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Abstract To support the low-carbon and sustainable operation of energy systems, this paper proposes an optimal scheduling model for an integrated electricity-heat-hydrogen energy system, considering both carbon capture and hydrogen blending technologies. The system incorporates wind turbines, gas turbines, gas boilers, coal-fired units, electric boilers, energy storage systems, and a coupled power-to-gas and carbon capture and storage (P2G–CCS) configuration. A tiered carbon trading mechanism is introduced to economically manage carbon emission costs. To address the uncertainty in wind power generation, a risk-averse strategy (RAS) model based on information gap decision theory (IGDT) is formulated to ensure robust system dispatch. Based on deterministic forecasts, three operation scenarios are designed to analyze the economic and environmental effects of introducing P2G and CCS technologies. Additionally, the robustness of the proposed model is evaluated under wind power fluctuation using IGDT. Simulation results show that the integration of P2G and CCS technologies significantly reduces total operating cost and carbon emissions, while enhancing system stability and risk resistance under uncertainty.

Keywords Integrated energy system, information gap decision theory (IGDT), carbon capture, hydrogen blending, tiered carbon trading mechanism.