Electric Power Systems Research 80 (2010) 760–769

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Stochastic multiobjective self-scheduling of a power producer in joint energy and reserves markets

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ARTICLE INFO

Article history:
Received 16 June 2009
Received in revised form
14 November 2009
Accepted 27 November 2009
Available online 28 December 2009

Keywords:
Stochastic self-scheduling
Multiobjective optimization
Emission quota arbitraging
Bidding strategy

ABSTRACT

This paper presents a stochastic multiobjective model for self-scheduling of a power producer which participates in the day-ahead joint energy and reserves markets. The objective of a power producer is to compromise the conflicting objectives of payoff maximization and gaseous emissions minimization when committing its generation of thermal units. The proposed schedule will be used by the power producers to decide on emission quota arbitrage opportunities and for strategic bidding to the energy and reserves market. The paper analyzes a scenario-based multiobjective model in which random distributions, such as price forecasting inaccuracies as well as forced outage of generating units are modeled as scenarios tree using a combined fuzzy c-mean/Monte-Carlo simulation (FCM/MCS) method. With the above procedure the stochastic multiobjective self-scheduling problem is converted into corresponding deterministic problems. Then a multiobjective mathematical programming (MMP) approach based on ε-constraint method is implemented for each deterministic scenario. Piecewise linearized fuel and emission cost functions are applied for computational efficiency and the model is formulated as a mixed-integer programming (MIP) problem. Numerical simulations for a power producer with 21 thermal units are discussed to demonstrate the performance of the proposed approach in increasing expected payoffs by adjusting the emission quota arbitrage opportunities.

1. Introduction

The objective of a power producer in competitive electricity markets is to maximize the expected value of profit over a given period. This paper considers a day-ahead joint energy and reserves market based on a pool in which every power producer would be responsible for its own decision on bidding in different markets [1].

As indicated in [2], the approaches for developing bidding strategies could be categorized into: equilibrium (game theoretic based) models and non-equilibrium models. Although equilibrium models, which are mainly based on the Nash equilibrium concept of game theory, were broadly employed for developing suppliers' bidding strategies and analyzing market power in energy markets [3,4], however, units' operational constraints such as ramp up/down limits, and minimum on/off time were not taken into account in most of the equilibrium models because the existence of equilibrium point could not be proven when integer variables were used in those models. Consequently, the simulated market equilibrium without considering the operational constraints of the units could not be applicable for real-world systems. Nonetheless, game theoretic models would be applicable for analyzing the potential market power of a power supplier and the optimal bidding strategy of price maker producers.

Moreover, different self-scheduling approaches as the non-equilibrium models have been reported for developing bidding strategies which are based on the deterministic price-based unit commitment by using the day-ahead forecasted prices [5,6]. However, there are many uncertainties in power systems such as forced outage of generating units as well as price forecasting inaccuracies (due to the electricity market dynamics) which is ignored by the above-mentioned references. As a result, stochastic self-scheduling techniques for scheduling of the power suppliers in uncertain trading environment have proposed in the literature.

A risk-constrained bidding strategy was proposed in [2] for a generation company (GENCO) to devise optimal bids in the day-ahead energy and ancillary services markets. The problem is formulated as a stochastic mixed-integer programming (MIP) and solved by commercial MIP solver. The tradeoff between maximizing expected payoff and minimizing risk due to the market price uncertainty is modeled explicitly by including the expected downside risk as a constraint. The self-scheduling problem of a price taker power producer with special focus on risk modeling was analyzed in [7] in which the revenue is characterized as a random

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doi:10.1016/j.epsr.2009.11.007