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Highlights

- Employing IGDT strategy for decision-making considering energy uncertainty.
- Optimization of power and heat balancing for reliable and low-carbon operation.
- Recirculation of green-powered fuel within system is enabled via power-to-gas.
- Interaction of electricity-heat-gas flows is analyzed under two risk principles.

Abstract As one of the most promising large-scale de-fossilization technologies currently available, Power-to-Gas (P2G) is expected to promote utilization of renewable sources and mitigate the effects of greenhouse gas. Through the coupling of P2G, Combined Heat and Power (CHP) as well as Carbon Capture and Storage (CCS), the P2G–CCS–CHP microgrid energy system could achieve hierarchical energy transfer and green-powered interconversion of gas, electricity and heat flows. However, the conversion of multiple energy shapes between different facilities is deeply intertwined with renewable energy sources, greatly increasing risk of unbalance operation and impacting the overall robustness and economic viability of system. To address these challenges, this study proposes a decision-making framework based on Information Gap Decision Theory (IGDT) method for a P2G–CCS–CHP system. The real-time balancing of heat & power loads and supply, the mechanism of gas-electricity-heat interaction, as well as recycling pattern of synthetic fuel within the system are carefully addressed to achieve optimal operation. Different scheduling schemes are obtained by setting up two separating decision principles, namely risk-seeking (RS) and risk-avoiding (RA), to solve these uncertainties and ensure robust decision making. Meanwhile, adaptability of decision-making methodology is analyzed based on several criteria including share of recycled green-powered fuel, ecological friendliness, carbon trading benefit, etc. Results show that adding of P2G module enables a 12.6% reduction in carbon emissions and generates 1252.2 kg of green powered gas, highlighting the eco-friendly nature of the multi energy system (MES). About 21.5% of the renewable energy flows participate the interconversion of electric-heat-gas and about 17.7% of total carbon flow is circulated as synthetic fuel within the system. In addition, conservative tendency is witnessed in the case of risk-seeking decision mode, leading to an approximate 13.22% increase in the operation costs, compared with risk-avoiding mode. The proposed IGDT decision strategy has shown significant compatibility in dealing with the impact of multiple uncertainties.

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