Docket #: S19-055

Real-time Lithium-ion battery health monitoring system

Stanford researchers have developed a new method to more accurately monitor battery State of Charge (SOC) and State of Health (SOH), over its entire lifetime. The knowledge of critical internal variables, such as SOC and SOH, are required by the Battery Management System (BMS) to ensure longevity, safety, and reliable operation of lithium-ion batteries. However, these variables cannot be measured directly via sensors.

This invention is an electrochemical model-based adaptive interconnected observer for combined estimation of lithium concentration in both electrodes, cell capacity, and aging-sensitive model parameters in real-time. Insight into these non-measurable quantities can help in utilizing the battery wisely within its safe operational limits without causing accelerated degradation or affecting its performance, and at the same time extend the warranty window used today by automakers. Effectively, this work aims to provide accurate SOC and SOH estimates of batteries used primarily in the transportation sector, but it can be extended to stationary storage applications, and more importantly to determine the feasibility of using aged lithium-ion cells in "second life" applications.

Figure

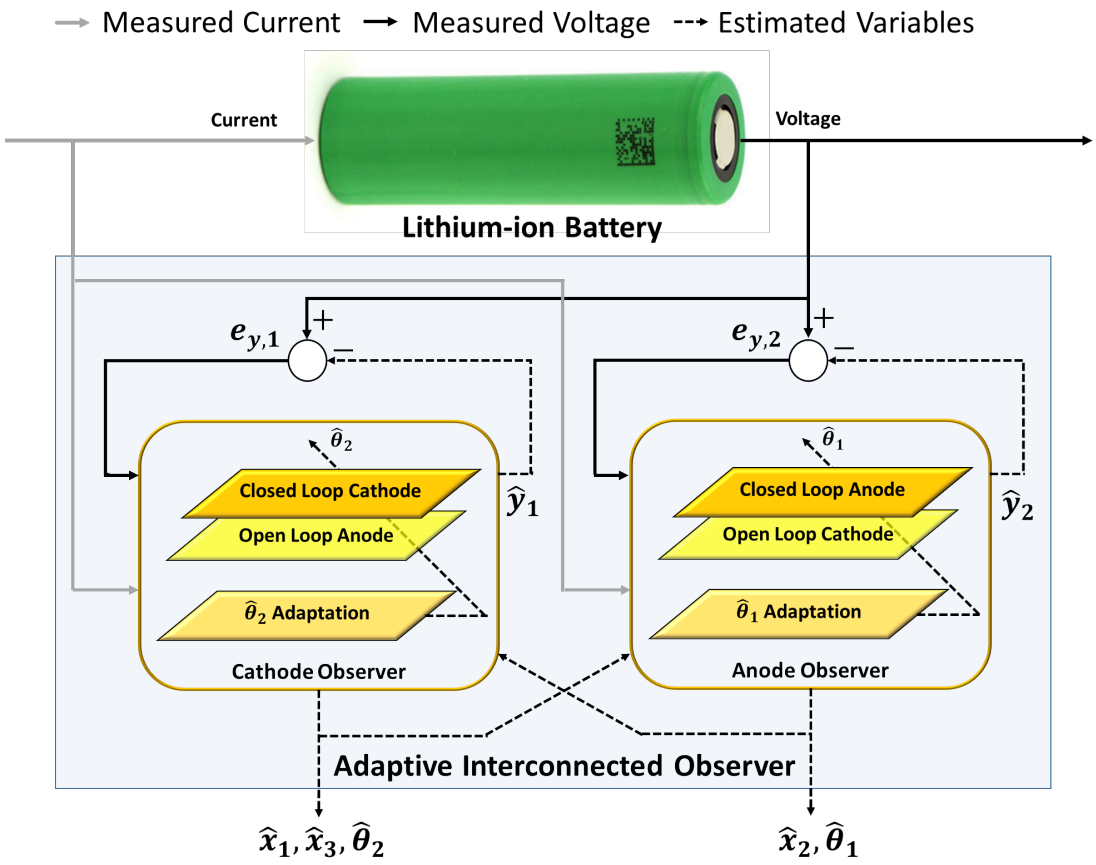


Figure description - The adaptive interconnected observer structure consists of a cathode observer and an anode observer that update each other via a bidirectional interconnection for the combined estimation of lithium concentration in cathode *(x^1)* and anode *(x^2)*, the total cell capacity *(x^3)*, and aging-sensitive parameters like the anode diffusion coefficient *(?1)* and the SEI layer ionic conductivity *(?2)*.

Stage of Development

- Demonstrated results for one type of battery
- Plans to calibrate model for other batteries
- Future work will account for other degradation mechanisms in the battery model

Applications

- **Li-ion Battery Management Systems (BMS)**
- End user applications include any electrochemical energy storage system composed of lithium-ion cells, such as in the transportation sector (**Battery**

Electric Vehicles, Hybrid Electric Vehicles), smart grids, and consumer electronics (laptop, phones, etc.)

Advantages

- **Real-time data**
- More accurate:
  - Electrochemical-model based adaptive observer
  - Two different observers for each electrode and interconnect to converge data
  - Sliding mode interconnected observer structure
  - Aging-sensitive parameters and the cell capacity
  - Incorporates aging-sensitive parameters such as anode diffusion coefficient and ionic conductivity in the SEI layer in real-time
- **Monitors over entire lifetime of battery allowing manufacturer warrantees**
- Can be used to improve current battery health estimators

Publications

- A. Allam and S. Onori, "Online Capacity Estimation for Lithium-Ion Battery Cells via an Electrochemical Model-Based Adaptive Interconnected Observer," in IEEE Transactions on Control Systems Technology
- Allam, Anirudh, and Simona Onori. "An interconnected observer for concurrent estimation of bulk and surface concentration in the cathode and anode of a lithium-ion battery" *IEEE Transactions on Industrial Electronics* 65.9 (2018): 7311-7321.

Patents

- Published Application: 20220163589
- Issued: 11,988,716 (USA)

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