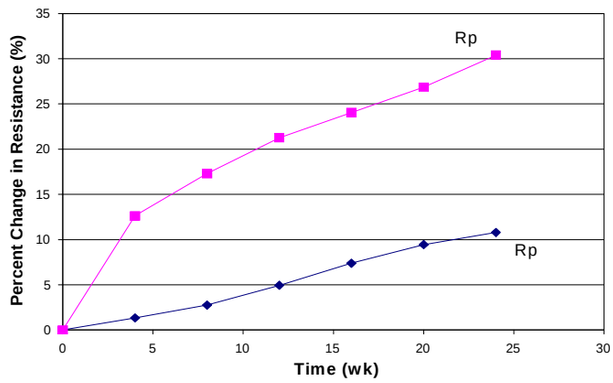

Fig. 2: Percent change in Ro and Rp as a function of time for an ATD Gen 2 cell at 45°C

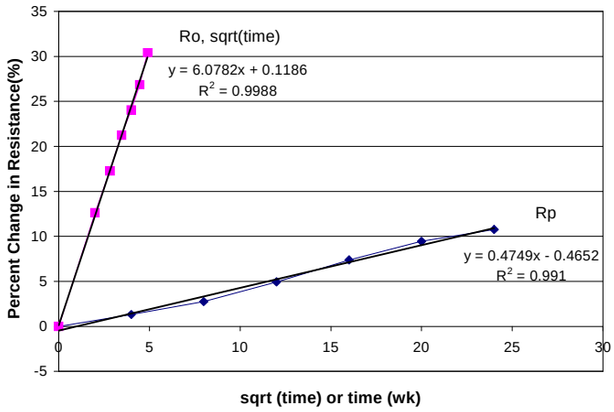

Fig 3: Time dependencies of Ro and Rp for an ATD Gen 2 cell at 45°C

References

1. PNGV Battery Test Manual, Revision 3, DOE/ID-10597, February 2001