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Insights into Methodologies and Stochastic Optimization of Thermal Energy Storage-Coupled Advanced Reactor Systems: A Comparison of Methods for Accessing Long-Term Sub-System Sizing Adequacy

Changing the World's Energy Future

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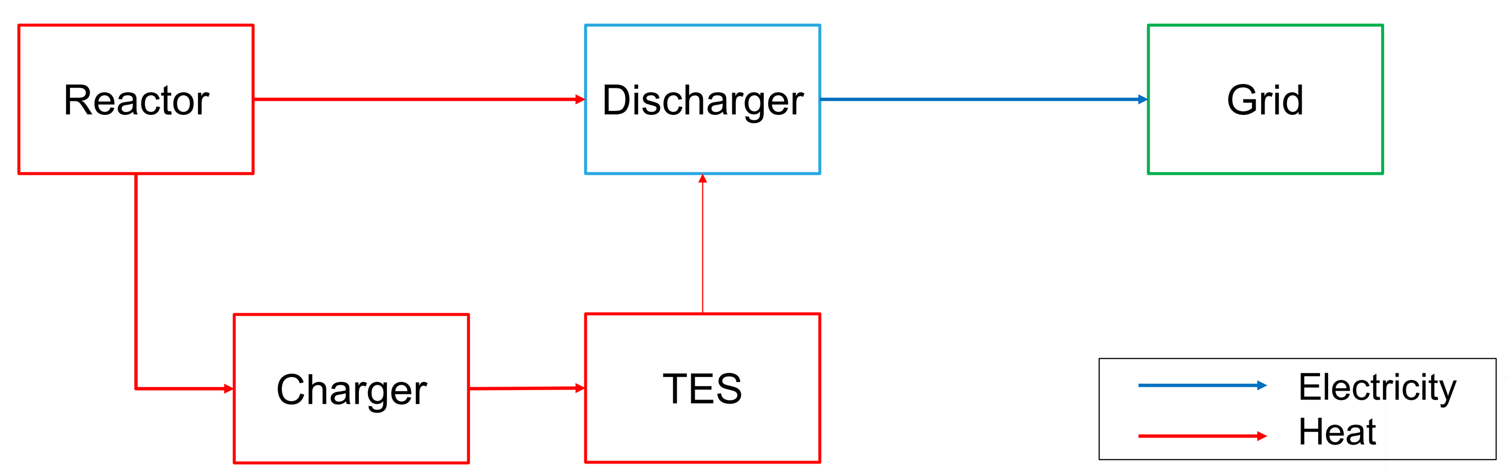
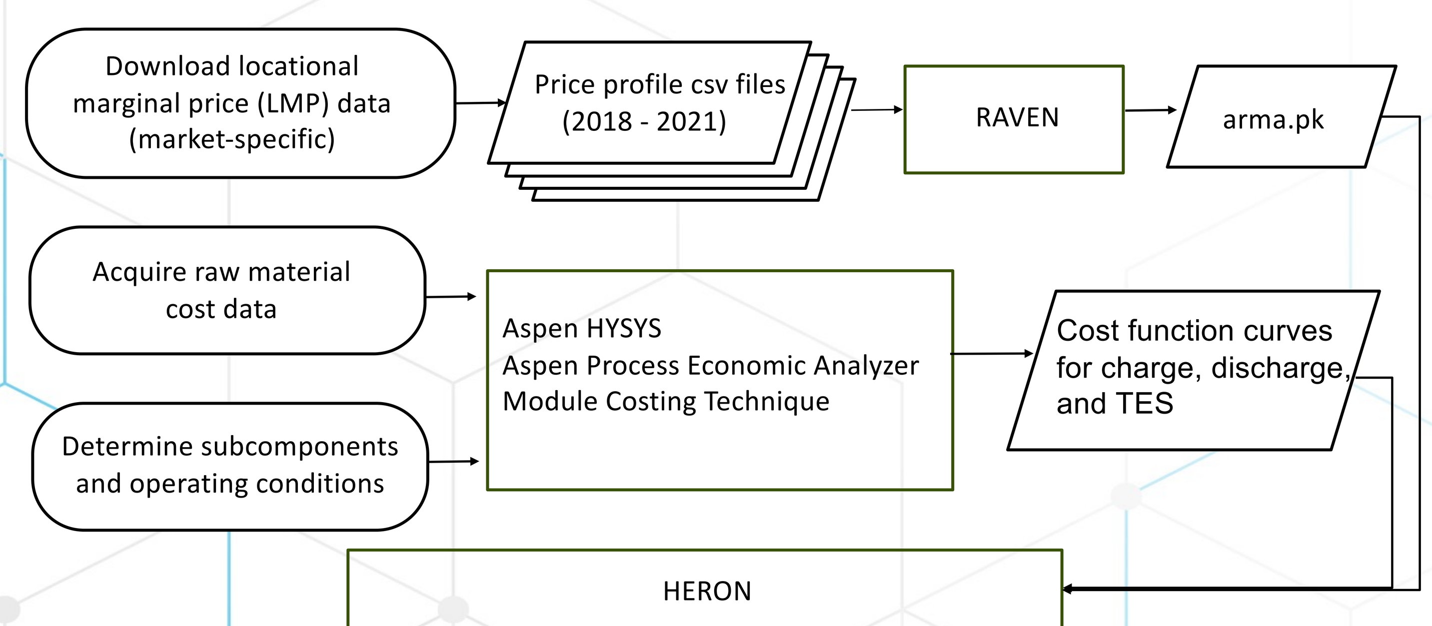
RESEARCH QUESTIONS

- What's the **optimal capacity** for a Nuclear-Thermal Energy Storage (TES) plant to maximize revenue?
- What's a **reasonable dispatch window** for the optimization process?
- How do **market signals** affect TES plant size and operations?



Schematic representation of the Nuclear-TES model: The concept positions TES as an energy arbitrage player within a competitive electricity market.



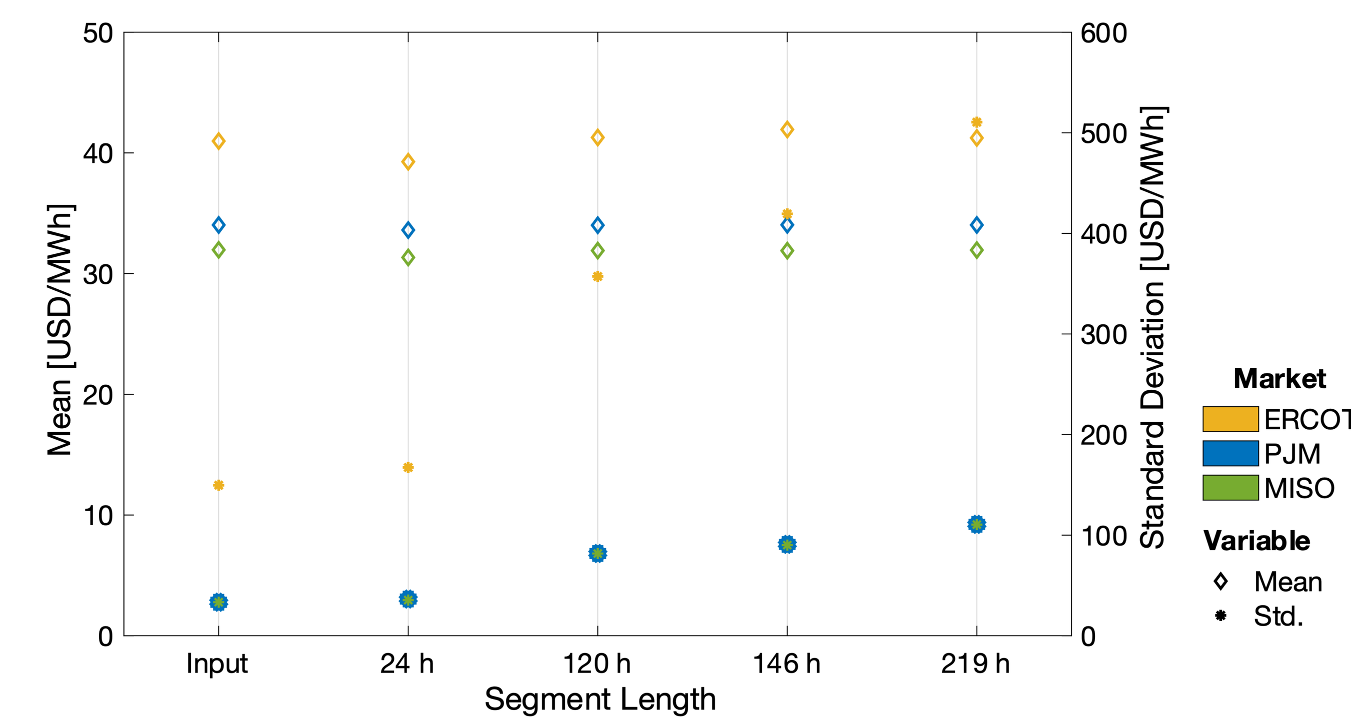
Workflow for HERON optimization: HERON uses trained electricity price signals as the main economic drivers, implementing cost functions to minimize the expenses related to three TES-coupled High Temperature Gas-cooled Reactor (HTGR) modules: charger, discharger (including Balance of Power (BOP)), and TES

DISCUSSIONS

- The average electricity price has a direct impact on overall economics, while **price volatility** affects the size of the TES
- A market characterized by a high, **single daily electricity price peak** would require a larger TES size compared to a market with a moderate, dual price peak
- A **five-day look-ahead window** may sufficiently capture the expected optimal sizing and its corresponding revenue

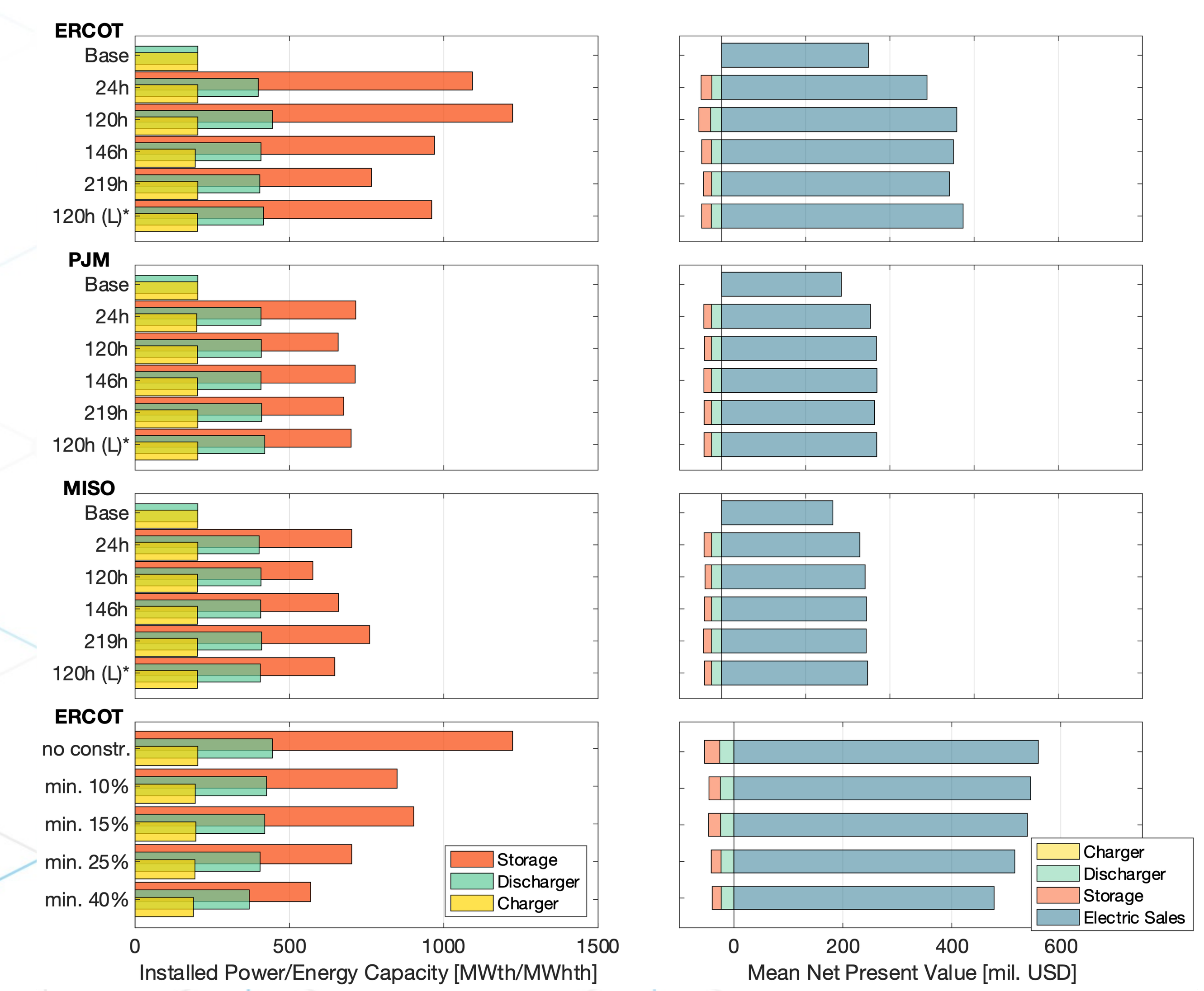
METHODS

RAVEN-Synthetic Data Creation



Real-Time Market (RTM) price statistics across the selected markets and segment lengths: The RAVEN synthetic data creation process extracts statistical characteristics from input signals from the ERCOT, PJM, and MISO markets to generate price signals with specified segment lengths; Each representation is weighted to represent a full year.

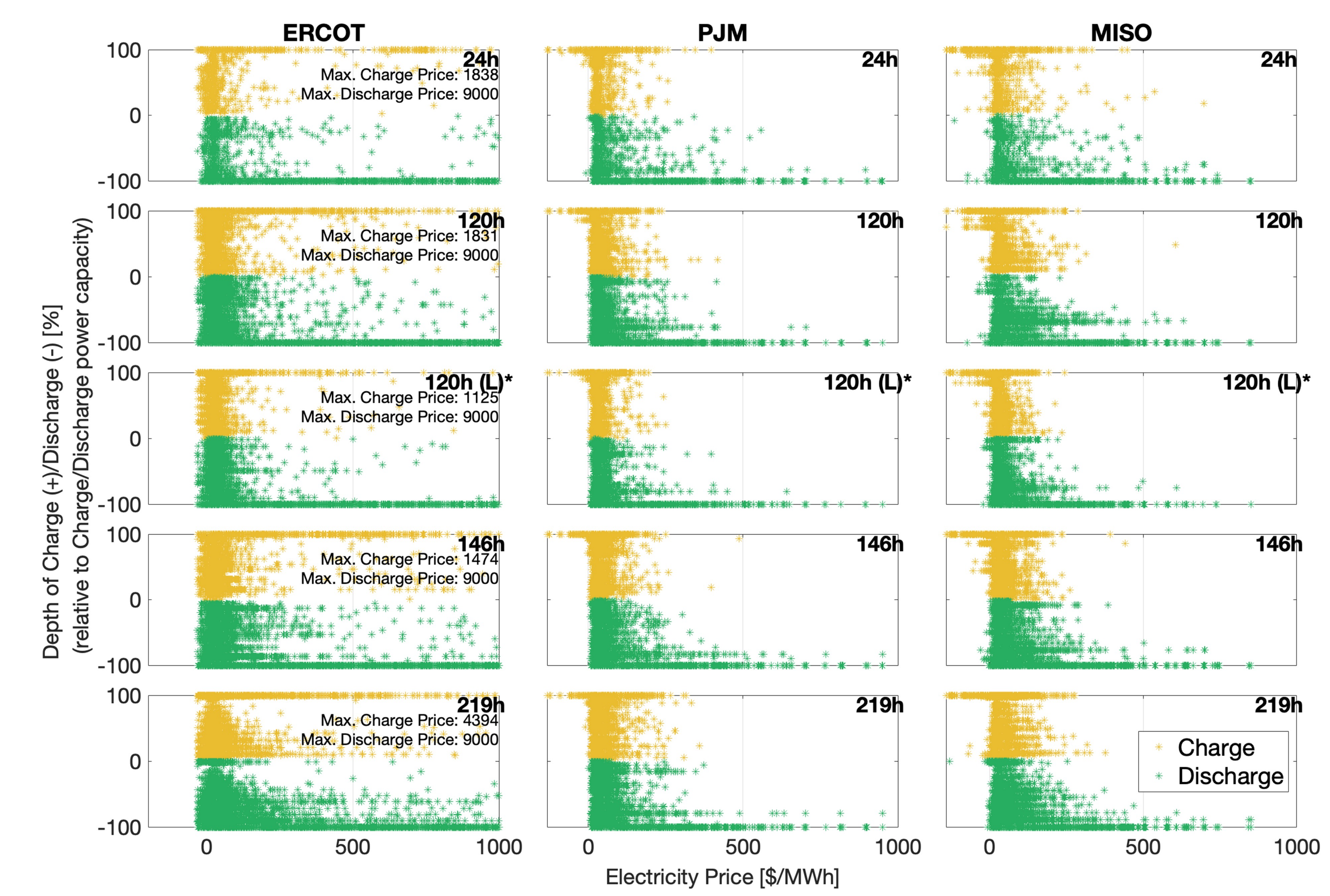
HERON-Automated Optimization



HERON-optimized cases for the HTGR-TES coupling superset capacity (left) and Net Present Value (NPV) (right): The average economics improved by 41%, 14%, and 13% for the ERCOT, PJM, and MISO markets, respectively, in comparison to the nuclear vendor's standard BOP configuration (Base); (L)*: reduced price volatility; min. 10 – 40 %; minimum generation level for the reactor.

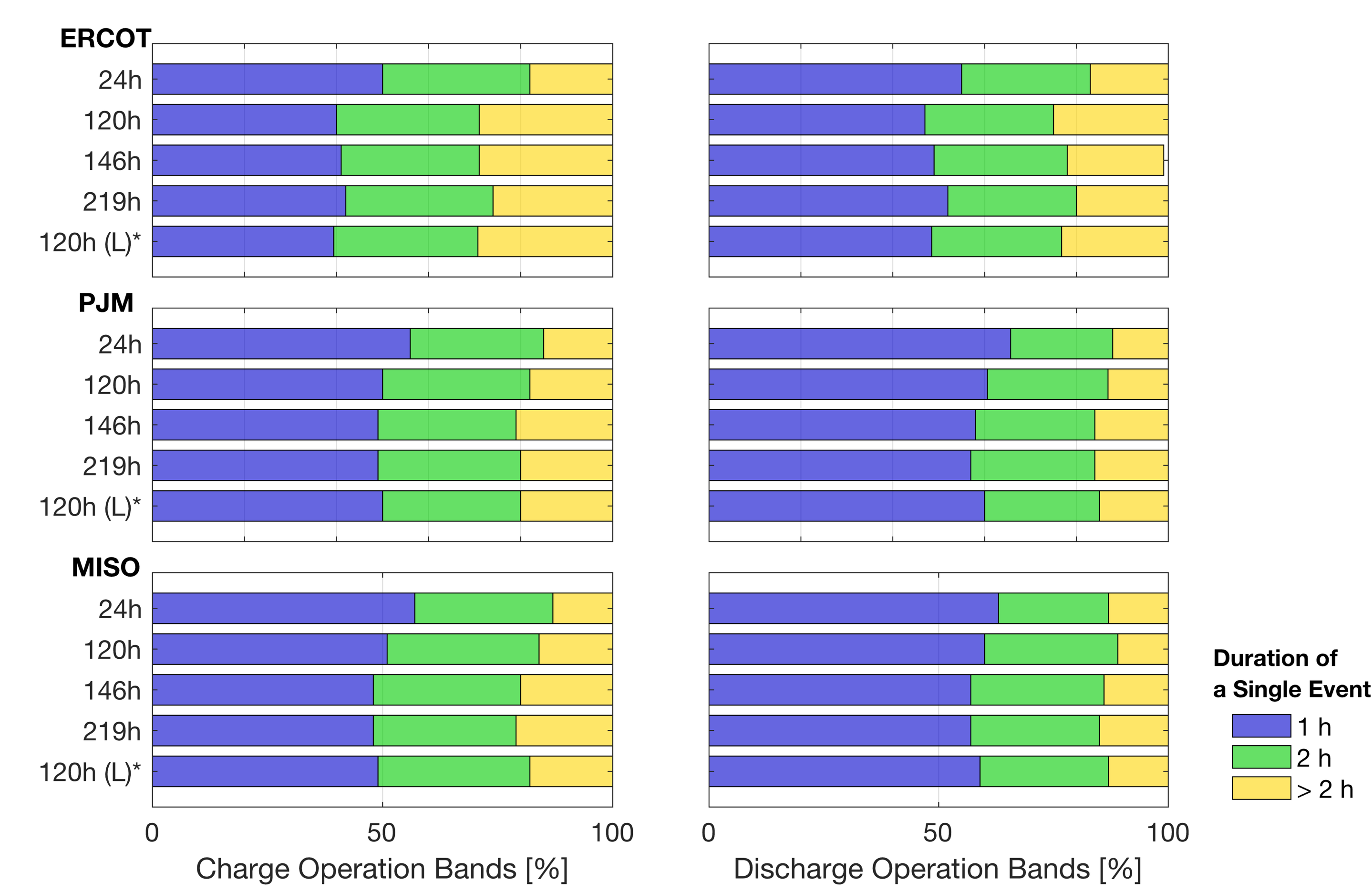
SENSITIVITY ANALYSIS

Temporal Factor Impact



Scatter plots illustrate the connection between electricity prices and net changes in TES level: As segment length grows, frequent active discharge (-50% to -100%) within the $0–400/MWh range boosts electricity sales due to extended look-ahead price information; This is noticeable in regions with infrequent price spikes, such as ERCOT, in contrast to MISO and PJM where daily peak prices are evenly distributed throughout the year.

Technical Parameter Impact



Contribution of different mode of charge/discharge operation to the TES state of charge profile: most TES modes are set for 1- or 2-hour duration. Discharge events are generally shorter than charge events due to TES optimization responding to price signals.

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