OPTIMAL DISPATCH MODELS FOR LONG-DURATION HYBRID ENERGY STORAGE AND MICROGRIDS IN ELECTRICITY MARKETS

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ABSTRACT

This poster presents ongoing research on optimal dispatch models for hybrid long-duration energy storage systems in electricity market applications, focusing on two innovative projects.

1. The first evaluates the **Sunshine Hydro Superhybrid system**, which integrates pumped storage hydro (PSH), hydrogen and hydrogen-based fuels production, and variable energy resources, coordinated through the AESOP optimization platform.
2. The second project develops a methodological framework for siting, sizing, and operating of battery energy storage systems (BESSs) within community microgrids for the **Kit Carson Electric Cooperative (KCEC)**, leveraging the Energy Storage Microgrid Optimization (ESMO) model to assess different configurations and operational strategies.

Both projects aim to enhance grid reliability, flexibility, and economic efficiency by applying rigorous dispatch and market models to hybrid systems integrating PSH, hydrogen, and batteries in real-world electricity market conditions.

MOTIVATION

Realizing the economic and operational value of **long-duration hybrid energy storage** requires optimal dispatch modeling that represents hybrid configurations, including pumped storage hydro (PSH), hydrogen, hydrogen-based fuels, and batteries, within U.S. market rules.

These projects define clear model structures and workflows that link assets, contracts, and market signals, and it reflects practical operating limits such as state-of-charge tracking and reservoir management.

The approach is used to evaluate planning and investment choices, compare alternative configurations, and test performance under normal conditions and extreme events.

Calibrated with project-specific data, the models provide transparent evidence to support sizing, siting, and operating decisions for both standalone storage and community microgrids.

SUNSHINE HYDRO SUPERHYBRID SYSTEM

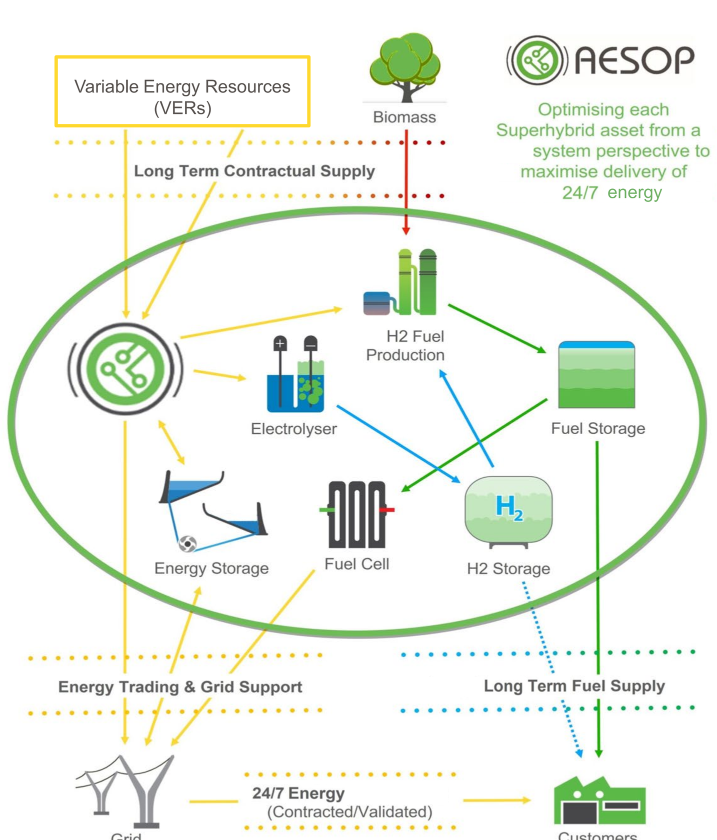
This project proposes a methodological framework to validate and adapt the AESOP tool and **the Sunshine Hydro Superhybrid** system for deployment in the U.S. electricity market, with an initial focus on CAISO [1]. The Superhybrid integrates VERs, biomass, PSH, hydrogen fuel production, and fuel storage into a coordinated system designed to deliver continuous power and support fuel production.

The **AESOP tool**, developed and implemented in the Australian market, optimizes the dispatch of each asset in the Superhybrid, improving financial performance while meeting contractual obligations and customer requirements.

The project aims to validate AESOP against **U.S. market conditions** and resource combinations, assess the financial viability of the Superhybrid, benchmark its performance relative to alternative pathways, and identify technical and market modifications needed for U.S. deployment.

The schematic illustrates the Superhybrid architecture: VERs supply power to both the grid and fuel production processes (electrolyzers, fuel cells, H_2 storage), supported by long-term contracts, storage assets, and trading strategies optimized by AESOP.

This configuration also enables balancing between variable generation and demand, ensuring efficient utilization of all system components while maintaining stable operations. By coordinating generation, storage, and consumption in real time, the system can respond effectively to market signals and operational constraints, enhancing overall reliability and economic performance.

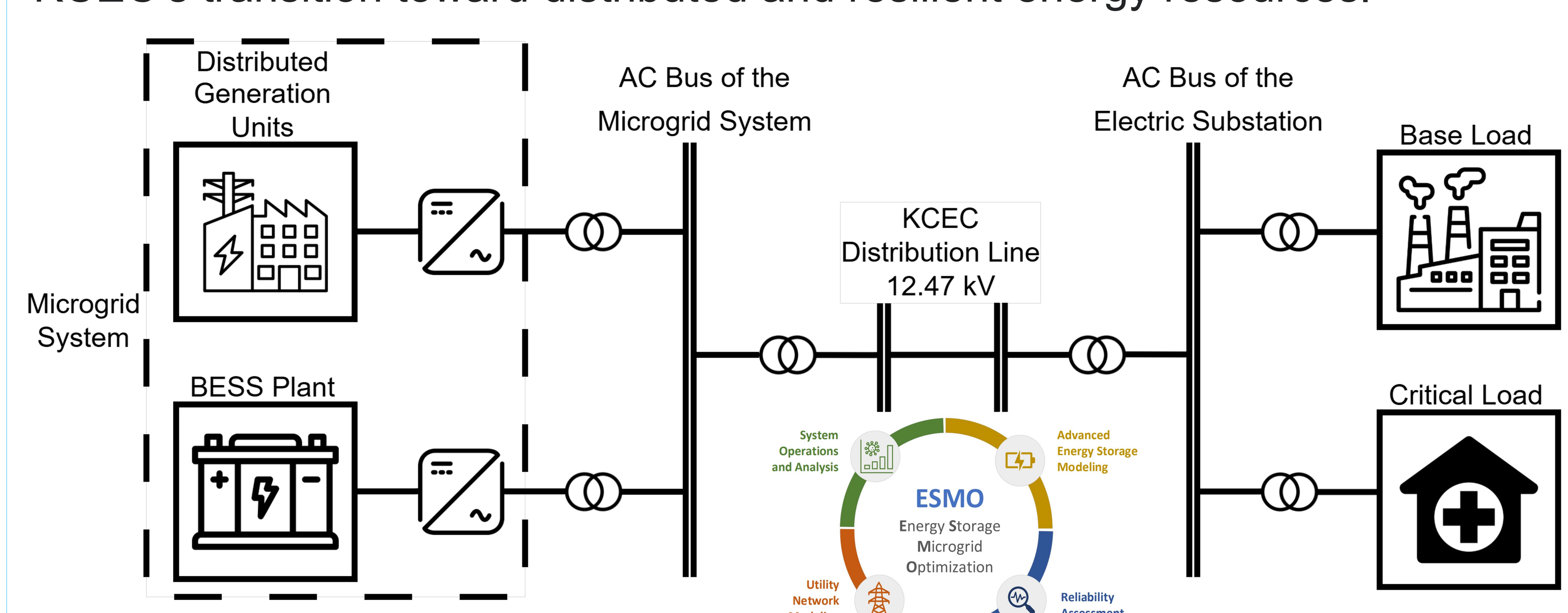


KIT CARSON ELECTRIC COOPERATIVE MICROGRIDS

This project proposes a methodological framework for designing and operating three community microgrids at critical sites in KCEC's service area. The microgrids combine distributed generation units and BESSs to sustain critical and base loads during extreme events like wildfires and snowstorms, improving resilience and reducing outage impacts.

ESMO [2], a least-cost dispatch framework, will be customized to KCEC's specific data and requirements to determine the optimal siting, sizing, and operation of distributed generation and BESS resources. This approach allows evaluating multiple scenarios to identify the most cost-effective configurations for reliability and economic performance. The framework will also assess the potential for additional economic value from **BESS participation in electricity markets**, particularly in the imbalance and ancillary services markets, to further enhance the microgrid's value proposition.

The schematic illustrates the system architecture, with variable generation units and BESS connected through inverters to the microgrid AC bus, interfacing with the 12.47 kV distribution line to serve both critical and base loads. These microgrids aim to enhance energy security for vital infrastructure, such as hospitals and water systems, while supporting KCEC's transition toward distributed and resilient energy resources.



CONCLUSIONS & NEXT STEPS

This ongoing work lays the groundwork for assessing the economic and operational value of long-duration hybrid energy storage systems in electricity market applications.

Preliminary efforts have focused on defining robust modeling frameworks and collecting the necessary data to represent the technical and market characteristics of the studied systems.

Next steps will involve calibrating the models with project-specific data, running scenario-based simulations, and analyzing outcomes to inform investment decisions and operational strategies.

The findings are expected to provide actionable insights into the optimal sizing, siting, and dispatch of hybrid storage assets to enhance grid reliability, flexibility, and economic performance.

REFERENCES

[1] A. Grimaldi, F. D. Minuto, J. Brouwer, A. Lanzini, Profitability of energy arbitrage net profit for grid-scale battery energy storage considering dynamic efficiency and degradation using a linear, mixed-integer linear, mixed-integer non-linear optimization approach, J Energy Storage 95 (2024), https://doi.org/10.1016/j.est.2024.112380

[2] Balducci, Patrick, Kwon, Jonghwan, Nwadiaru, Vivian, et al., "Rosario Strait Tidal Energy plus Energy Storage — Preliminary Economic Assessment," Jan. 2024, https://doi.org/10.2172/2283071