Book Review

Fernando Lopes, Helder Coelho, Eds., *Electricity Markets with Increasing Levels of Renewable Generation: Structure, Operation, Agent-based Simulation, and Emerging Designs*, Springer, Cham, 2018; ISBN: 978-3-319-74261-8

The electricity industry has been in the forefront of the energy sector since the industrial era. During the last decades, with the technological leaps in the IT sector and the strong shift in the utilization of renewable energy sources, the industry faces new challenges. Furthermore, the globalization of the energy markets and the need for energy security has led to the creation of strong internal markets, with the European Countries being a prime example. Starting from the initial harmonization of the technical regulations in these markets, the shift from fossil based generation to renewable, extending to the wholesale market and price coupling and leading to the integrated day-ahead market, new challenges and opportunities arise for current and future energy practitioners.

With the constant increase in the installed capacity of wind and solar electricity systems, which are expected to continue, and the need to keep on reserve existing thermal power plants as back-up, the transformation of current energy systems will rely heavily on cross-border trade and higher network adequacy needs, according to the International Energy Agency (IEA). So, electricity markets need to evolve, integrating both cross-border balancing and intra-day markets and thus, ensuring that wholesale markets are fully functioning. This will not be achieved without the utilization of smart grids and meters as an efficient way to share reserve capacity on a wider scale and balance the grid. Technology offers more alternatives in the form of pricing policies, dynamic tariff systems that take into account demand side response, etc which take into consideration the ever expanding penetration of renewable variable generation.

The book by Fernando Lopes and Helder Coelho, “Electricity Markets with Increasing Levels of Renewable Generation: Structure, Operation, Agent-Based Simulation and Emerging Designs” covers a distinct gap in the literature covering how electricity markets are expected to operate in the near future and how they should be modelled, taking into consideration the introduction of agent based modelling in the simulation of the, constantly increasing in complexity, energy markets.

The book is divided into three parts of 11 chapters in total, which cover the Electricity Markets and Autonomous Computational Agents, Electricity Markets with Large Penetrations

of Variable Generation and Agent Based Simulation of Electricity Markets with Increasing levels of Variable Generation.

As the book caters to the needs of both traditional energy practitioners and IT specialists in the field, the first part covers the basics of electricity markets as well as software agents providing readers with a solid understanding of the concepts associated with the development of models and systems for the electricity markets.

More specifically, Chapter 1 introduces the electricity market types for the various related products, such as energy reserves, transmission rights, and capacity, along with a list of the potential impacts from the variable generation on market outcomes. Chapters 2 and 3 present a general framework for agent-based simulation of electricity markets. The framework is based on a coherent set of concepts, along three groups of dimensions: market architecture, market structure, and software agents. The framework aids in comparing different related research efforts and enables the development of future models and systems. Chapter 2 presents the architecture of power markets, including the three key market sectors of wholesaling, retailing, and central coordination and transmission, along with some important market types, such as pool and bilateral, and discusses the role of the main entities operating in electricity markets. Chapter 3 presents some important features of agency, such as agent architecture and capabilities and discusses various agent types, namely reactive, model-based, goal-based, utility-based, and learning agents and important agent characteristics, such as autonomy, proactiveness, social ability, and adaptability.

In the second part the authors tackle the challenges associated with the ever-increasing penetration of renewable energy sources in the electricity mix and the corresponding variable generation issues. This comes just as most European Countries are about to retire a substantial share of their fossil based power generating capacity in the coming years and substitute them with low-carbon technologies. In order for this transition to be seamless and successful, energy markets specialists will need to achieve efficient energy pricing by integrating investments at the right location and time.

Specifically, Chapter 4 looks at the current status of the Nordic power market, analyzing the hourly market data for Western Denmark for a period of 10 years, particularly the occurrence of extreme events, concluding that the current market design was able to handle the amount of the installed wind power efficiently. On the other hand, the hydro power capacity was limited, and larger penetrations of wind power would require additional measures. Chapters 5 and 6 focus on two key issues related to market design: incentivizing flexibility in short-term operations and revenue sufficiency for long-term reliability. Actually,

Chapter 5 discusses whether existing markets provide adequate incentives for suppliers to offer their flexibility into markets to meet the increased levels of variability and uncertainty introduced by variable generation. It presents in depth market design features to incentivize flexibility, both existing, such as scheduling, dispatch, settlement intervals, ancillary service markets, payment / profit guarantees, and emerging, such as pay-for-performance regulation, primary frequency control, convex hull pricing, and flexible ramping provision. Then, Chapter 6 discusses whether suppliers have enough opportunity to recover their variable and fixed costs to remain in the market, focusing on the investment time horizon and the installation of adequate generation capability. The chapter also describes two primary market mechanisms adopted by electricity markets to mitigate resource inadequacy and revenue insufficiency, namely scarcity pricing and forward capacity markets, discussing recent market design changes to address issues due to increased variable generation, such as dynamic demand curves for operating reserve and forward flexible capacity requirements. Finally, Chapter 7 examines the impact of significant levels of Variable Generation on reliability requirements by considering three situations: open cycle gas turbines only, plus wind power plants, and plus nuclear plants by using data from the Swedish market and comparing the results with nuclear power, alone.

The third part covers the agent-based simulation of electricity markets, with specific emphasis on the impacts that variable generation has on the electricity markets and how demand response techniques can be used in order to provide economically viable solutions.

Chapter 8 presents an agent-based simulation tool, called MATREM, for the simulating of the behavior and outcomes of electricity markets with Variable Generation. The tool supports power exchange (day-ahead and intra-day markets) and derivatives exchange, i.e. futures market for bilateral contracts. The tool can model marketplaces for negotiating the details of long-term bilateral contracts by representing as BDI agents various market entities involved, such as generating companies, retailers, consumers and market operators. Then, Chapter 9 discusses the global policy landscape of variable generation and the merit order effect (MOE), followed by investigating a Portuguese case study where the MOE effect achieved a reduction in the day-ahead prices of wind power, using the MATREM tool. Next, Chapter 10 examines demand response in electricity markets to incentivize system flexibility and help managing the variability and uncertainty introduced by Variable Generation. Two such programs in Spain and Portugal are examined using the MATREM tool, and recommendations for consideration by state institutions, system operators, electric utilities, and other market participants to foster demand response are presented. Finally, Chapter 11

combines the simulation of electricity markets and smart grids with the physical emulation of laboratory micro-grids conveying an additional impact to agent-based modeling and simulation of power and energy systems. The chapter presents to new tools for multi-agent simulation of electricity markets and multi-agent smart grid, called MASCEM and MASGriP, respectively, along with a case study of a smart grid of several real loads, such as residential houses and buildings and one commercial building, distributed generation (photovoltaic and wind power) and storage units.

Concluding, the book explores in depth the intersection between electricity markets and multi-agent systems. To the best of our knowledge this is the first single volume that tries to achieve this, having a large scope, from more traditional to emerging electricity markets and from market design to agent-based simulation. The book covers theory, avoiding excessive formalisms but retaining precision, as well as practice, presenting real-world case studies and simulation tools for modeling and evaluating electricity markets. Last, but not least, we have to admit that although this is an edited book and each chapter has a different list of authors, the content, the organization and the coherency of the book have been carefully ensured by the editors.

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