Tutorial 2: Battery Physics-Based Modeling and their Applications

Christopher R. Lashway received his B.S. in electrical engineering technology at the University of Central Florida, Orlando in 2008 and M.Eng. degree in electrical engineering at Pennsylvania State University – Harrisburg in 2010. He moved on to work as an engineer for the Naval Surface Warfare Center in Dahlgren, Virginia on a wide range of Marine Corps and Naval projects focusing on mobile power and energy solutions. From 2010 to 2012, he supported the Squad Electric Power program, an effort focused on consolidating proprietary non-rechargable batteries found in tactical radios and night vision equipment through developing a central power manager with a lithium ion battery pack. During this period, he detailed at the Naval Research Laboratory as an electrical integration lead to combine wearable space-grade solar panels with the power manager to charge on-the-go. He then went on to support the Modular Tactical Vehicle Refresh (MTVR), a Marine Corps Systems Command effort which focused on hybridizing standard cargo trucks through the integration of a lead acid battery bank and an auxilary generator. He is a currently a PhD candidate at the Energy Systems Research Laboratory at Florida International University in Miami, FL where his research is focused on hybrid energy storage modeling through finite element analysis and improving multi-chemistry battery management systems.

Abstract—The lead acid and lithium ion battery have become staples to power many aspects of our lives. The lead acid battery remains a dependable resource to provide steady, reliable power for both vehicles and the grid, alike. Unfortunately, their deployment in electric vehicles (EV) have been limited as a result of long charging periods and particularly, a limited state of health (SoH) sensitive to high discharge currents and deep depth of discharge. The lithium ion battery has emerged as a proven alternative for applications synonymous with high charge and discharge currents. Accurate modeling and simulation of batteries remain a challenge and can present the designer with a number of options from a traditional 1st order Randles equivalent circuit model, up to a physics-based model based on finite element analysis. In this tutorial, multiphysics models for the lead acid and lithium ion batteries will be derived and the fundamentals will be discussed and compared to common electrochemical equivalent circuits. Their operational performance and some applications will be discussed. An extension will then be made to enhance the physics-based models to account for the degradation processes which impact SoH. A discussion over battery SoH mechanisms and the usage of impedance spectroscopy to obtain the equivalent circuit in industial systems will be connected to the multiphysics domain showing how information from these processes can be reflected within the physics-based model.