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A multistage stochastic approach for the optimal bidding of variable renewable energy in the day-ahead, intraday and balancing markets

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ABSTRACT

Market agents with renewable resources face amplified uncertainty when forecasting energy production to securely place bids in electricity markets. To deal with uncertainties, stochastic modelling has been applied to optimize the bidding strategy of these market agents. However, studies found in the literature usually focus on day-ahead and balancing markets, leaving aside intraday markets that could be used to correct bidding positions as uncertainty gets resolved. This paper proposes a multistage stochastic decision-aid algorithm based on linear programming to optimize the bidding strategy of market agents in three different electricity markets - day-ahead, intraday, and balance markets. The market agent represents a Virtual Power Plant with wind, solar PV, and storage technologies, and its participation in three electricity markets was compared to the participation in DA and BM markets only. Results show that participating in all three markets increased the profit achieved by the VPP agent by 10.1% while also decreasing the incurred imbalances by 63.8%. The results demonstrate that having accurate tools to deal with the multi-settlement framework of electricity markets while considering the uncertainties of daily operations is key to a successful integration of renewable energy resources into electricity markets and power systems.

1. Introduction

1.1. Motivation

Due to the dissemination of accessible and currently ubiquitous Information and Communication Technologies (ICTs) [1], several new market agents - including aggregators, hybrid power plants, and Virtual Power Plants (VPPs) [2] - are now contributing to the provision of energy services in many countries. These agents endow distributed *renewables* with some control over energy production and storage systems, giving them the flexibility of operation [3] and the risk reduction necessary for full active participation in electricity markets [4] as well as meeting local demand for electricity both in stand-alone and grid-connected systems [5]. Using new techniques (*e.g.*, artificial intelligence [6,7]) energy actors such as aggregators and VPPs allow different small-scale renewable power plants to benefit from the economy of scale and market knowledge necessary to increase their revenues. This capability ultimately reduces the need for subsidized tariffs [8] by giving them dimension and visibility to system operators and electricity markets. Despite their beneficial contributions, these new energy actors still face significant barriers to entry in some European markets. The main challenge stems from the high spatial and temporal variability of the renewable natural resources [9], which ultimately translates into considerable difficulties when forecasting energy production [10,11] to securely place bids in the electricity markets. In fact, this increased uncertainty could also have implications for other market agents, such as gas-fired power plants, as discussed in Ref. [12] where authors simulated scenarios varying wind power levels to study the effect of wind power levels on market behaviors and system operations.

In a symmetric and voluntary pool market, as is the case of most European energy markets, both the generators and the demand units send their buying/selling offers (indicating the volume of energy and price) to the energy market operator ahead of time [13]. For instance, a market agent participating in the day-ahead market needs to place bids in day D-1 for all hours of day D. Market agents with controllable power plants (like natural gas or hydro) have only

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