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FINANCIAL RISK-ORIENTED ANALYSES IN THE SCHEDULING OF MULTI-ENERGY MICROGRIDS

Abstract:

The present study investigates a multi-objective strategy for scheduling Multi-Energy Microgrids (MEMs) with Power to X (P2X) conversion technology in advance. The P2X technology serves as the fundamental framework for these microgrids, incorporating multiple energy conversion systems and diverse energy storage technologies to optimize efficiency. The primary objective is to reduce operational expenses, mitigate risks, and decrease carbon emissions. Two risk management tools, namely Conditional Value at Risk (CVaR) and a robust approach, are recommended to address the financial risks involved in MEM's scheduling. The study results for the considered microgrid imply that an operator's adoption of a risk-neutral approach necessitates procuring a substantial portion of power from the day-ahead electricity market. In addition, implementing a risk-averse strategy by a MEM operator results in diminished participation in the energy market through reduced bidding and an increased overall presence in the real-time market.

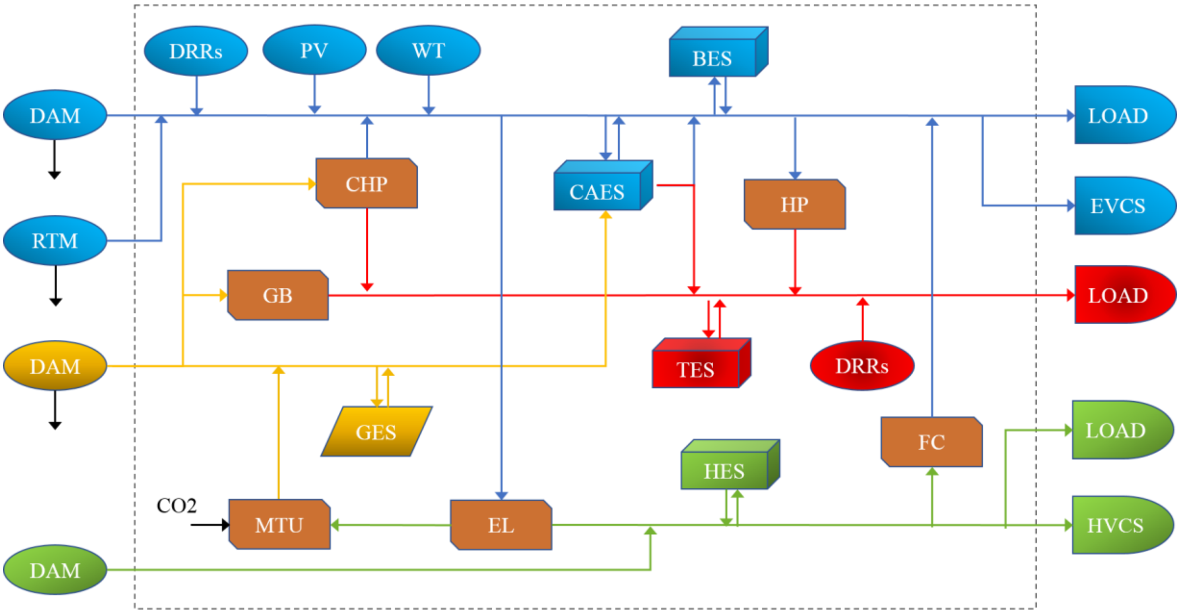
Keywords:

P2X conversion, MEM, CVaR, Robust, Emission, Multi-objective

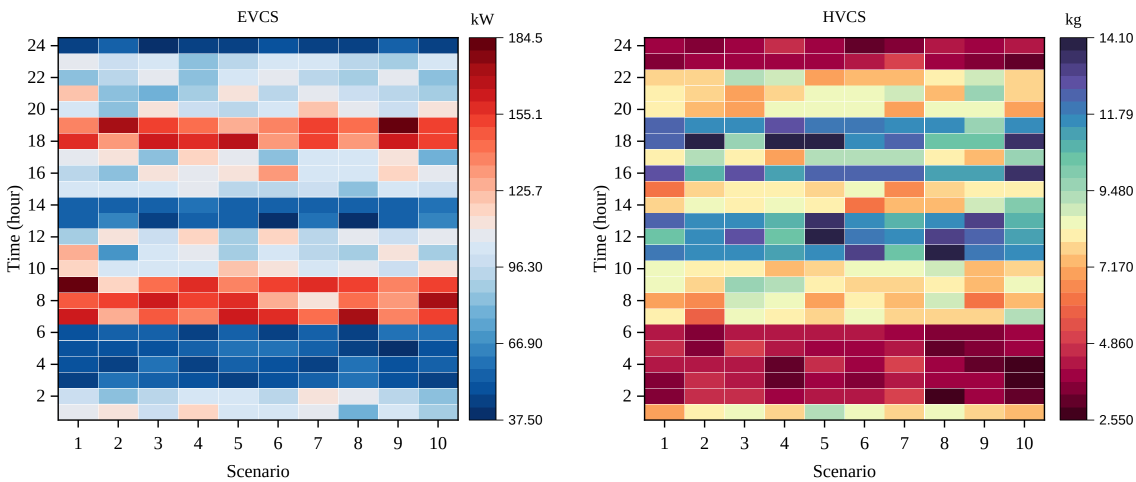
1 Introduction

The global approach to energy is shifting towards renewable sources at an accelerating pace, moving away from traditional energy systems. To meet the growing energy demand, a holistic approach is necessary, leading to the emergence of Multi Energy Microgrids (MEMs). MEMs provide a unified solution for fulfilling various energy needs, including electricity, heating, cooling, water, and hydrogen. In addition to the conventional MEMs structure, Power-to-X (P2X) technology offers the potential to significantly enhance the flexibility and resilience of an energy system. P2X conversion technology involves converting electricity or other energy sources into gaseous or liquid fuels. This technology also allows for the seamless integration of renewable energy sources with various carriers, like natural gas or heat. Additionally, integrating energy storage technologies such as Battery Energy Storage (BES), Compressed Air Energy Storage System (CAES), Thermal Energy Storages (TES), Hydrogen Energy Storage (HES), and Gas Energy Storage (GES) can enhance the profitability and flexibility of P2X-based MEMs. Recent studies have shown that eco-emission scheduling of MEMs, along with the role of energy storage and P2G facilities, can reduce operation costs and natural gas purchases by significant percentages. Additionally, optimal scheduling of a grid-connected MEM ensures its robustness, and profitable scheduling of a MEM incorporating P2X conversion facilities has been explored to optimize participation in energy markets [1]-[3].

This study examines a hybrid Robust/CVaR scheduling model for a MEM designed to optimize operational costs, reduce CO2 emissions, and manage financial risks. The goal is to introduce a general triple-objective programming model for eco-emission scheduling of P2X-based MEMs, allowing operators to supply demands in a cost-effective, eco-friendly, and risk-controlled manner. Figure 1 illustrates the energy system structure of the proposed MEM, which serves carrier loads, charging power for Electric Vehicle Charge Station (EVCS), and hydrogen fuel for Hydrogen Vehicle Charge Station (HVCS). The input energy for this MEM comes from Day-Ahead Markets (DAMs), renewable Photovoltaic (PV) and Wind Turbine (WT) units, and Demand Response Resources (DRRs) linked to incentive-based programs. Additionally, P2X conversion units include Combined Heat and Power (CHP), Gas Boiler (GB), Heat Pump (HP), Electrolyzer (EL), Fuel Cell (FC), and Methanation Unit (MTU). By utilizing PX facilities, renewable resources, energy markets, and storage technologies, this system aims to meet its energy demands with the lowest operating costs.



Figures 1. Energy routes in a MEM with inputs, outputs, conversion, and storage units

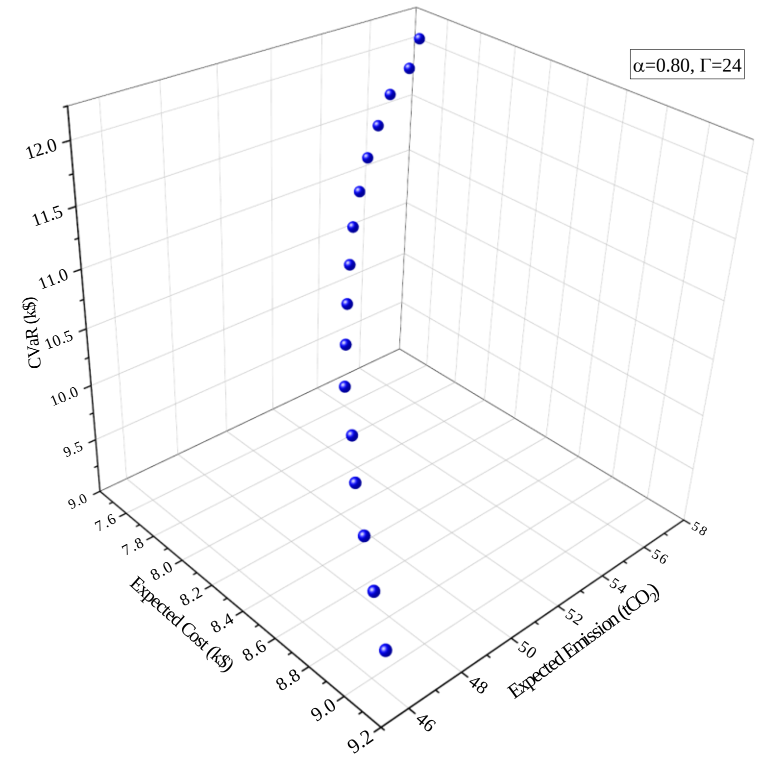


Figures 2. Scenario-based charging demands of EVCS and HVCS

2 Results

Utilizing the MEM system illustrated in Figure 1, we conducted validation of the proposed risk-based eco-emission scheduling model. The scenario involved simulation under 10 scenarios for random variables and an adoption of a robust approach to the market price. Figure 2 illustrates the charging demand at electric and hydrogen vehicle stations across different scenarios. In addition, the energy market data, encompassing both the DAM and RTM, was acquired from Nord Pool for January 12, 2024. The Pareto front, as shown in Figure 3, was obtained for the confidence level of 0.80 and maximum conservatism concerning the market price. Analysis of the figure reveals that at a CVaR of \$12,000, the operating cost amounted to \$7570, with carbon emission registering the highest value at 57.30 tCO_2. As the CVaR risk diminishes and the level of risk aversion increases, the anticipated cost rises to \$9,000 while the emission rate declines to

46.19 tCO_2. The most cost-effective option, with a confidence level of 0.80 and zero budget of uncertainty, is realized when the CVaR value is $12,073. However, implementing a risk-neutral strategy for a confidence level of 0.95 and maximum robustness leads to a risk value of $12,595. Notably, the operational cost of the MEM exhibits a clear rise attributed to the robust approach concerning increasing RTM prices. Specifically, implementation of a risk-averse approach and maintenance of the utmost conservatism on the RTM price results in a $34 rise over the projected cost for the corresponding CVaR, with a confidence level of 0.80.



Figures 3. Pareto solution set expressing the cost, emission and CVaR risk

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References

[1] Safaei, H., Keith, D.W. and Hugo, R.J., 2013. Compressed air energy storage (CAES) with compressors distributed at heat loads to enable waste heat utilization. Applied energy, 103, pp.165-179.

[2] Chen, J.J., Qi, B.X., Rong, Z.K., Peng, K., Zhao, Y.L. and Zhang, X.H., 2021. Multi-energy coordinated microgrid scheduling with integrated demand response for flexibility improvement. Energy, 217, p.119387.

[3] Wan, Y., Kober, T., Schildhauer, T., Schmidt, T.J., McKenna, R. and Densing, M., 2023. Conditions for profitable operation of P2X energy hubs to meet local demand with energy market access. Advances in Applied Energy, 10, p.100127.