Battery Degradation Model for Optimal Design and Control of a Building-Level Microgrid

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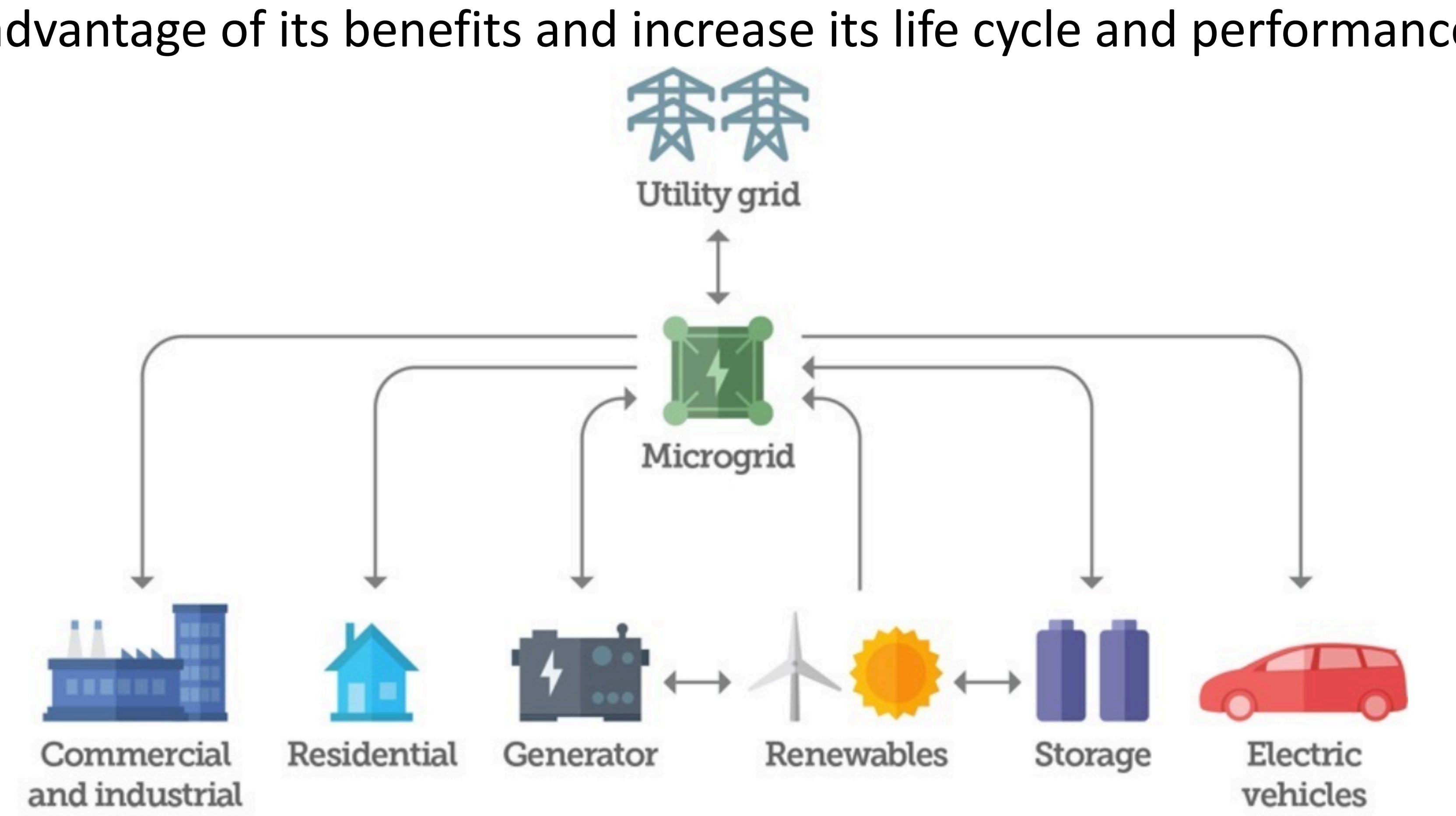
Introduction

- A microgrid is small scale network of electricity demanding and producing structures connected to a source of supply that is typically attached to a larger scale centralized grid but has the ability to function independently as an island.
- Benefits of implementing a microgrid include energy efficiency, resiliency, sustainability, and cost efficiency.
- Optimizing the size of resources in a microgrid will take full advantage of its benefits and increase its life cycle and performance.



Source: LG CNS

Background

- For long term use applications, the aging and degradation of batteries is a common concern.
- Battery life is highly influenced by its intended function, purchasing the wrong sized battery for an application can lead to a decreased life cycle and unnecessary additional cost.
- Solid Electrolyte Interface (SEI) layer growth and the isolation of active material (AM) are the two primary causes of battery degradation.

Tools

- A reduced-order capacity loss model that represents the degradation of graphite anodes due to SEI and the isolation of active material, developed and validated by the authors of Refs. [1], improves computational efficiency without compromising model accuracy.
- The programing platform MATLAB was used to build a code based on the reduced-order degradation model shown in Table 1.

Table 1
Reduced-order degradation model. [1]

Q_{SEI}	$Q_{SEI} = \int_0^t \frac{k_{SEI}\exp\left(-\frac{E_{SEI}}{RT}\right)}{2(1+\lambda\theta)\sqrt{t}}dt$
θ	$\theta = \exp\left[\frac{nF}{RT}(\eta_k + U_n^{OCP} - U_s^{OCP})\right]$
η_k	$\eta_k = \frac{RT}{\alpha F}\ln(\xi + \sqrt{\xi^2 + 1})$
ξ	$\xi = \frac{R_s I}{6\varepsilon_{AM,0} i_0 V}$
U_n^{OCP}	See Appendix A
U_s^{OCP}	$U_s^{OCP} = 0.4$
Q_{AM}	$Q_{AM} = \int_0^t k_{AM}\exp\left(\frac{-E_{AM}}{RT}\right)\cdot SOC\cdot\lvert I\rvert dt$
Total capacity loss	$Q_{loss} = Q_{SEI} + Q_{AM}$

Process and Methods

- Identify variables in the reduced-order degradation model and their appropriate units.
- Input variables and equations from the reduced-order degradation model into MATLAB.
- Compare capacity loss values computed with source experimental data.

Table 2
Key parameters used in the simulation. [1]

Fitted parameters	Value	Unit
k_{SEI}	6684.8	$1/sec^{1/2}$
E_{SEI}	39146	J/mol
k_{AM}	1.368	1/Ah
E_{AM}	39500	J/mol
λ	5.51×10^{-5}	

Table 3
Coefficients of the simplified reduced-order model. [1]

Fitted parameters	Value	Unit
k_{SEI}	6684.8	$1/sec^{1/2}$
E_{SEI}	39146	J/mol
k_{AM}	1.368	1/Ah
E_{AM}	39500	J/mol
λ	5.51×10^{-5}	

Challenges and Obstacles

- Modeling current, SOC, and capacity loss as a constant required inefficient computations and resulted in incorrect values compared to the source experimental data.
- Modeling current, SOC, and capacity loss as a matrix and implementing a for loop in MATLAB resulted in more efficient computations.

Results and Discussion

Building a MATLAB code using the reduced-order degradation model established a foundational model with the capability to efficiently predict the total degradation of batteries due to SEI, and the isolation of active material based on variables such as temperature, SOC, current and depth of charge. Once this foundational model can validate the experimental data produced by the authors of Refs. [1], it can essentially be used to optimize the sizing of resources in a building-level microgrid. Looking at more complex scenarios, such as scenarios in which a microgrid is operating independently, as and island and taking demand flexibility into consideration, one has the potential ability to purchase smaller batteries, thus reducing the total cost of the system.

Acknowledgements

The CERI REU Program, The Millennium Scholars Program and Dr. Atamturktur.

References

[1] Xing Jin, Ashish Vora, Vaidehi Hoshing, Tridib Saha, Gregory Shaver, R. Edwin García, Oleg Wasynczuk, Subbarao Varigonda. (2017). Physically-based reduced-order capacity loss model for graphite anodes in Li-ion battery cells. *Journal of Power Sources*, 342, 750-761