Applied Energy, vol.426, no.Part C, pp.128765, December, 2026.

A multi-bound robust optimization approach for renewable-based VPP market participation considering intra-hourly uncertainty exposure

H. Nemati; A. Ortega Manjavacas; E. Lobato Miguélez; L. Rouco Rodríguez

Abstract-

With the ongoing transition of electricity markets worldwide from hourly to intra-hourly bidding, market participants—especially Renewable Energy Sources (RES)—gain improved opportunities to adjust energy and reserve schedules and to benefit from more accurate higher-resolution forecasts. However, this shift requires participants to update decision-making frameworks and to strengthen uncertainty management in order to fully exploit the new market potential. In particular, Renewable-Based Virtual Power Plants (RVPPs) aggregating dispatchable and non-dispatchable RES must account for these changes through market-oriented scheduling methods that efficiently address multiple uncertainties, including electricity prices, RES generation, and demand consumption. In this vein, this paper proposes a multi-bound robust optimization framework to simultaneously capture these uncertainties, explicitly incorporate intra-hourly variability, such as that arising under 15-minute market resolution, and differentiate the deviation levels (frequent, moderate deviations and rare, extreme ones) of uncertain parameters. The proposed approach yields less conservative and more implementable bidding and scheduling decisions, thus improving RVPP profitability in both energy and reserve markets. Simulation studies compare the proposed method with standard robust optimization and evaluate the operational, market-strategy, and economic impacts of quarter-hourly versus hourly market resolution. Results indicate that the normalized absolute differences, across different uncertainty-handling strategies, between hourly and 15-minute schedules are 18.0–34.2% for day-ahead traded energy, and 28.7–65.6% and 10.1–16.3% for upward and downward reserve traded in the secondary reserve market, respectively. Furthermore, using the optimistic single-bound robust optimization profit as a common normalization reference, the proposed multi-bound approach achieves normalized profit gains of 24.9–49.2% across the considered strategies.

Index Terms- Renewable-based virtual power plant; Multi-bound robust optimization; Intra-hourly uncertainty; Energy and reserve markets

Due to copyright restriction we cannot distribute this content on the web. However, clicking on the next link, authors will be able to distribute to you the full version of the paper:
Request full paper to the authors

If you institution has a electronic subscription to Applied Energy, you can download the paper from the journal website:
Access to the Journal website

Citation:
Nemati, H.; Ortega, A.; Lobato, E.; Rouco, L. "A multi-bound robust optimization approach for renewable-based VPP market participation considering intra-hourly uncertainty exposure", Applied Energy, vol.426, no.Part C, pp.128765, December, 2026.