



COMPUTATIONALLY TRACTABLE BATTERY DEGRADATION MODELS FOR OPTIMIZATION AND CONTROL

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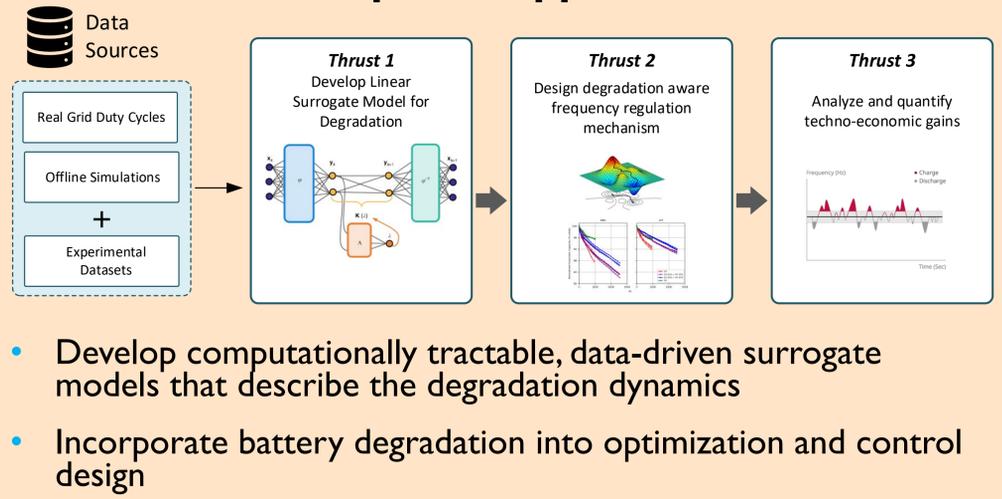
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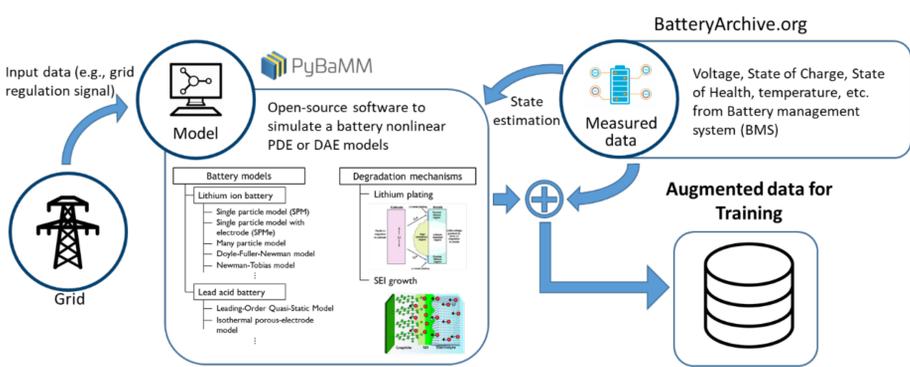
Overview

- Utilizing BESSs for grid services leads to degradation
- Grid services and controls need to be optimized
 - Balance grid service requirements and degradation
- Physics-based degradation models though accurate are computationally expensive for optimization and control
 - Simplified models are unable to capture all relevant dynamics
 - Alternative approach is to apply conservative constraints
- Need to incorporate accurate models that capture the degradation to balance the cost of battery degradation and optimal performance in real-time.

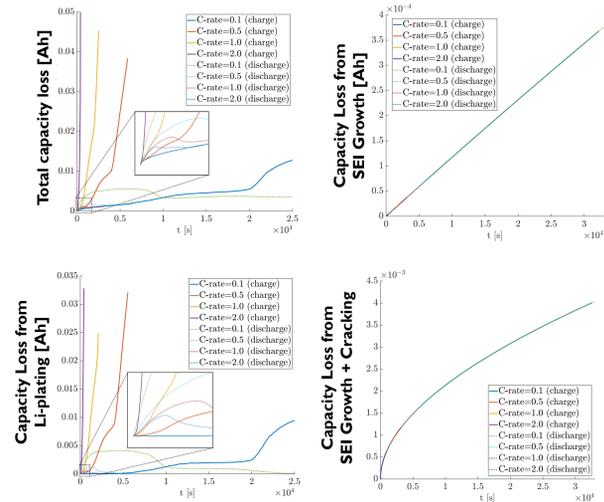
Proposed Approach



Data Collection for Training Data-Driven Degradation Models

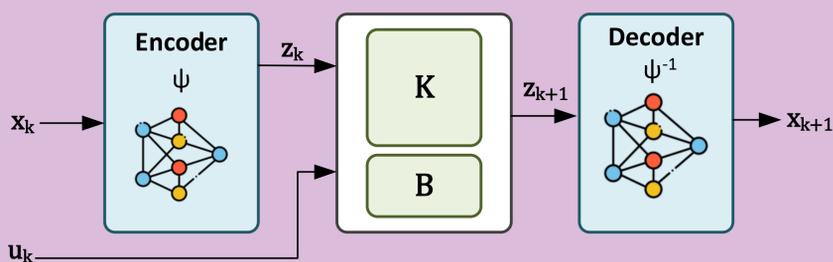


Simulation Parameters	
Application	Power intensive, stationary
Cathode types	LFP (LiFePO ₄)
Anode types	Graphite
Input signal/cycle	New England regulation signal [1]
C-rate	0~2 C
Temperature	25 °C (Assuming efficient cooling capabilities)
Rated energy	5.0 Ah
Voltage limits	2.5~4.2 [V]
Model	SPMe
Parameters	Prada et al., 2013 [2] for electrochemical model, OKane et al., 2022 [3] for degradation models.
Degradation mechanisms	<ul style="list-style-type: none"> Solid electrolyte interphase (SEI) growth, Cracking with SEI growth Lithium plating [3].



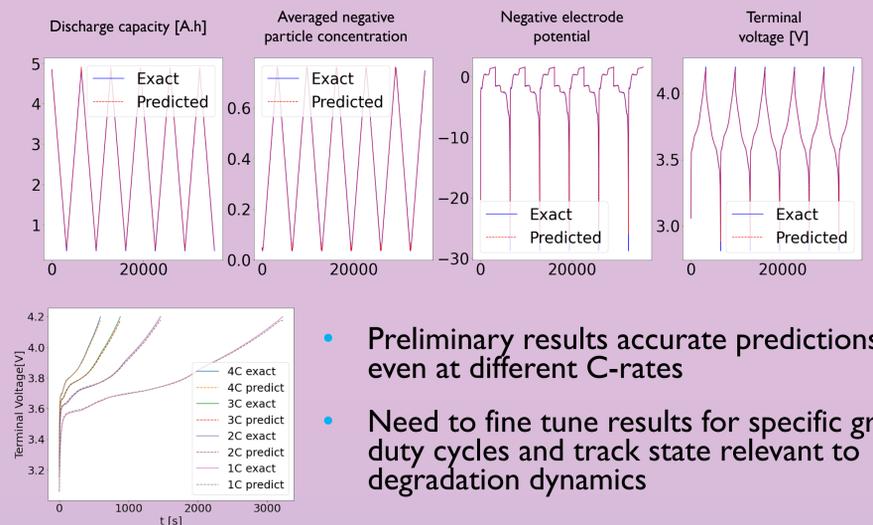
- Developed code to generate duty cycles based on frequency regulation data from ISO
- Developed code to run PyBaMM simulations based on the generated duty cycles

Machine Learning-based Modeling



- Transform the system into higher-dimensional space
- Neural-networks used to approximate transformation functions
- Reduced-order models are linear in high-dimensional function space, which maintains global accuracy while simplifying the original model

Preliminary Results



- Preliminary results accurate predictions even at different C-rates
- Need to fine tune results for specific grid duty cycles and track state relevant to degradation dynamics

Future Work

- Extend the existing work on data-driven modeling to incorporate battery degradation dynamics
- Combine data-driven model into frequency regulation formulation
- Show effectiveness of control performance and economic benefits of integrating degradation surrogate models.

[1] <https://www.iso-ne.com/markets-operations/iso-express>

[2] Eric Prada, D. Di Domenico, Y. Creff, J. Bernard, Valérie Sauvant-Moynot, and François Huec. A simplified electrochemical and thermal aging model of LiFePO₄-graphite Li-ion batteries: power and capacity fade simulations. Journal of The Electrochemical Society, 160(4):A616, 2013. doi:10.1149/2.053304jes.

[3] Simon E. J. O'Kane, Weilong Ai, Ganesh Madabattula, Diego Alonso-Alvarez, Robert Timms, Valentin Sulzer, Jacqueline Sophie Edge, Billy Wu, Gregory J. Offer, and Monica Marinescu. Lithium-ion battery degradation: how to model it. Phys. Chem. Chem. Phys., 24:7909–7922, 2022. URL: <http://dx.doi.org/10.1039/D2CP00417H>. doi:10.1039/D2CP00417H.