Chang, Ximao; Dong, Jiaang; Wei, Riguang and Li, Ran, 2026, Optimal Scheduling of Integrated Energy System with Multiple Hydrogen Energy Applications and Carbon Capture Based on IGDT, *Journal of Chinese Society of Power Engineering*, vol. 46, issue 4, pp.198–207 (in Chinese).

DOI: 10.19805/j.cnki.jcspe.2026.240811

Keywords carbon capture; hydrogen energy application; info-gap decision theory; integrated energy system; optimal scheduling.

Abstract To tackle problems such as the low conversion efficiency of surplus wind power, high carbon emissions, and uncertainties in source and load within integrated energy system (IES), an optimization scheduling model for IES incorporating multiple hydrogen energy applications and carbon capture was proposed based on info-gap decision theory (IGDT). Initially, the power-to-gas process was subdivided into two components: electrolyzers and methanation reactors. Additionally, hydrogen energy applications including hydrogen fuel cells, hydrogen-blended combined heat and power (CHP) systems, and hydrogen-blended gas boilers were introduced to fully leverage the advantages of hydrogen energy. Subsequently, liquid-storage carbon capture was integrated and operated in coordination with hydrogen energy applications. Then, a system optimization scheduling model was established with the objective of achieving a low-carbon economy. Building on this foundation, IGDT was employed to address uncertainties in source and load fluctuations, and two scheduling strategies—risk-averse and opportunity-seeking—were formulated based on different risk attitudes. Results demonstrate that, compared with the IES model without multiple hydrogen energy applications and carbon capture, by the proposed model, the total operating cost is reduced by 16.9%, the carbon emission is decreased by 29.4%, and the conversion efficiency of surplus wind power is improved by 32.1 percentage points. Furthermore, the risk-averse strategy is found to improve the system resilience against uncertainty fluctuations, albeit at the cost of increased operational expenses. Conversely, the opportunity-seeking strategy capitalizes on favorable uncertainties to secure potential benefits, albeit with an accompanying level of risk.

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