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A two-stage stochastic programming model for electric energy producers

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Abstract

The bilateral contract selection and bids definition constitute a strategic issue for electric energy producers that operate in competitive markets, as the liberalized electricity ones. In this paper we propose a two-stage stochastic integer programming model for the integrated optimization of power production and trading which include a specific measure accounting for risk management. We solve the model by means of a novel enumerative solution approach that exploits the particular problem structure. Finally, we report some preliminary computational experiments.

Keywords: Electricity markets; Power optimization; Stochastic integer programming.

1. Introduction

In the last few years a liberalization process has spread over many electricity markets around the world, generating deep changes in an economic context that has been very conservative for a long time. In particular, the electricity industry is evolving into a distributed and competitive framework in which market forces drive the price of electric energy. The main difference with respect to the previous structure has been the introduction of competition into the different phases that characterize the electric system. In many countries the new competitive paradigm provides two ways for the generation companies (GENCOs, for short) to sell electric energy:

- a power pool, i.e. an e-commerce marketplace articulated in sessions where producers and consumers submit production and consumption bids, respectively;
- bilateral contracts, that are independent agreements between producers and eligible consumers.

This paradigm reflects a hybrid model of market structure that offers a true customer choice and encourages the creation of a wide variety of services and price options to best meet individual customer needs. A detailed description of the liberalized electric market features can be found in [1].

In this new context the operators have to face new operational problems for the efficient management of their activities, since new issues, such as, for example, the market price forecasting and the risk management, have become critical [2].

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For a long time, the well-known Unit-Commitment problem has represented the main modeling approach for the production-side efficient management in markets based on thermal production. Besides the classical deterministic versions of this problem (see for example [3–5]), many efforts have been carried out in order to define mathematical models that could explicitly deal with the uncertainty that characterizes the production activity. Examples in this direction have been the works of Jacobs et al. [6], who applied the stochastic programming framework for hydroelectric generation scheduling, Takriti et al. [7] and Nowak and Romisch [8], who formulated Unit-Commitment models under uncertainty, Fleten et al. [9], who proposed a model that combines hydroelectric system generation as well as investments in financial markets. Sen et al. [10] have proposed a comprehensive approach for production decisions and opportunities in the wholesale power market in which statistical models of the markets and decision models for the producer are integrated.

With the liberalization of electricity markets the main objective in power optimization has shifted from cost minimization to profit maximization by taking into account the new trading instruments that the market offers. Thus, the simultaneous optimization of power production and trading has become a crucial issue. In this respect, we cite the recent contribution of Nowak et al. who in [11] have proposed a two-stage stochastic integer model for the simultaneous optimization of power production and day-ahead power trading. Here the main source of uncertainty is related to foreign bids. In [12] the authors have proposed a mathematical model aimed at optimizing energy offers into an electricity pool market. The dynamic programming framework is used to construct optimal offer stacks in successive time periods over a fixed planning horizon. A multi-stage stochastic programming model to optimize capacity allocation on multi-auction energy markets, taking into account the uncertainty due to the different market session outcomes, has been proposed in [13].

In this paper we address the problem of defining the optimal allocation of the production capacity over a fixed planning horizon by considering two main selling possibilities, that is the bilateral contracts and the selling bids to submit on the day-ahead market. It is worthwhile noting that the evaluation of these two alternatives is carried out with a different frequency and on the basis of a different level of available information. In particular, bilateral contracts are evaluated some weeks (or months) before the production period they refer to. Their selection is carried out considering the residual capacity of the generation plants and preliminary estimations about market prices for the periods interested by the contracts. Selling bids are submitted on the market until the day before the periods they refer to. Their definition must take into account the generation profile, the existing contracts and a more accurate forecast about market prices.

We observe that the two selling alternatives allow to pursue different strategic aims. For example, usually the acceptance of bilateral contracts implies to sell energy for a medium–long time with lower revenues than the corresponding market prices. Apparently this choice can seem poorly profitable but it guarantees a certain production level and sure revenues for some periods. On the other hand, the bidding strategy could aim at achieving higher profit levels, accepting the risk due to the uncertainty that characterizes the market outcomes. Moreover, some bids could be defined in order to avoid discontinuities in the generation profile. To sum up, the planning process should take into account the profitability of the contracts, the effects on the production scheduling and the possibility to offer the energy on the market.

It is evident that the whole production planning is a complex decision-making problem, whose solution is highly influenced by the evolution of the economic and operative conditions which are not known when decisions have to be taken. Hence, the definition of a suitable model requires the explicit consideration of the main sources of uncertainty affecting the decisional problem: solutions based on expected value or worst-case evaluations can result in poor or even infeasible recommendations. To this aim, we have considered the stochastic programming framework [14] where uncertainty is represented by a probabilistic model, i.e. uncertain data are modeled by random variables defined on a given probability space typically assumed discrete. Within the stochastic programming, the nature of the decisional process has suggested to consider the two-stage paradigm. Here, the decision variables are partitioned into two different subsets: the first-stage decisions, i.e. actions to undertake in face of uncertainty and the second-stage decisions, i.e. corrective actions to choose after the realization of the random variables. In our problem, it is evident that decisions regarding the bilateral contracts represent first-stage actions, whereas decisions on the selling bids are second-stage decisions since they are influenced by the uncertain market outcomes.

In order to put our contribution within the scientific literature, we observe that to the best of our knowledge the problem introduced above has not been addressed before. The only interesting contribution in the same direction is due to Escudero, who in the discussion of the paper of Conejo and Prieto [15], defined a two-stage stochastic programming model for the bilateral contracts selection that takes into account the uncertainty due to the market operations and proposed different approaches for both price-maker and price-taker operators.