Designing Microgrids Through Open-Source Modeling and Machine Learning

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Abstract

- Microgrids are community-based semi-independent power grids that are advantageous for renewable energy efficiency and black- and brownout resiliency
- Current open-source models do not realistically or comprehensively simulate the components of a microgrid, none are intended for design, and closed-source design tools do not provide the accessibility necessary to account for the eccentricity of microgrids
- We propose an open-source model and design tool that begins to solve the above problems and serves as a foundation for continued open-source development of microgrid design and simulation tools

Objectives

Adapt a current open-source microgrid model to:

1. More realistically model microgrid components
2. Have design capability in addition to simulation
3. Be more modular
4. Thoroughly document code to facilitate open-source use

Background

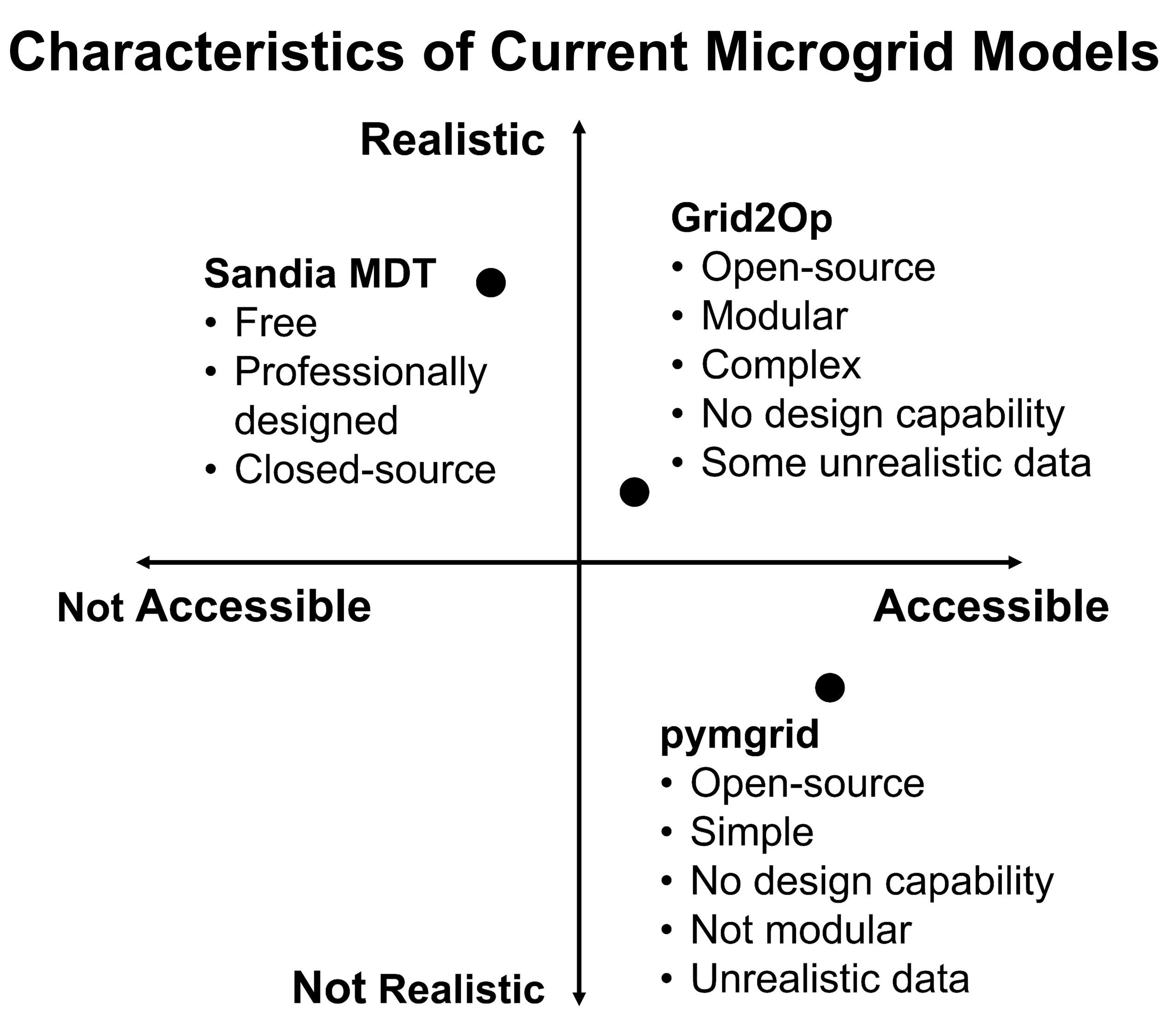

Figure 1: *A summary of the practical characteristics of current microgrid models. Scale is arbitrary.*

Program Flow

A **function optimization algorithm** is the core of the microgrid design program. This kind of algorithm minimizes (or maximizes) a function's output and returns the corresponding input values.

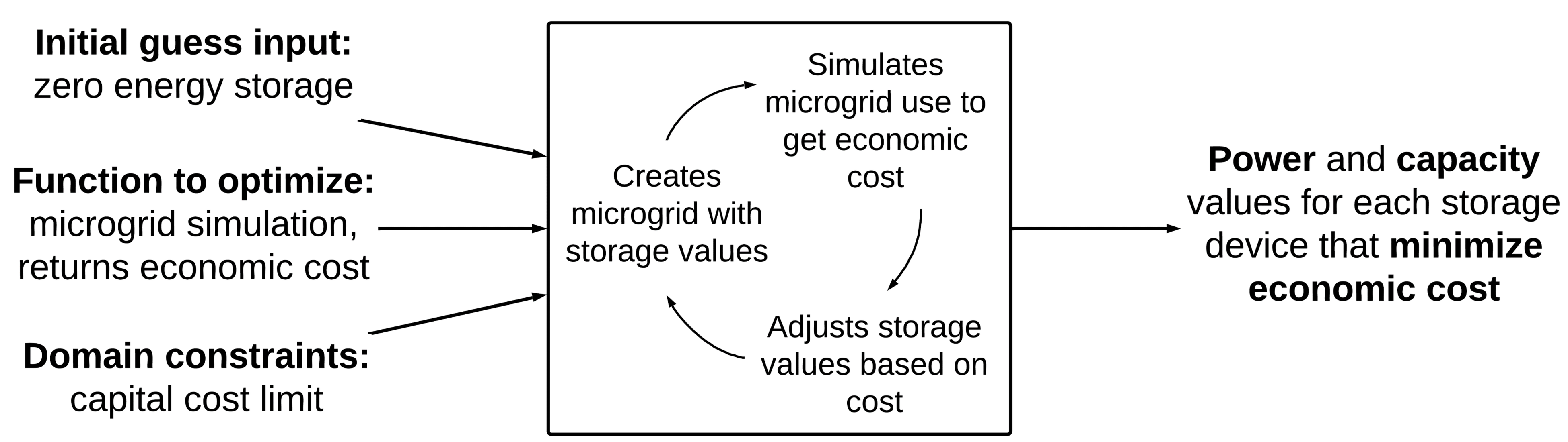

Figure 2: *a flowchart depicting how the algorithm operates in our program*

A **reinforcement learning algorithm**, Deep Q-Learning, manages the simulated microgrid.

Q-Learning

- Based on scored pairs of states and actions
- Scores updated dynamically to optimize decision-making while a program runs
- Table of pairings gets exponentially larger with additional state and action variables

Deep Q-Learning

- Uses a neural network to estimate the scores of state-action pairs
- Beneficial in real-world scenarios where:
  - States are continuous
  - States or actions have 2+ variables

Model Structure

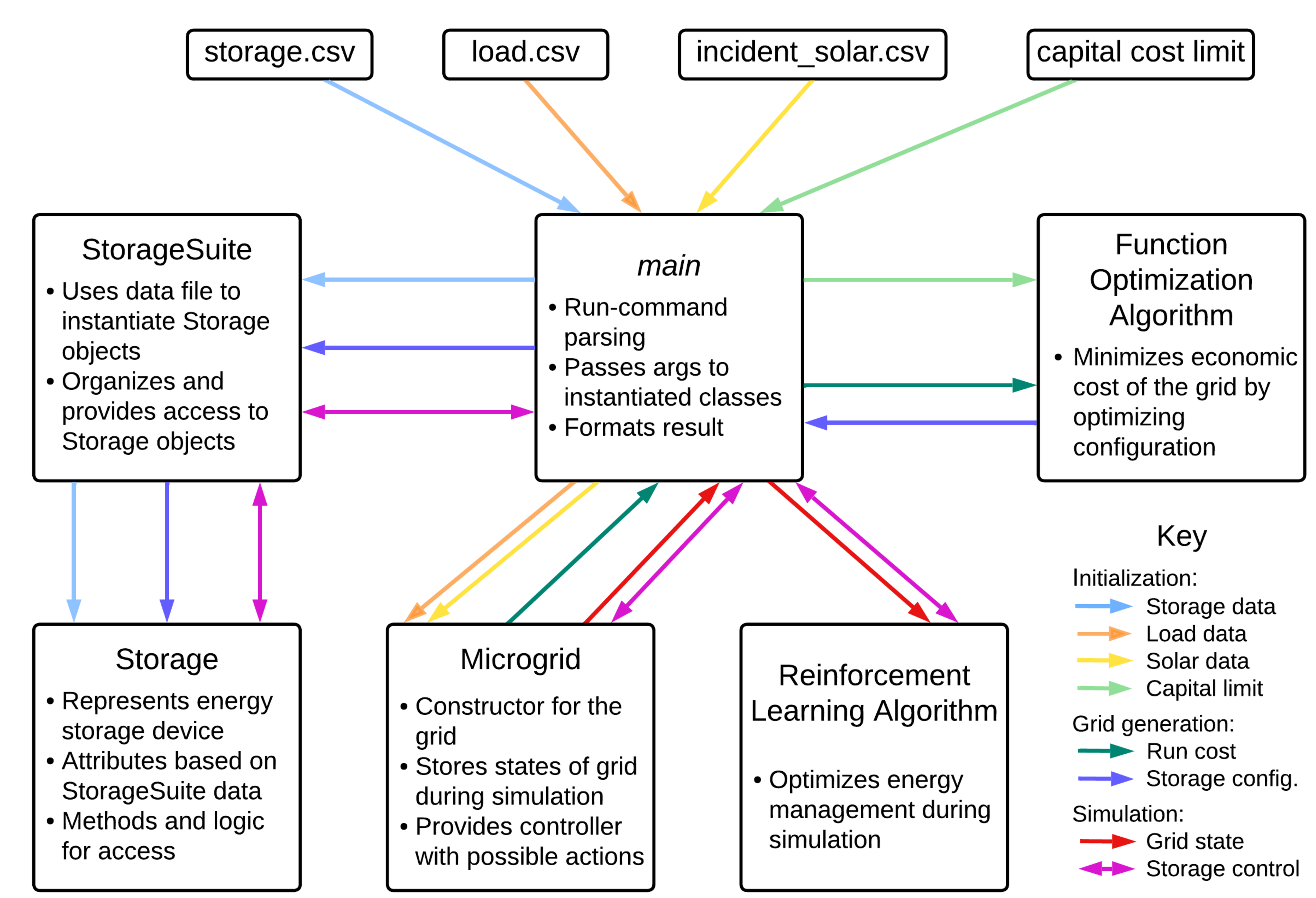

Figure 3: *Colored arrows, showing how distinct data are used, almost exclusively pass through the main method rather than being reliant on other classes, facilitating modification and interchange without disrupting dependencies.*

Realistic Modeling

A literature review was undertaken to convert testing data of various energy storage devices to formulae usable by code. This was done by:

1. Gathering data from multiple academic and industry test studies
2. Calculating appropriate regressions of the data
3. Converting the equations to Python syntax and storing in a CSV table
4. Writing methods to access and solve the equations for a given runtime status

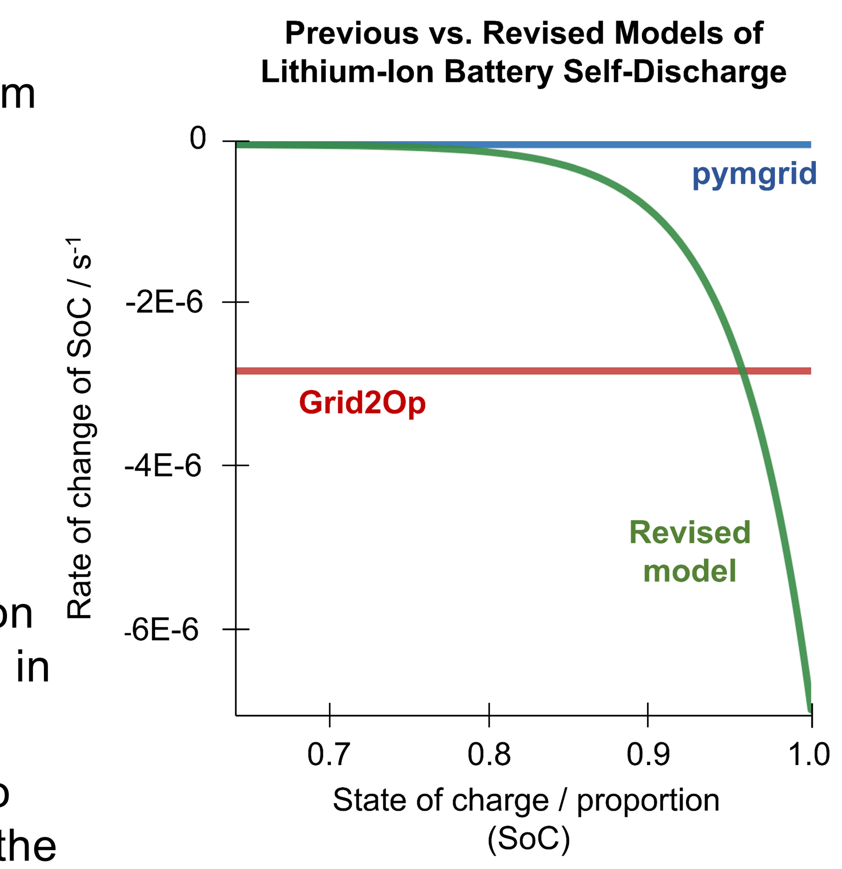

Figure 4: *Comparison of extant models and our model of an example device property*

Conclusions

This work demonstrates that an open-source, modular, and realistic model and design tool for microgrids is feasible. Though our program is not fully developed, the above traits facilitate future open-source development.

Future work identified can be separated into model development, testing, and research. First, this program needs development of its storage and generation classes, as well as geospatial simulation. Second, the ML algorithms used in this program need to be thoroughly tested against other algorithms for runtime and efficacy to select the best algorithm for a particular or general usage of this program. Third, this model can be used to research how different combinations of storage affect performance.

References

References: Code:

Acknowledgments

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