CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

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Project Number

S0809

Project Title

A Novel Model to Optimize the Efficient Use of Lithium-Ion Batteries in Renewable Energy Storage Systems

Abstract

Objectives

Lithium-ion batteries are a central component of all renewable technology today, including hybrid/electric vehicles and grid energy storage systems. However, these expensive batteries are used inefficiently and replaced too soon as there exists no accurate way to measure their remaining capacity outside a laboratory setting. The objective of this project was to develop a practical method to estimate the remaining useful life of a lithium-ion battery by building a novel, prognostic model that predicts capacity loss with high accuracy. Such an algorithm could report in real-time how efficiently a battery is being used and extend battery life by years.

Methods

Initial analysis of capacity loss versus multiple battery cell operating conditions was done using published data from lithium-ion batteries studied under different experimental conditions in a laboratory setting where capacity is easily measured. MathWorks' MATLAB software was used for data processing and analysis to build the model. The model was validated on a second generated data set. In parallel, a neural network was trained to predict capacity.

Results

The stochastic prognostic model was able to predict capacity loss and therefore remaining useful battery life with high accuracy (average error <1.5%) using only readily measured battery characteristics. In addition, a cubic relationship between capacity and resistance was found. This is the first time a correlation between these two variables has been reported. It was also found that a battery cell s ratio also significantly affected the rate of capacity loss. Trends between the error of the model and various battery operating characteristics were established, allowing capacity to be predicted stochastically within a narrow confidence interval. Based on these findings, the remaining useful life of a battery can now be stochastically represented by a third-degree polynomial function of resistance for differing cell ratio. The neural network predicted capacity within 0.5% but is not stochastic.

Conclusions

This is the first time a prognostic model that stochastically predicts the capacity loss of a lithium-ion battery has been created. This can be used to maximize a battery s efficiency and extend its life by several years, as well as increase driver safety and grid reliability through accurate estimation of remaining useful battery life. Since the model can incorporate multiple inputs (such intensity and frequency of use) it is also able to provide an output tailored to each individual user. This model has important implications at both consumer

Summary Statement

I built a prognostic stochastic capacity model that uses easily measurable battery characteristics to accurately predict in real-time the remaining useful life of lithium-ion batteries used in renewable energy storage systems.

Help Received

Drs. Simona Onori, Harikesh Arunachalam, Abdullah-al Mamun, and Anirudh Allam from Stanford introduced me to MATLAB and provided me with guidance.