Tiannan Ma, Gang Wu, Hao Luo, Yiran Ding, Cuixian Wang and Xin Zou, Market clearing optimization of auxiliary peak shaving services with participation of flexible resources, February 2026, *Processes*, 14(4):599, DOI: 10.3390/pr14040599

Abstract Amid China's pursuit of the "dual carbon" goals, the development and large-scale integration of renewable energy have become a core pillar of the power system transition. However, the intermittency and uncontrollability of wind and photovoltaic (PV) power have intensified peak-regulation conflicts after large-scale grid integration. Traditional coal-fired units lack sufficient flexibility to accommodate renewable energy fluctuations, while their willingness to participate in deep peak shaving remains low due to high associated costs. Addressing these challenges requires both enhanced system-level peak-regulation flexibility and effective market incentives for thermal units. Motivated by the limitations of existing studies that often consider individual flexibility resources or deterministic market mechanisms in isolation, this study investigates a coordinated multi-resource peak-regulation framework combined with an optimized market-clearing mechanism for deep peak-shaving ancillary services. First, flexibility resources are classified, and the peak-regulation mechanisms of source–load–storage coordination and auxiliary service markets are analyzed. Second, a wind–PV–thermal–storage operation cost model is established, followed by a two-layer peak-regulation market-clearing model that explicitly accounts for wind–PV uncertainty. The upper-level model minimizes total system operating costs through the coordinated dispatch of demand response and energy storage, while the lower-level model minimizes power purchase costs under a unified marginal clearing price. In addition, an uncertainty modeling framework based on Information Gap Decision Theory (IGDT) is introduced to manage renewable generation uncertainty and support decision-making under different risk preferences. Case studies are conducted to verify the effectiveness of the proposed framework. The results show that: (1) synergistic peak shaving through energy storage and demand response reduces the system peak–valley difference from 460 MW to 387.87 MW and decreases wind–PV curtailment costs from 355,000 yuan to 15,700 yuan, thereby alleviating thermal unit pressure and improving renewable energy accommodation; (2) the unified marginal clearing price mechanism reduces total system operating costs by 41.07% and significantly lowers the frequency of deep peak shaving for thermal units, enhancing their participation willingness; and (3) the IGDT-based model effectively addresses wind–PV uncertainty by providing optimistic and pessimistic scheduling strategies under different deviation coefficients. These results confirm that the proposed framework offers an effective and flexible solution for coordinated peak shaving in power systems with high renewable energy penetration.

Keywords flexible resources; peak-shaving auxiliary service market; UMCP; IGDT [Info-Gap Decision Theory]; clearing optimization.

\website\IGT\ma-etal2026abs.tex 11.2.2026