LITHIUM-ION BATTERY DEGRADATION WITH APPLICATION TO WAVE ENERGY CONVERTERS

A. Jayasinghe[1], N. Fernando[1], H. Wolgamot[2], J. Apsley[3], P. Stansby[3], S. Kumarawadu[4], L. Wang[1] and C. Gaudin[2]
[1]RMIT University, [2]The University of Western Australia, [3]University of Manchester, [4]University of Moratuwa

Wave Energy Converters (WECs) enable renewable power extraction from ocean waves. The intermittent and dynamic behaviour of wave energy requires capture and storage of energy extracted by the WEC. This work investigates the use of Lithium-ion batteries (LIBs) in this application. LIBs offer high energy density, fast response, low self-discharge rate, and high performance. However, the dynamic nature of the power generation pattern in application to a WEC may result in the degradation of LIBs due to dynamic nature of the charge-discharge cycles. This work investigates the application of a LIB electrochemical model coupled with a dynamic simulation of a Moored Multi-mode Multibody Power Take-off System to demonstrate the capability to predict LIB degradation using simulations. The State of Health (SOH) of the LIB is used as an indicator for battery degradation based on capacity reduction. The work will also present the simulation results of potential increase in lifetime by having supercapacitor energy storage to mitigate the rapid energy transfer from the LIB

LIB Degradation

Lithium-ion batteries (LIBs) degradation occur as a combination of several mechanisms. These mechanisms contribute to three main degradation modes which can manifest as battery capacity fade or power fade in the battery. The most common degradation modes are; Loss of Lithium Inventory (LLI), Loss of Active Material (LAM), and Stoichiometric drift and impedance change.

LIB Electrochemical Model

The Doyle–Fuller–Newman (DFN) model is described with six governing equations. This model is a comprehensive electrochemical model which solves the physical equations of battery cell using numerical methods. The DFN model's geometry is depicted in Fig. 1.

Variation of EIS with Cycle Ageing

Electrochemical Impedance Spectroscopy (EIS) is a non-invasive that can be use to characterize impedance of an electrochemical system. Therefore it can be use to estimate transfer function of current an voltage of a LIB cell and subsequently the impedance. The DFN base model is coupled with three - degradation models using PyBaMM simulation tool.

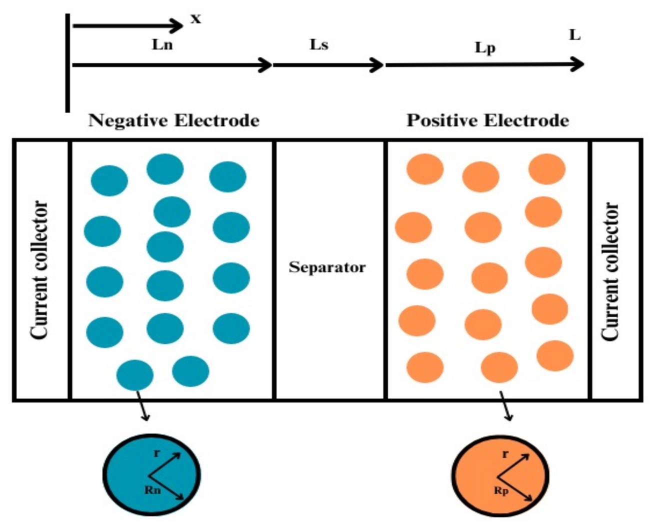

Fig. 1: DFN Model Schematic Diagram

The rate of change of the degradation depends on how the cell has been cycled during its lifetime. As the impedance of cell is provided by EIS, the SOH of battery can be observed. The SOH of a battery cell can define as follows;

$$SOH = \frac{Q_{aged}}{Q_{fresh}}$$

$$SOH = \frac{R_E - R_C}{R_E - R_1}$$

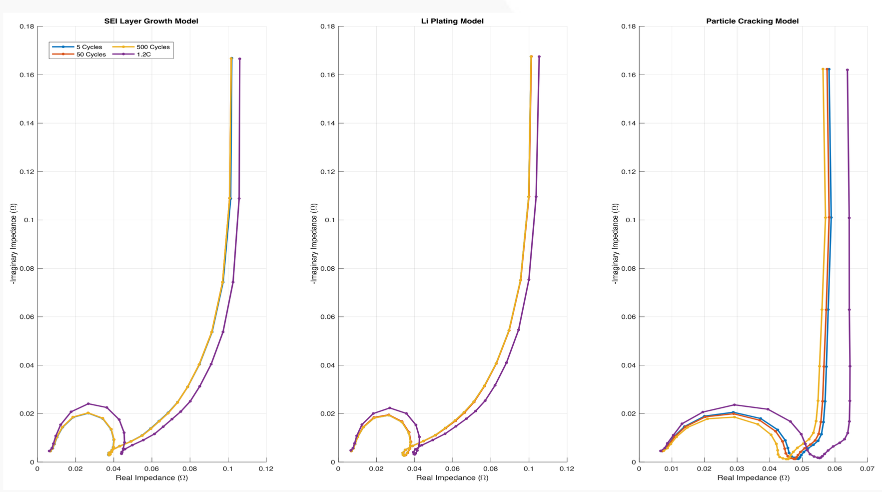

Fig. 2. EIS for cycle ageing simulations

The changes of simulated EIS for different degradation mechanism are shown in Fig. 2 for cycling ageing.

Application to WEC

The dynamic power generation pattern in WEC applications may degrade LIBs due to variable charge-discharge cycles Emulating a WEC-mechanical model is expected to aid in system understanding and performance prediction. The system overview is shown in Fig. 3 and Fig. 4 shows PTO waveforms. By emulating real-world mechanical behaviour, including complex interactions and dynamics the charge - discharge pattern can be identified.

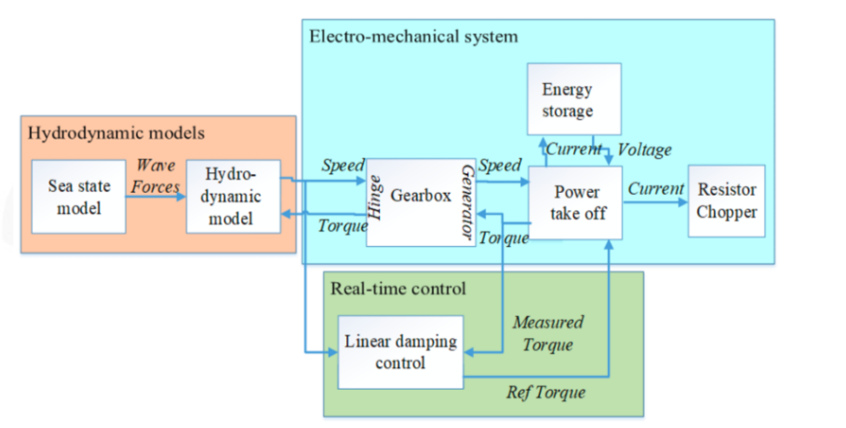

Fig. 3. System Overview

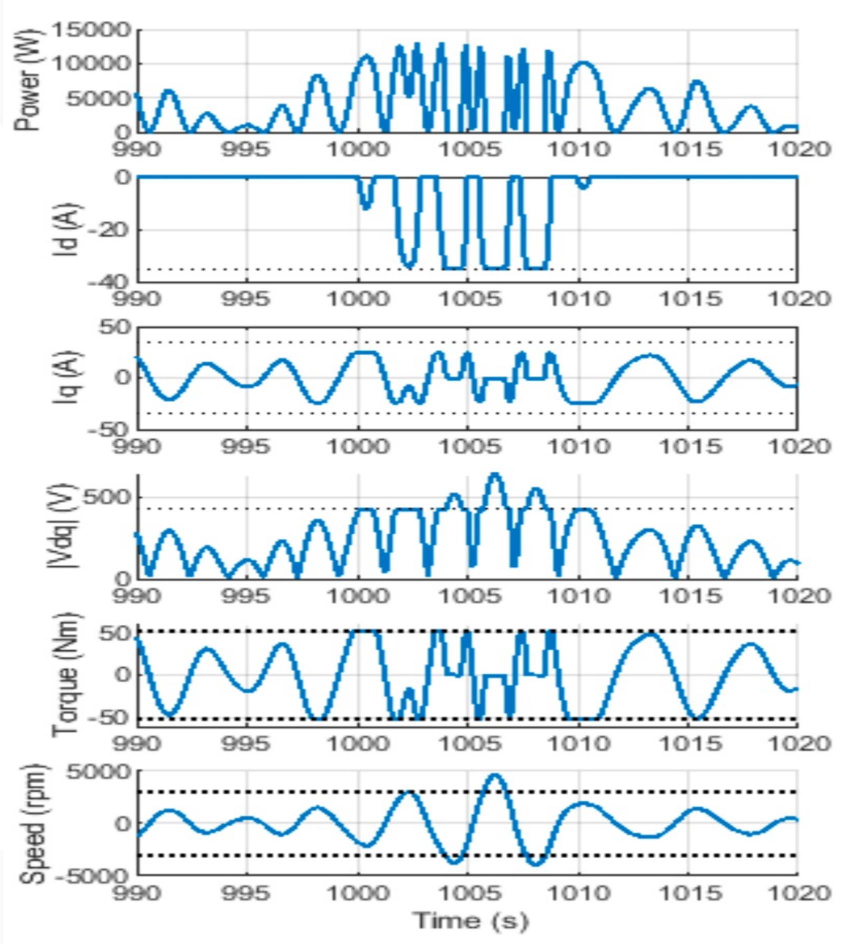

Fig. 4. PTO Waveforms

Once these patterns are identified and matched for equivalent cycle counting, they can be input into PyBaMM. This allows for the determination of the LIB cell's EIS, facilitating an estimation of the cell's state of health (SOH).

RMIT UNIVERSITY
THE UNIVERSITY OF WESTERN AUSTRALIA

CONTACT INFORMATION:
Akila E. Jayasinghe
Phone: 0456210342
Email: akila.jayasinghe@rmit.edu.au