Project Note 74

Data-Driven Estimation for Battery Systems to Optimise Performance and Reduce Degradation

Project Funded by Scottish Enterprise, 2022 - 2023

Batteries are essential for electric vehicles and other forms of green energy-powered transportation, such as hydrogen-fuelled vehicles. Batteries are rechargeable and provide fast energy delivery to compensate for the slow response of fuel cells in hydrogen fuelled vehicles. The Battery Management System (BMS) manages the battery to maximise performance, which depends on environmental conditions, and thus reduce battery degradation and lengthen the lifetime. A key element of the BMS is to estimate the critical variables of the battery, such as state-of-charge and state-of-health.

Using physical equations to model systems is desirable when possible but variables such as wear and degradation are notoriously difficult to estimate, which is where a BMS can benefit from the availability of data. The premise in this project was that estimation accuracy of such variables can be improved using data-driven Artificial Intelligence (AI) based methods to replace, or enhance, model-based estimation. To test this, a BMS data analysis and design tool has been produced that enables the battery system designer to tune the system. One of the features of the tool is that it can automatically sort the data to obtain the most influential components, and thereby reduce the computational loading and the effort required for algorithm development and training.

The tool can be used offline to generate an estimator in the learning phase and the solution can then be implemented online in an efficient numerical algorithm. It enables ISC to deliver BMSs speedily and has the potential to be used by OEMs in new vehicle design.

The use of data in the estimation of such wear and degradation variables can improve both the reliability and accuracy of estimates. The data can be used not only for the initial offline development of the estimator, but also for continuous online improvement. In this project, the focus has been on the first phase, that is the initial offline estimator development.

Battery Management System Data Analysis and Design Tool

The BMS design tool is available in MATLAB Simulink and easy to use by both manufacturing companies and consultancy support services. There are parameters to initialise in the BMS system but given a sufficient length of data the importance of this initialisation diminishes, and the system relies more upon learning from the data.

Two learning methods are supported, Artificial Neural Networks (ANNs) and Support Vector Machines (SVMs). The use of ANNs to learn from data is now common practice particularly when large data sets are available. A neural network does not require physical equations to be known but uses a network of neurons, often at multi-levels, with weightings. The network is trained on data available through which the weightings are optimised. The trained network can then be used in real-time with current measurements, providing estimates of key signals. The SVM method also provides learning and implementation solutions, but on a different mathematical basis. The properties of the solutions and performance also differ. For BMS applications, the SVM solution was found to be preferrable.

ISC Limited
36 Renfield Street
Glasgow G2 1LU
Scotland UK

t +44 (0) 141 847 0515
f +44 (0) 141 221 1706
e iscmail@isc-ltd.com
w www.isc-ltd.com

Figure 1. System with two Outputs – Example of Data-Driven Algorithm Design Using the BMS Analysis and Design Tool

Use of Artificial Intelligence in Industry

ISC has been developing its skills in AI and machine learning (ML) over the last decade, mostly in the automotive and process industries. Although AI has had success in industrial applications to assist management planning and future initiatives, the engineering applications of ML have been more limited.

The BMS estimation problem studied in this project is an excellent application for the AI/ML technology and demonstrates its value in meeting Scotland's need to develop capabilities in this growth area, and in enhancing the performance of new and existing industrial control systems.

ISC Limited is grateful for the support of Scottish Enterprise on the project.

ISC Limited supplies control consultancy services to various areas of the automotive industry, including EV/HEV powertrain, combustion engine, autonomous vehicles, and batteries/storage. The services supplied include model-based optimal control for engine management, engine and SCR catalyst system modelling and calibration, system identification and nonlinear parameter estimation for engine models, comparative evaluation of classical and advanced control for electronic throttle position, evaluation of control strategies for engine temperature control.

For a direct client reference and more information contact:

Andy Clegg, Managing Director

ISC Limited
36 Renfield Street
Glasgow G2 1LU
Scotland UK

t +44 (0) 141 847 0515
f +44 (0) 141 221 1706
e iscmail@isc-ltd.com
w www.isc-ltd.com