Electric Power Systems Research 80 (2010) 9–18

Contents lists available at ScienceDirect

Electric Power Systems Research

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

Electricity market equilibrium model with resource constraint and transmission congestion

F. Gao[a,*,1], G.B. Sheble[b,2]

[a] ABB, Inc., Santa Clara, CA 95050, USA
[b] Portland State University, Portland, OR 97207, USA

ARTICLE INFO

Article history:
Received 11 September 2007
Received in revised form 6 August 2008
Accepted 24 July 2009
Available online 23 September 2009

Keywords:
Bidding strategy
Electricity market
Nash equilibrium
Optimal control
Supply function equilibrium
Transmission planning

ABSTRACT

Electricity market equilibrium model not only helps Independent System Operator/Regulator analyze market performance and market power, but also provides Market Participants the ability to build optimal bidding strategies based on Microeconomics analysis. Supply Function Equilibrium (SFE) is attractive compared to traditional models and many efforts have been made on it before. However, most past research focused on a single-period, single-market model and did not address the fact that GENCOs hold a portfolio of assets in both electricity and fuel markets. This paper first identifies a proper SFE model, which can be applied to a multiple-period situation. Then the paper develops the equilibrium condition using discrete time optimal control considering fuel resource constraints. Finally, the paper discusses the issues of multiple equilibria caused by transmission network and shows that a transmission constrained equilibrium may exist, however the shadow price may not be zero. Additionally, an advantage from the proposed model for merchant transmission planning is discussed.

1. Introduction

In US, pre-deregulation the wholesale electricity price is set and regulated by FERC or State Public Utility Commission (SPUC). A vertical integrated electric utility only operates based on cost minimization in a short-run, and keeps a rate of return supervised by FERC or SPUC in a long run.

Current industry structure generally requires separating the functions associated with selling and buying electric energy, the generation and distribution (or consumption), from transmission. Market participants have to face the volatility of price and make sure profitable in a long run. Instead of discussing all of players, this paper will mainly focus on the short-run operation strategies of GENCOs. The traditional economic dispatch (EDC) and unit commitment (UC) programs used by electric utilities for many years are only helpful to GENCOs who own multiple generation facilities when they make one offer to the market and then need to dispatch their units in the most economic fashion to deliver this offer. A profit based bidding decision support system is critical for GENCOs to operate in the new environment.

The previous research on bidding strategies is methodologically classified into the following three groups.

1.1. Pure optimization model

The first group of research pays attention to a specific player, the one under study. The idea is to simplify "the rest of the world" as a set of exogenous variables (stochastic or deterministic). The group of study has developed many mathematical programming models to find an optimal bidding strategy (*e.g.* Dynamic Programming, Fuzzy Linear Programming, and Stochastic Dynamic Programming, etc.). A bidding strategy using Markov Decision Process (MDP) is proposed in [1]. The authors discussed the impacts of production limit and market share on optimal bidding strategies. The number of states is reduced by classifying peak/off-peak load, peak/off-peak price. A decision aid for scheduling and hedging (DASH) model is proposed in [35] for power portfolio optimization. The inputs of the model, electricity demand, electricity forward price, gas forward price, and electricity spot price are captured by several stochastic processes. A multiple time scale decision-making problem is solved considering both long-term financial and short-term operational constraints. The group of models is usually easier to generalize and analyze because of well-established mathematical foundation. The disadvantage is that the methods do not model the behavior aspect of players.

* Corresponding author. Tel.: +1 408 2346805.
E-mail addresses: feng.gao@us.abb.com (F. Gao), gbsheble@pdx.edu (G.B. Sheble).
[1] Member, IEEE.
[2] Fellow, IEEE.

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doi:10.1016/j.epsr.2009.07.007