

Notes FYP

George W. Kirby

200328186

November 2, 2025

Supervisor: Dr. Ross Drummond

1 Constraining the research

Instead of a *black box battery* model, the goal is now to focus on the actual optimal charging method themselves, to reduce degradation. Specifically the constant current stage of the charging cycle, as this is where most of the heat is generated, research shows this to be a large factor of degradation alongside instantaneous applied voltages.

2 Data Analysis on Dans Data

Gave a good insight to the degradation patterns on an array of lithium batteries, data was analysed and plotted on jupyter notebook. Despite not complete draining etc, resting points, internal resistance and *importantly* temperature were able to be extracted from the data too

3 Lithium Battery Modelling

Starting off, only knowing the basics of batteries, i.e the resistance increases over time, capacity drops etc. I'm continuing learning the various battery models, behaviours etc.

- For the most part, atleast within the context of the problem, the dynamics of the battery can be modelled with an equivalent circuit model (ECM). Subject to vary between cycles
- Looking at dans data, parameters will be different between cells, as well as cycle degradation, but if the degradation can be modelled based off initial parameters, then an optimal charging method can be found for a given battery at a given time.
- Degradation causes:
 - SEI layer growth via pores \approx not really solvable, grows square root over time and cycle number
 - Lithium plating
 - Causes increased ageing and safety risks, its the deposition of metallic lithium on the anode surface, happens at high charging currents and low temperature. Since during charging, the lithium ions move , through the sei into the anode, if the ions cannot intercalate fast enough, they deposit and can become metallic lithium. Especially when charging is forced, local overpotential can cause the lithium plating, can cause dendrites **this is one of the main constraints for the charging profile**
 - Active material loss (from parts mentioned above)
 - SEI Brakeages
 - Charging too **high** of a temperatures causes mechanical stress on the sei layer, causing it to crack and reform, consuming more lithium ions in the process. Loose sei material can also float in the electrolyte, causing further issues.
 - Electrolyte decomposition
- Superlinear battery degradation known as "Knee" is where degradation drops rapidly over later cycles.

4 Machine learning techniques

Spent a fair amount of time learning about the basic machine learning techniques, then NN methods, then applying with pytorch. Managed to get a basic raw NN to work for fashion sets, then began looking at CNNs and LSTMs for learning data, in the hopes it could predict battery degradation over time. However, given the sheer data needed, as well as a very large possible set of outputs and too many inputs to consider, it did not look feasible to continue down this route. Atleast for a black box approach, to parameterise the current state of health, perhaps this could be used to live tune the current profile.

5 Current work and Results

6 Current plan

Look at existing charging methods, including the complex ones and continuous ones (explain complexity and non generalisability).

References

- [1] M.-K. Tran, M. Mathew, S. Janhunen, S. Panchal, K. Raahemifar, R. Fraser, and M. Fowler, "A comprehensive equivalent circuit model for lithium-ion batteries, incorporating the effects of state of health, state of charge, and temperature on model parameters," *Journal of Energy Storage*, vol. 43, p. 103252, Nov. 2021. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2352152X2100949X>
- [2] M. Lucu, E. Martinez-Laserna, I. Gandiaga, K. Liu, H. Camblong, W. Widanage, and J. Marco, "Data-driven nonparametric Li-ion battery ageing model aiming at learning from real operation data – Part A: Storage operation," *Journal of Energy Storage*, vol. 30, p. 101409, Aug. 2020.
- [3] Y. Li, W. Guo, D.-I. Stroe, H. Zhao, P. Kjær Kristensen, L. Rosgaard Jensen, K. Pedersen, and L. Gurevich, "Evolution of aging mechanisms and performance degradation of lithium-ion battery from moderate to severe capacity loss scenarios," *Chemical Engineering Journal*, vol. 498, p. 155588, Oct. 2024. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S1385894724070797>
- [4] L. Chen, C. Chang, X. Liu, J. Jiang, Y. Jiang, and A. Tian, "Physics-informed neural networks for small sample state of health estimation of lithium-ion batteries," *Journal of Energy Storage*, vol. 122, p. 116559, Jun. 2025. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2352152X25012721>
- [5] J. Tebbe, A. Hartwig, A. Jamali, H. Senobar, A. Wahab, M. Kabak, H. Kemper, and H. Khayyam, "Innovations and prognostics in battery degradation and longevity for energy storage systems," *Journal of Energy Storage*, vol. 114, p. 115724, Apr. 2025. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2352152X25004372>
- [6] T. Kalogiannis, M. S. Hosen, M. A. Sokkeh, S. Goutam, J. Jaguemont, L. Jin, G. Qiao, M. Berecibar, and J. Van Mierlo, "Comparative Study on Parameter Identification Methods for Dual-Polarization Lithium-Ion Equivalent Circuit Model," *Energies*, vol. 12, no. 21, p. 4031, Jan. 2019, publisher: Multidisciplinary Digital Publishing Institute. [Online]. Available: <https://www.mdpi.com/1996-1073/12/21/4031>
- [7] M.-K. Tran, M. Mathew, S. Janhunen, S. Panchal, K. Raahemifar, R. Fraser, and M. Fowler, "A comprehensive equivalent circuit model for lithium-ion batteries, incorporating the effects of state of health, state of charge, and temperature on model parameters," *Journal of Energy Storage*, vol. 43, p. 103252, Nov. 2021. [Online]. Available: <https://www.sciencedirect.com/science/article/pii/S2352152X2100949X>