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Risk-constrained optimal strategy for retailer forward contract portfolio

Abdollah Ahmadi [a], Mansour Charwand [b], Jamshid Aghaei [c,*]

[a] Department of Electrical Engineering, Iran University of Science and Technology, Tehran, Iran
[b] Department of Electrical Engineering, Tarbiat Modares University, Tehran, Iran
[c] Department of Electrical and Electronics Engineering, Shiraz University of Technology, Shiraz, Iran

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ABSTRACT

In the medium term planning, the objective of an electricity retailer is to configure its forward contract portfolio and to determine the selling price offered to its clients. To procure the electricity energy to be sold to the clients, a retailer has to face by two major challenges. Firstly, at buying electricity energy, it must cope with uncertain pool prices and sign forward contracts at higher average prices. Secondly, at selling electricity, it should handle the demand uncertainty and consider this fact that customers might choose a different retailer if the selling price is not competitive enough. In this paper the financial risk associated with the market price uncertainty is modeled using expected downside risk, which is incorporated explicitly as a constraint in the mixed-integer stochastic optimization problem. Roulette wheel mechanism and Lattice Monte Carlo Simulation (LMCS) are employed for random scenario generation wherein the stochastic optimization problem is converted into its respective deterministic equivalents. The proposed optimization problem is solved by a decomposition technique using Benders decomposition algorithm. A realistic case study is implemented to demonstrate the capability of the proposed method.

1. Introduction

During the past two decades, the electric industry throughout the world has been subjected to major changes. The power industry has moved from a vertically integrated structure to a more competitive one. The restructuring of electric industry has changed the role of traditional entities and created new entities such as Generation Companies (GENCOs), regulated Transmission Companies (TRANSCOs), and Load Serving Entities (LSEs). In this new environment, entities such as retailers have been emerged acting as intermediaries between GENCOs and customers. A retailer buys electricity power and other ancillary services and sells them to its customers directly in retail markets or indirectly through aggregators [1].

Many researchers have focused on the wholesale side; few references are found focusing on the retail electricity market. In [2], the tools and techniques needed for customers and retailers to actively participate in an electricity market are presented. In [3], a decision-making framework for a retailer based on the stochastic programming is proposed to determine the electricity sale price to the customers on the basis of the Time-Of-Use (TOU) rates and manage a portfolio of different contracts in order to procure its demand and to hedge against risks within a mid-term period. In [4,5], a stochastic programming methodology is proposed to determine the optimal selling price based on the fixed pricing and the amounts of power purchased from the pool and forward contracts. In addition, some options such as call options and self-production units are used in [5]. Ref. [6] presented a two-stage stochastic programming approach to solve the mid-term decision-making problem faced by a power retailer with the goal to maximize the expected profit at a given risk level while Conditional Value-at-Risk (CVaR) has been used to limit the volatility of the expected profit. Ref. [7] proposed a strategy for offering optimal price to customers based on load profile clustering techniques that uses an improved weighted fuzzy average *K*-means. In [8], a medium and a short term strategy for a retailer are proposed that in the short-term program, the amount of energy purchased from the pool and the amount of interruptible load are determined while the quantity of energy bought from bilateral contract and selling price are settled through medium-term decisions.

In [9], a stochastic optimization model is proposed to determine the optimal electricity sale price to customers. Also, this model is used to determine the amount of power purchased from options such as pool market and bilateral contracts. The risk of spot market transactions is modeled by a semi-variance approach. In [10], new electricity retail market model is developed considering price risk of electricity retailer, called Capital Asset Pricing Model (CAPM). The CAPM is demonstrated to determine the retail electricity price for the end users while the retailer purchases electricity only from

* Corresponding author. Tel.: +98 912 586 5573; fax: +98 0711 7353502.
E-mail address: aghaei@sutech.ac.ir (J. Aghaei).

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Nomenclatures

Sets

t	set of hours
ω	set of scenarios
i	set of blocks in the price-quota curves
f	set of forward contracts
j	set of power blocks in the forward contracting curves
l	set of client groups

Constants

T	number of time periods
Ω	number of scenarios
N_I	number of blocks in the price-quota curves
F	number of forward contracts
N_J	number of power blocks in the forward contracting curves
L	number of client groups
$\bar{E}^R_{l,i,t}(\omega)$	energy associated with block i of the price-quota curve of client group l in period t and scenario ω (MW h)
$\bar{\gamma}^R_{l,i}$	upper limit of the price in block i of the price-quota curve pertaining to client group l (€/MW h)
$\bar{P}^F_{f,j}$	upper limit of the power contracted from block j pertaining to the forward contracting curve of forward contract f (MW)
$\lambda^F_{f,j}$	price of block j pertaining to the forward contracting curve of forward contract f (€/MW h)
z_0	targeted profit
$\pi(\omega)$	probability of a scenario

Variables

C^F_t	cost of purchasing from forward contracts in each period (€)
$C^P_t(\omega)$	net cost of trading in the pool in period t and scenario ω (€)
P^F_f	power purchased from contract f (MW)
$P^F_{f,j}$	power purchased from the jth block of the forward contracting curve belonging to contract f (MW)
$E^R_{l,t}(\omega)$	energy supplied by the retailer to client group l in period t and scenario ω (MW h)
$E^P_t(\omega)$	energy traded in the pool in period t and scenario ω (MW h)
$\rho^P_t(\omega)$	energy price in the pool in period t and scenario ω (€/MW h)
γ^R_l	selling price settled by the retailer for client group l (€/MW h)
$\gamma^R_{l,i}$	price of the ith interval of the price-quota curve for client group l (€/MW h)
$IN^R_{l,t}(\omega)$	revenue obtained by the retailer from selling to client group l in period t and scenario ω (€)
$\tilde{\lambda}^p$	dual variables of inequalities in the feasible slave problem
$\tilde{\lambda}^r$	dual variables of inequalities in the infeasible slave problem
$A_{l,i}$	binary variable which is equal to 1 if the selling price offered by the retailer to client group l belongs to block i of the price-quota curve, otherwise 0
$k(\omega)$	auxiliary binary variable for one scenario.
$RISK(\omega)$	downside risk for a scenario
$EDR(z_0)$	expected downside risk for a given target profit
$PROFIT(\omega)$	profit in scenario ω (€)

the pool market. The Risk Adjusted Recovery On Capital (RAROC) factor is used to quantify the price risk in the proposed model. The suggested model in [10] has been extended by [11] to use the RAROC risk index for a retailer to be simultaneously contributed in pool market and bilateral contracts. An analytical method for optimal purchase allocation and demand bidding are discussed in [12]. Optimizing the behavior of a large purchaser in Norway having the ability to purchase from the day-ahead or the real-time market is studied in [13]. A techno-economic model for calculating the optimal electric power and energy selling prices is addressed in [14]. Also, determination of appropriate future load of a retailer is discussed in [15,16]. Ref. [17] presents a fundamental model to evaluate the risk of a retailer and a methodology for its use. Also, this paper compares its analytical performance with traditional techniques obtained from the option-pricing theory. Ref. [18] models an entity that its objective is to exchange energy between GENCOs and customers with minimum cost (end-users) through its own units, bilateral contracts and pool market. Also, [18] has used contract-for-differences for modeling of forward contracts. Also, in the proposed model in [18], financial risk has been considered using CVaR index.

The problem of electricity procurement for a large consumer from the pool market or bilateral contracts is addressed in [19]. Risk in [19] has been modeled by Markowitz approach and objective function is to minimize the expected cost of electricity procurement for large consumer considering three different cases; (i) buying from the pool, (ii) buying from retailers or generators through bilateral contracts, and (iii) self-production, taking uncertainty into consideration in the electricity pool prices.

The main contributions of this work with respect to the earlier ones can be briefly summarized as follows:

(1) A new stochastic midterm framework has been proposed for an electricity retailer including objective functions like expected value of the profit and Expected Downside Risk (EDR) allowing them to decide their optimal level of involvement in forward contracting and in the pool as well as deriving optimal selling prices for clients.
(2) Applying a bi-level procedure to solve the proposed stochastic problem and obtain the best solution. At the first level, Roulette wheel mechanism and Lattice Monte Carlo simulation (LMCS) are employed for random scenario generation. Using above procedure, the stochastic problem is converted into corresponding deterministic problems (scenarios) in which expected downside risk-constraint method is implemented to solve each deterministic scenario at the second level. Stepwise price-quota curve and stepwise forward contracting curve are applied in this paper where the problem is formulated as a MIP problem.
(3) Because of portfolio optimization with respect to a risk measure is coherent, in this paper closed-loop expected downside risk is investigated to overcome the flaws of quintile risk measures that is a coherent risk measure.
(4) Applying Benders decomposition algorithm [20–22] as a capable solution method to obtain global results of the retailer decision in the mid-term horizon as well as reducing computational burden.