

Optimal Resilient Scheduling Strategy for Electricity-Gas-Hydrogen Multi-Energy Microgrids Considering Emergency Islanding

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Introduction

Motivations

- **Multi-Energy Systems:** Coordinating different energy systems can improve overall performance
- **Hydrogen-Gas Blending:** A novel way to enhance connection between power and gas systems
- **Microgrid Emergency Islanding:** Microgrids are important resilience resources to support local loads through emergency islanding during maingrid outages

Contributions

- **Multi-Energy Microgrid Resilient Operation:** A resilient multi-energy microgrid operation strategy is proposed considering hydrogen-gas blending and uncertain emergency islanding requirements.
- **Unified Normal and Resilient Operation Model:** An operation scheduling model is proposed for multi-energy microgrids considering both normal and resilient operation (emergency islanding) modes using two-stage stochastic optimization.
- **Improved Progressive Hedging Algorithm:** An improved progressive hedging algorithm is proposed to accelerate the solution process of the formulated problem by applying a scenario grouping technique and an asynchronous update mechanism.

Problem Description

System Overview

- **Multi-Energy Microgrid:** Include a power system, a natural gas system, and a hydrogen system.

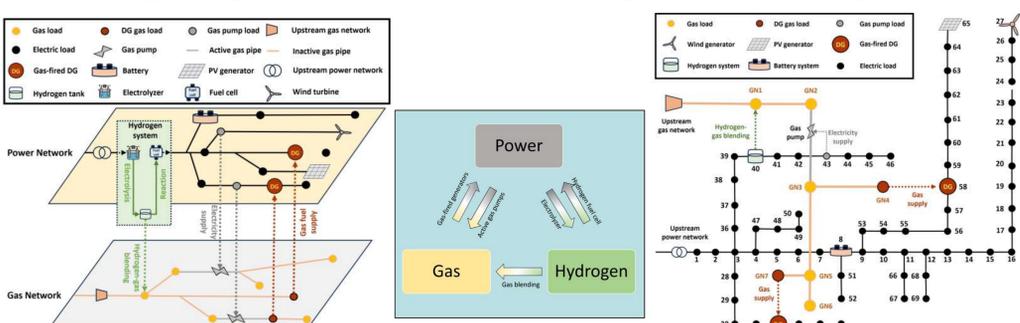


Fig. System overview

Fig. System illustration and energy conversion

Operation Scheduling

- **Energy Prices:** The time-of-use prices are applied to electricity, and the gas price is assumed constant.
- **Uncertainties:** The uncertainties are modeled using representative scenarios with probability distributions.
- **Emergency Islanding Requirement:** Modeled using the $T-\tau$ criterion (T is the total scheduling horizon, τ is the required continuous islanding duration).
- **Two-Stage Operation Scheduling:** The first stage optimizes the scheduling decisions for the current period. The second stage optimizes future periods.

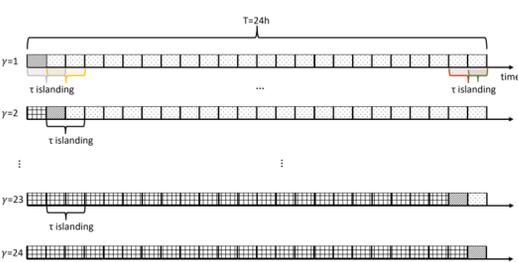


Fig. Two-stage problem with emergency islanding

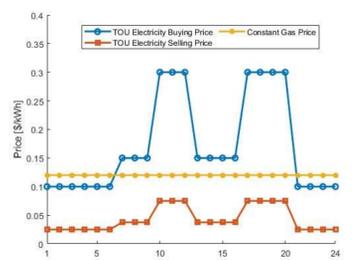


Fig. Energy Price

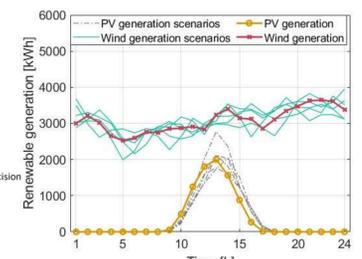


Fig. Netload scenarios

Solution Methodology

Progressive Hedging Algorithm

- The primary problem will coordinate the optimal first-stage solutions from secondary problems. The secondary problems will adjust their optimal first-stage solutions by including the penalty terms that penalizes deviations from the coordinated first-stage solution to achieve convergence.

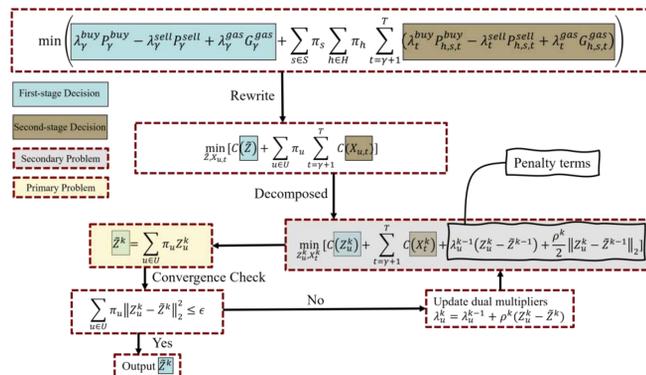


Fig. Progressive hedging algorithm

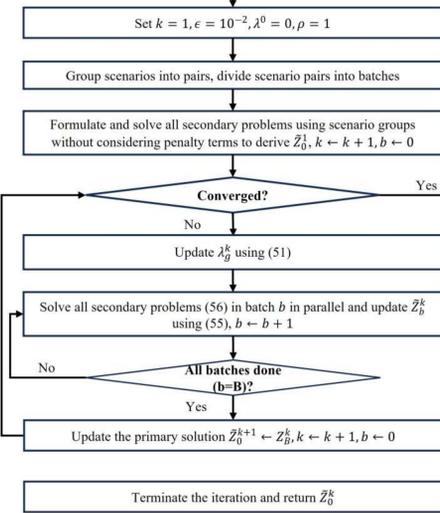


Fig. Improved progressive hedging algorithm

Distributed Solution Method Based on Progressive Hedging Algorithm

- **Scenario Grouping:** Each secondary problem can simultaneously solve several scenarios to pre-coordinate the first-stage decisions of these grouped scenarios and accelerate convergence.
- **Asynchronous Update:** The secondary problems are solved in batches due to limited computational resource. The optimal first-stage solution is computed after each batch is solved instead of waiting for all secondary problems are solved.

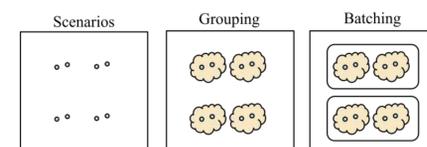


Fig. Scenario grouping and asynchronous update

Results and Discussion

Scheduling Results under Normal Operation

- **Impact of Hydrogen-Gas Blending:** With hydrogen-gas blending, surplus energy during low-price hours are transformed into hydrogen and blended into the gas system to reduce gas cost. Overall, the hydrogen-gas blending operation can reduce 0.45% of the total cost.

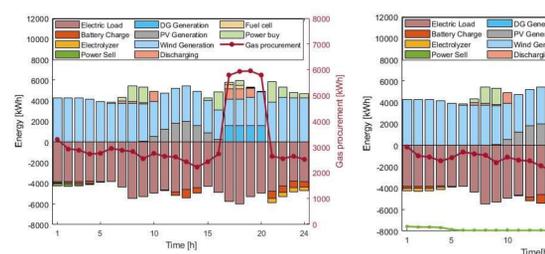


Fig. Scheduling results under normal operation

Fig. Cost comparison under normal operation

Economic and Resilient Performance under Resilient Operation

- **Load Loss Comparison:** If emergency islanding is required during high-netload hours, normal operation will lead to load loss, and the resilient operation can significantly reduce load loss (reduce by 91.05% even in the worst-case scenario).

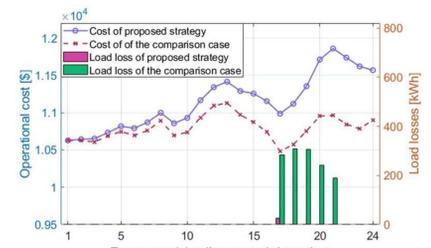
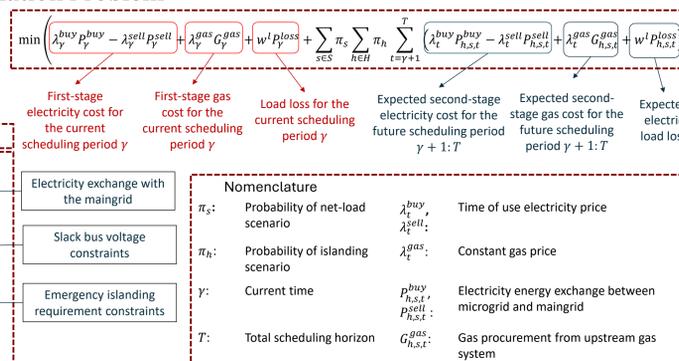


Fig. Economic and resilient performance under resilient operation

Problem Formulation

Two-Stage Stochastic Optimization Problem

- **Objective Function:** Minimizing the total operational cost in power and gas systems and electric load loss.



- **Constraints:** Include operation mode switching constraints, power system constraints, gas system constraints, hydrogen system constraints, and cross-system constraints.

Faster Convergence

- **The Proposed Algorithm:** By combining the scenario grouping technique and asynchronous update mechanism, the proposed algorithm can reduce the computational burden by 31.33% (from 11.17 to 7.67 iterations).

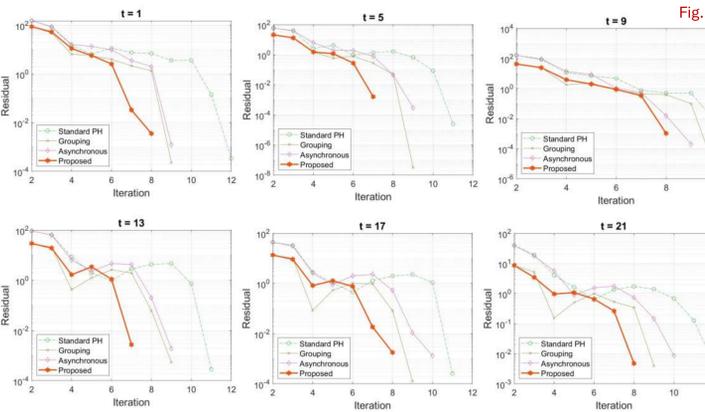


Fig. Convergence of different algorithms

Future Work

- **Predictive Models:** Developing predictive models that correlate maingrid outage durations with extreme weather parameters, enabling more adaptive and effective scheduling strategies for MEMGs.