Optimal Charging Profile for Mechanically Constrained Lithium-Ion Batteries

BharatKumar Suthar,[*, a] Venkatasailanathan Ramadesigan,[*, b] Sumitava De[*, a], Richard D. Braatz[c] and Venkat R. Subramanian[**, z,a]

[a]Department of Energy, Environmental and Chemical Engineering, Washington University, Saint Louis, MO 63130 USA

[b]Department of Energy Science and Engineering, Indian Institute of Technology Bombay, Mumbai 400076, India

[c]Massachusetts Institute of Technology, Room 66-370, Cambridge, MA 02139

This presentation considers the problem of obtaining the optimal current profile for charging a lithium-ion battery. Faster computing and advancement in nonlinear programming algorithms has made it possible to use transport and electrochemical engineering-based nonlinear models (1) to derive optimal charging profile in real time.

Conventional charging profiles for lithium-ion batteries (e.g., constant current followed by constant voltage) are not derived by keeping capacity fade mechanisms in mind. These charging profiles are not only inefficient in terms of lifetime usage of the batteries but also slower (2) since they do not exploit the changing dynamics of the system. Previous efforts are made in getting optimal charging profiles with different objective functions (2, 3) but none of them include stress based constraints. The progress made in understanding the capacity fade mechanics (4-7) has paved the way to including that knowledge in deriving optimal controls. This work explores the possibilities of using transport and electrochemical-based models in deriving open-loop optimal charging profiles that minimize capacity fade (i.e., restrict the development of normal and tangential stresses in the solid phase, voltage increase, and other capacity fade mechanisms) with a restricted supply of charging current. Different capacity fade mechanisms are implemented to derive the open-loop optimal control.

[*] Electrochemical Society Student Member
[**] Electrochemical Society Active Member
[z] vsubramanian@seas.wustl.edu

Acknowledgements

The work presented herein was funded in part by the Advanced Research Projects Agency – Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR0000275.

References

1. S. Santhanagopalan, Q. Guo, P. Ramadass and R. E. White, Journal of Power Sources, **156**, 620 (2006).
2. R. Klein, N. A. Chaturvedi, J. Christensen, J. Ahmed, R. Findeisen and A. Kojic, Optimal charging strategies in lithium-ion battery, in Proceedings of the American Control Conference, p. 382 (2011).
3. R. N. Methekar, V. Ramadesigan, R. D. Braatz and V. R. Subramanian, ECS Trans, **25**, 139 (2010).
4. J. Christensen and J. Newman, J Solid State Electr, **10**, 293 (2006).
5. S. K. Rahimian, S. C. Rayman and R. E. White, J. Electrochem. Soc., **157**, A1302 (2010).
6. P. Arora, R. E. White and M. Doyle, J. Electrochem. Soc., **145**, 3647 (1998).
7. R. Deshpande, M. Verbrugge, Y.-T. Cheng, J. Wang and P. Liu, J. Electrochem. Soc., **159**, A1730 (2012).