Robust Bidding Strategy for Microgrids in Joint Energy, Reserve and Regulation Markets

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***Abstract*—As a controllable entity, a microgrid (MG) can provide ancillary service (AS) for the power system operations while satisfying local load demands. The grid-friendly nature of the MG can be fully utilized by coordinating various distributed energy resources (DERs). In this study, a robust bidding strategy is developed for MGs serving as price-takers in joint energy, reserve and regulation markets. By coordinating various DERs, including wind turbines (WTs), photovoltaic panels (PVs), micro-turbines (MTs) and energy storage systems (ESSs), the MG is able to strategically allocate the capacities. To address the uncertainties in renewable generation and market prices, a hybrid stochastic/robust optimization (RO) technique is adopted. Case studies validate the effectiveness of the proposed bidding model and approach.**

I. Introduction

As a controllable entity, an MG is able to provide energy and ASs for the power system by coordinating various DERs. This grid-friendly manner is helpful for accommodating renewable energy and maintaining the reliable operation of the power system. Therefore, with the rapid increase of DERs, it is significant to exploit the potentials of the MGs to provide flexibility for the power system. In this study, a robust bidding strategy is developed for MGs serving as price-takers in joint energy, reserve and regulation markets. The market framework of the Electric Reliability Council of Texas (ERCOT) is adopted, shown in Fig. 1.

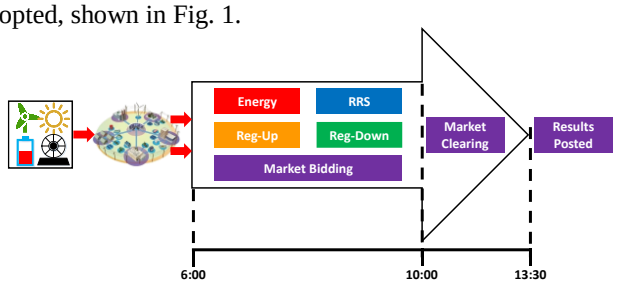

Fig. 1 The market framework of ERCOT.

An MG bids in the day-ahead energy and AS markets. The ASs include Responsive Reserve Service (RRS), Regulation Up (Reg-Up) Service and Regulation Down (Reg-Down) Service. The bidding strategy has to be decided and submitted before the closure time (10:00 a.m.) of the day-ahead markets.

II. Robust Bidding Model for Microgrids

By coordinating various DERs, the MG is able to strategically allocate the hourly capacities in energy and AS markets. The objective is as follows:

$$\max_{\substack{Bidding\\Capacity}} \min_{\substack{Renewable\\Energy}} \sum_{\substack{Price\\Scenario}} weight \cdot \left(R^{Energy} + R^{RRS} + R^{REG} - Cost \right) \quad (1)$$

The constraints include the operational constraints of WTs, PVs, MTs and ESSs. The robust bidding model is aimed at maximizing the total revenues from energy and AS markets against the worst-case scenario caused by the uncertainties in wind and photovoltaic power. In the proposed model, the market prices are modeled by scenario-based stochastic programming. RO is adopted to address the uncertainties in renewable power. Then the model can be transformed into a mixed-integer linear programming (MILP) problem by introducing dual and auxiliary variables.

III. Case Studies

A real-world MG in ERCOT is tested. Three cases are designed to demonstrate the effectiveness the proposed model. In Case 1, the MG bids in joint energy and AS markets with high robustness conservatism; In Case 2, the MG only bids in the energy market with high robustness conservatism; In Case 3, the MG bids in joint energy and AS markets with low robustness conservatism. The optimal bidding strategies of the MG in Case 1 are shown in Fig. 2. The revenues from different markets in the three cases are shown in TABLE I.

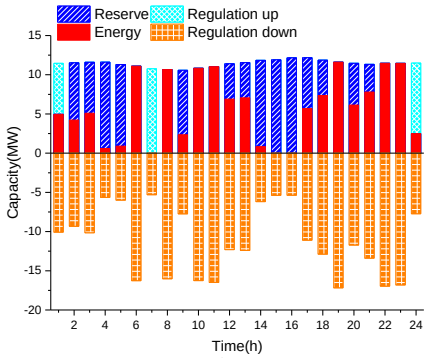

Fig. 2 The optimal bidding strategies of the MG in Case 1.

TABLE I Revenues from Different Markets

	Energy ($)	Reserve ($)	Regulation ($)	Total ($)
Case 1	1401.42	2467.67	2786.38	6655.47
Case 2	2854.39	0	0	2854.39
Case 3	2006.76	2574.13	2979.86	7560.75

Comparing the results in Case 2 and Case 1, the MG can further increase its day-ahead revenues by bidding in reserve and regulation markets. Comparing the results in Case 3 and Case 1, because the MG expects more renewable generation in real time with smaller robustness conservatism, more revenues can be earned from day-ahead markets.