Foreword for the special section on wind and solar energy: uncovering and accommodating their impacts on electricity markets

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I. CONTEXT AND MOTIVATIONS

ELECTRICITY network and markets were designed based on a long history of dealing with various forms of dispatchable generation, as well as a fairly predictable inelastic electricity consumption pattern, in a centralized top-down manner. Little uncertainty was involved on both generation and demand sides, hence allowing for a design of electricity markets accounting for the necessity of a forward optimal allocation, with a real-time mechanism supporting actual power system operation. An excellent overview of electricity markets in the USA was given in [1], complemented by a discussion of their future evolution. This paper is a perfect example of the rate at which the context evolved over the last decade since, when published in 2005, this article did not mention the potential role of renewables in evolving electricity markets. For comparison, the discussion on the potential impact of wind energy on electricity markets was already initiated in Denmark [2], where instantaneous wind penetration had reached 100%.

Owing to the ever-increasing penetration of variable renewable energy (wind and solar photovoltaic) generation in power systems, the electricity market paradigms of today are being challenged. Their zero marginal cost, combined with their inherent variability and limited level of predictability, has led to a growing consensus such that (potentially radical) changes in electricity market design and operations are required; see [3] for instance. Besides, the inherent differences in the way these markets were originally designed, for instance in Europe and in the USA [4], may clearly influence the necessary developments for optimal integration of distributed energy resources, e.g., depending upon grid considerations and operational practice. A review of recent evolutions of electricity markets towards better integration of renewables (as well as demand response) can be found in [5]. On the academic side, a number of scholars are investing substantial efforts in developing and benchmarking new proposals for the integration of renewables in electricity markets, while also bringing these ideas to students and young researchers for them to eventually contribute to tackling these challenges ahead of us. For a comprehensive overview, the reader is referred to [6].

For the case of some European countries with substantial renewable energy penetration already, e.g., Germany and Denmark, negative effects on power system operation as well as on investment in the capacities necessary to insure acceptable levels of power system reliability are being observed. Such a context motivated the proposal for this special section of the
the reasonable computational costs necessary to obtain the commitment and dispatch solutions. This could hence make it a relevant candidate for practical implementation.

Another promising approach to revisiting market-based operation of power system would consist in revisiting the ways reserves, allowing to subsequently cope with unforeseen events, are defined. The proposal of Lyon et al. [10] is to consider dynamic reserve policies following a zonal model, where the reserve zones are determined prior to clear the day-ahead market. The implications in terms of costs and payments, system reliability, as well as market transparency, are subsequently analyzed.

More generally, considering the way electricity markets may be impacted by renewables, De Sisternes et al. [11] describe an elegant market modeling setup allowing to analyze the impact of bidding rules and regulatory uncertainty on revenues and consumer costs, even for complex market setups in terms of bidding rules. Their proposal framework then allows them to look at transitory regimes where market setups and generation mix are not adapted to the share of renewables in the system, which is likely to be the case for nearly all electricity markets worldwide.

For electricity markets where new products are thought of and designed in order to better accommodate the variability of renewable power generation, while rewarding units providing such services, limited knowledge exists on the potential strategic behavior of these service providers, especially in a network-constrained setup. In that vein, Moiseeva et al. [12] propose a comprehensive game-theoretical framework permitting to analyze strategic behavior of units offering ramping capability.

Still focusing on strategic behavior, but on the side of renewable energy producers, it is also of utmost importance to analyze and understand how their potential forming of coalitions could bring positive and/or negative effects to electricity markets. Zhang et al. [13] look at this problem of coalition formation under uncertainty in power generation (and resulting penalties induced by resulting balancing needs), proposing a formulation permitting to derive interesting conclusions on the impact of coalition formation. Their analysis supports the idea that beneficial coalition of renewable energy producers would indeed exist, having the effect of reducing uncertainty while not necessarily yielding market power.

Besides market operation and gaming aspects, potential strategies for transmission and generation expansion planning are significantly affected by the increased penetration of renewables. Studying these problems require the formulation of complex optimization problems reflecting the game-theoretical aspects involved. The proposal of Maurovich-Horvat et al. [14] is a representative example of employing hierarchical optimization to compare different setups for transmission and wind investment in a deregulated environment. In parallel, Levin and Botterud [15] describe a mixed-integer program for generation expansion, allowing to analyze the impact of increased deployment of wind power generating capacity on revenues of conventional generators. This framework is subsequently employed to discuss profitability for thermal and peaking units based on a simplified case-study for Illinois.

III. Closing

Finally, we must acknowledge the efforts of the authors and reviewers who have worked hard on improving the contents of the various papers, in order to sharpen the original ideas proposed, and to optimize their presentation. Prof. Antonio Conejo, Editor-in-Chief for the journal, ought to be acknowledged for his support and guidance all along the process of preparing this special section, from discussing the original proposal to its finalization.

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