Title:

Development of Data-Driven methods for Capacity Estimation and Prognosis for Lithium-Ion Batteries

Abstract:

Capacity, which quantifies the available energy in a fully charged Li-ion battery, is the leading and an important index which can be used in interfering the State-of-Health or the remaining useful life. Today Li-ion batteries are a standard energy storage solution for a variety of applications such as satellites, automobiles and smart grid applications etc. due to their high energy density, lightness of weight and long lifetime as compared to contemporary solutions such as lead-acid, nickel-cadmium and nickel-metal-hydride cells. Due to importance on the batteries for such application, failure of a battery could lead a loss of operation, reduced capability, downtime, and even catastrophic failure. This Data-Driven approach presents a way to estimate Lithium-ion battery's Capacity which represents the specific energy in Ampere-Hour. This work explores the Data-Driven method that can be used in estimating the current capacity and forecasting the capacity trend for the future charge cycles of the battery whose internal health parameters are difficult to gauge. The features used to develop Data-Driven Capacity Degradation model are obtained from Voltage Measurements observed during the charging phase of the battery which is operated in constant current-constant voltage charging protocol. With the developed Model, Capacity Degradation can be estimated in respect with cyclic ageing of the battery. Gradient Boosting Regression Tree (GBRT) integrated with Auto-Regression Integrated Moving Average (ARIMA) is used for Capacity Estimation and Prognosis. Features obtained are used to train GBRTs models with target value as the true capacity obtained using Coulomb Counting from Consecutive Discharge Cycle, and for prognosis ARIMA models are developed to forecasts the features for future unobserved cycles using observed features and used as an input feature in another GBRT model to provide the predicted capacity for the unobserved cycles with the confidence interval. In actual operation, batteries are seldom fully charged/discharge, therefore during online capacity estimation, not all the features will be available if the full range of Voltage Measurements obtained during charging cycle were used to develop a data-driven model. To solve the issue of data unavailability during partial charge/discharge, the presented method does not require the full range of voltage measurements for prediction instead uses two sets of measurements belonging to different voltage ranges and since the features are obtained during charging of the battery, it does not affect the normal working on the battery. In addition to this, the proposed method also presents a method for missing value imputation in case one of the voltage feature set is not observed using one-step forecasting via the ARIMA model. The result presented using lithium-ion battery data provided by NASA and CALCE experiments demonstrates the effectiveness and accuracy of the proposed battery capacity estimation and prognosis framework.