Practical implementation of Online Condition Monitoring of Lithium Ion Batteries using Pseudo Random Signals

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Objectives

- develop an electrical equivalent circuit model of the battery.
- design and develop a converter for injecting pseudo-random signals into the battery, using an electronic load.
- Analyse the results and discuss findings.

Introduction

- Lithium-ion batteries are swiftly overtaking other energy storage options in terms of popularity.
- This is due to their rising energy density and sharp decline in production costs over the previous ten years.
- This thesis is both theory and practically based and it will focus on the monitoring of lithium ion batteries(Li (NCoMn)O2).
- A cell's internal impedance values across a range of frequencies are frequently obtained.
- The impedance values are used to deduce a cells state of charge and health.
- Two common methods for complex impedance measurement are pseudo-random binary sequence (PRBS) and Electrochemical Impedance Spectroscopy(EIS) injection techniques.
- A straightforward Thevenin battery model equivalent circuit was employed in simulation to generate realistic results shown below.

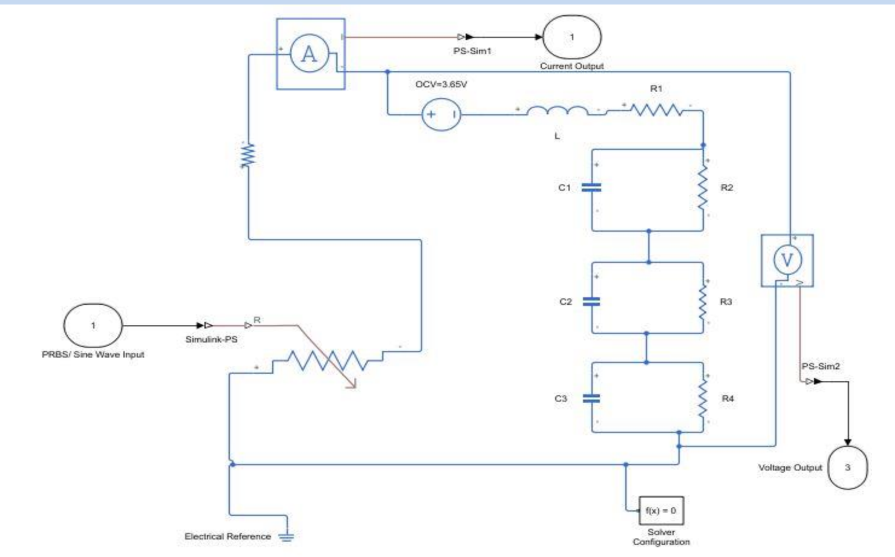

Figure 1: The fully electrically equivalent circuit model in Simulink

Methodology

- The electrical circuit in Figure 1 was practically modelled
- A bi- directional boost converter shown in Figure 2 and Figure 3 was designed and built to inject the perturbation signals into the battery.
- A LAUNCHXL-F28379D microcontroller in Figure 3 was used to generate the PRBS signals with MATLAB as the interface between the launchpad and user.
- The frequency range of the PRBS signal was from 0- 2680Hz.
- The whole structure of the selected cell's impedance model, from the diffusion area to its high-frequency inductive end, was sufficiently captured within the given range.
- The sinusoidal signal for EIS measurements was produced using a 3320A 20Mega Hz function generator.
- The frequency was manually changed on the function generator.

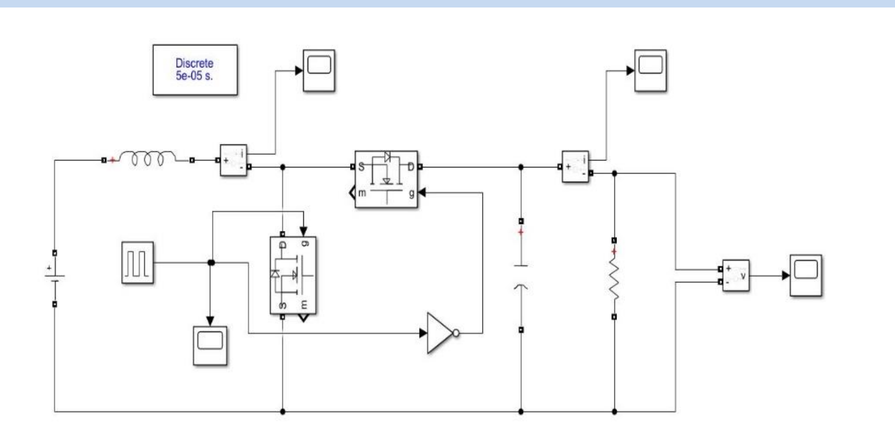

Figure 2: Bi-directional boost converter in Simulink

Methodology

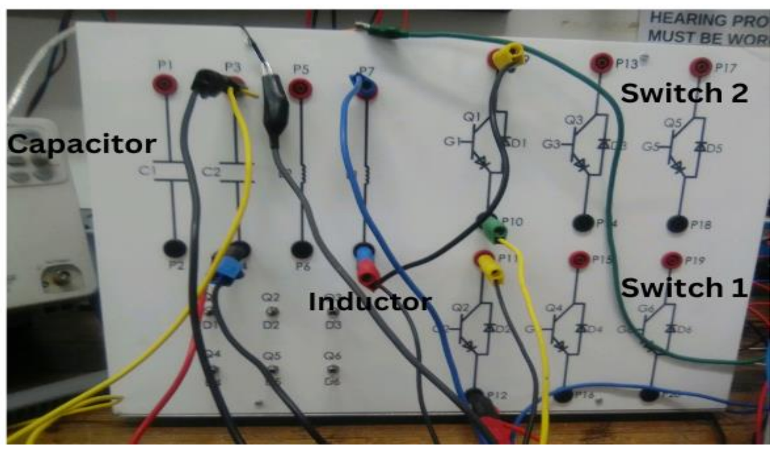

Figure 3: Bi-directional Boost Converter

Figure 4: LAUNCHXL-F2837D microcontroller

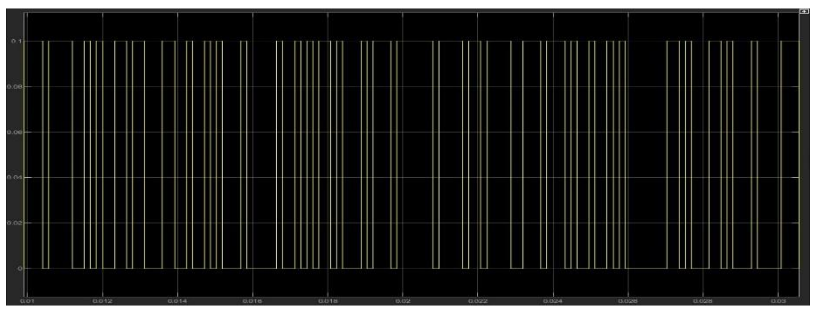

Figure 5: PRBS Signal injected into the battery from the microcontroller

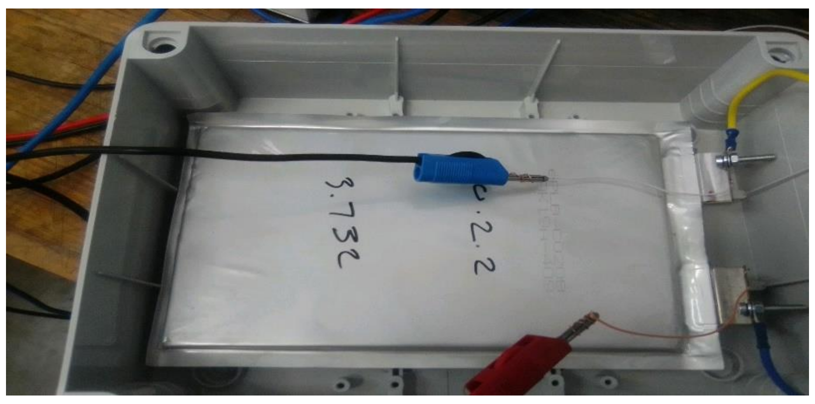

Figure 6: Li (NCoMn)O2 Battery Cell used for the experiment

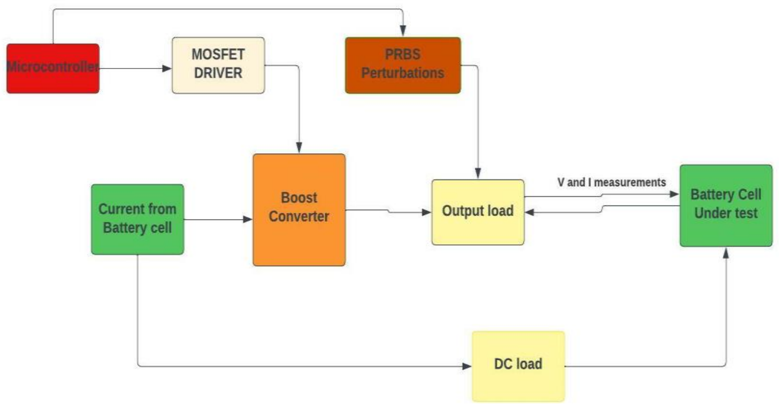

Figure 7: Simplified Model of the System

Results

	Discharging		Charging	
Tests	EIS	PRBS	EIS	PRBS
frequency< 1	4.18	4.80	3.2	4.25
1< frequency<500	3.10	3.60	4.8	3.2
frequency>500	6.5	3.50	3.1	4.05
f(All frequencies)	4.4	4.50	4.38	4.2

Table 1: Switching Errors for PRBS against EIS

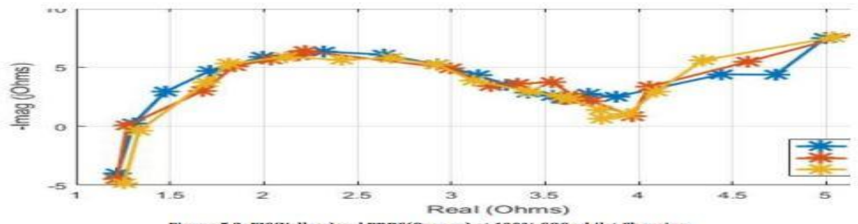

Figure 5.3: EIS(Yellow)and PRBS(Orange) at 100% SOC whilst Charging

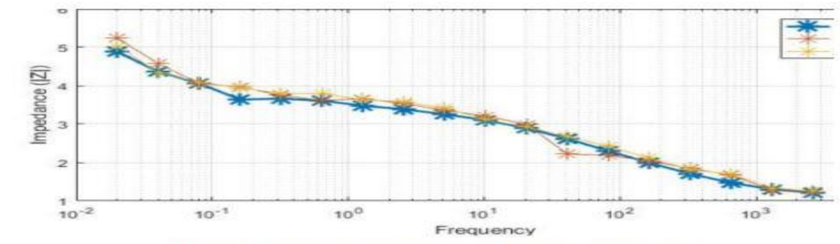

Figure 5.4: Results on a switching converter at 100% SOC whilst Charging

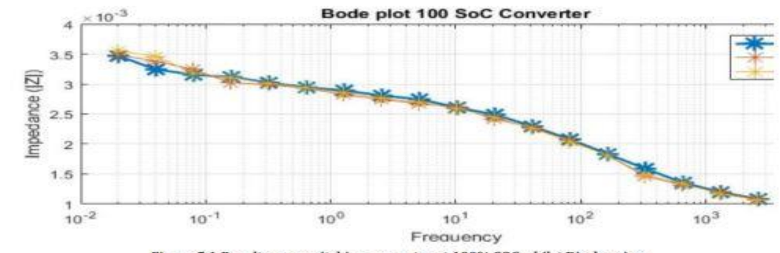

Figure 5.1:Results on a switching converter at 100% SOC whilst Discharging

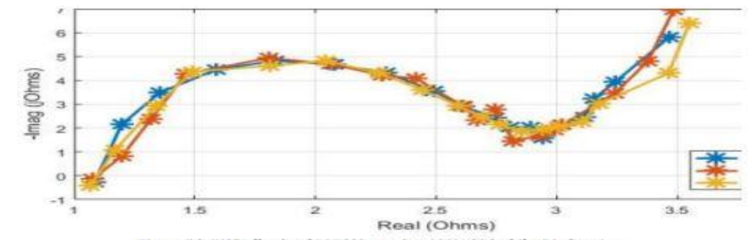

Figure 5.2: EIS(Yellow)and PRBS(Orange) at 100% SOC whilst Discharging

Conclusions

- The two methods used in this project demonstrate their ability to measure the battery's impedance.
- The PRBS method had significantly lower errors for frequencies above 500 Hz (Table1).
- This might be because they interpret information differently (faster) than EIS.
- For lower frequencies, however, EIS deployment had resulted in better results.
- it becomes clear that PRBS is well suited for large-scale operations since it can tolerate extremely high frequencies with little inaccuracy
- The output inductor and output currents both had a lot of noise due to no filter being implemented.
- The use of a microcontroller or function generator to perform EIS and PRBS on a switching converter was then shown to be possible

Recommendations

- The implementation of low pass filters so as to eliminate unwanted frequencies.

References

[1] B. Paul and W. A, “A comparison of the different broadband impedance measurement,” 2016 IEEE Energy Conversion Congress and Exposition, Milwaukee, 2016.