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Portfolio optimization under lower partial moments in emerging electricity markets: Evidence from Turkey

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ABSTRACT

Optimization of the electricity markets under modern portfolio theory has a crucial role for financial decision makers. Power suppliers in deregulated electricity markets need to optimize their generation capacities and bidding strategies so as to effectively participate in bilateral contract and spot markets. Market players have to deal with continuously changing electricity prices in competitive electricity market environment during their daily routine system operations. Electricity not like the others is a unique product/service and cannot be stored economically, however it should be generated and consumed simultaneously. In addition to all, power suppliers face with fuel price, water regime, delivery, and network risks. In view of the scene described above, prudent decision making methodologies are of critical importance to maximize profit while minimizing managing risks.

This paper presents a comprehensive comparison of mean-variance, down-side, and semi-variance methods for optimization in electricity markets and the corresponding methodologies to maximize the return while minimizing risk. Real Turkish day-ahead market data set between December 2009 and December 2012 is used in numerical calculations. Generation cost data of Hydraulic plants, lignite coal fired thermal power plants, and natural gas combined cycle power plants are taken into consideration in the course of optimization evaluations. In the present of real data, these methods can also be applied to renewable energy generation types. These three methods were able to be applied to all case scenarios effectively and produced efficient frontiers, optimal/minimal portfolios, and utility functions successfully. The results have revealed that the methods significantly provide decisions for power suppliers with different risk aversion levels, and for various instruments to maximize the profit while minimizing the associated market risks, and to meet generation obligations. Consequently, financial optimization under Lower Partial Moments constraints would give notable results in analyzing the efficient frontiers for electricity markets in Turkey.

Contents

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1. Introduction

In a widespread manner, there is a remarkable tendency for deregulation of electricity markets and restructuring of vertical integrated electricity power industry. The deregulation whereby vertically integrated and mostly state owned companies in electricity power industries are being transformed into independent power producers (IPPs), distributors and retail companies, brings competition to the previously monopolistic markets [1]. After these transformations, this new electricity market environment is quite volatile in comparison to any other security or commodity market [2]. This development process forces IPPs to diversify their sales and generation portfolios with different conventional and renewable alternatives to decrease their relative risks. Apparently, if the situation is observed from the classical portfolio theory point of view, it can easily be seen that this approach is well known and very familiar to us. According to classical portfolio theory, the risk of portfolio quickly declines and converges to market risk as more and more securities are added. Application of the theory would not only be seen from studies applied directly to the stock markets but also easily be proven with a few mathematical calculations [3–6]. Nonetheless, this is not a systematic approach to lower risk (variance) small and is not enough to invest in many securities [7]. It is necessary to avoid investing in securities with high correlation factor among themselves. Given these realities, clear determination of the risks and taking further necessary strategic steps for risk management are very important to reach the generation companies' main objective, which is to maximize their profit and minimize associated risks [1,3,8].

In the literature, risk management is defined as the process to achieve the desired balance of risk and return through a special trading strategy under investment constraints and includes two main aspects; risk control and risk assessment [9]. While both asset valuation and risk measurement are accepted under risk assessment techniques, hedging and portfolio optimization fall into risk control techniques. Hedging is an indispensable tool to offset the risks of position with buying some other derivatives like future, forward, options, swaps etc. There are studies which investigate the hedging the risk of the spot price with forward and future contracts [10,11]. Hedging techniques, using futures contracts in electricity market, appear to have lower standard deviation or risk [11]. The focus of this paper is the portfolio optimization with mean-variance and lower partial moments which are down-side risk and semi-variance risk approaches [12]. By using portfolio optimization methodologies demonstrated here, market players can manage their market risks systematically and produce more profit with the application of risk-return based bidding strategies.

Portfolio optimization, listed among risk control techniques, refers to optimal allocation of energy trading securities with the aim of maximizing benefits while minimizing the corresponding risks [3]. Apart from numerical methods like Monte Carlo simulation, there are two types of methods which can be used to solve portfolio optimization issues: Decision Analysis and Modern Portfolio Theory (MPT) [1,2,9,12]. MPT and its derivative approaches have been used for portfolio optimization in stock and electricity markets. However, it is more prevalent in stock markets than in electricity markets. [1,3,7–9,13–20]. Only limited studies have been performed using lower partial moments approaches such as mean-variance, down-side, and semi-variance methods in electricity markets. Despite of the fact that they are widely used in stock exchange markets and very popular in financial literature, they are brand new approaches for electricity markets. So far some significant arguments, which are the main references of this study, in the literature have been conducted by using mean-variance, down-side risk, and semi-variance methods or some other adapted ones in electricity markets. The approaches used by them are reviewed and listed as follows:

- An overall framework of risk management for Gencos' trading in a competitive electricity market was demonstrated and standard risk management technique Value at Risk (VaR) was used in assessment of trading portfolios [21]
- Day-ahead market was taken as a risky asset and other bilateral contracts were taken as different risky assets [19],
- Pricing nodes or areas were defined as group risky assets and bilateral contracts were defined as risk free assets [17],
- Each 24 h of a day in a day-ahead market was assumed as separate risky assets while bilateral contracts were assumed as risk-free assets. Mean–variance was applied [3,15],
- Asset allocation was applied to bilateral and spot markets by taking into consideration the constraints of hydro power plants and spot market price risks via lower partial moments (down-side and semi-variance) [1],
- Adapted Markowitz portfolio selection theory was used to determine optimal schedule and market bids of a battery storage, and to maximize revenues from joint operation in day-ahead and real-time markets [22].

This paper aims to provide a critical analysis regarding to theoretical background of portfolio optimization techniques based on mean-variance, down-side risk, and semi-variance and attempts to demonstrate some case studies for the decision makers to understand the pros and cons of the methodologies. The main goals of this paper are to demonstrate the applicability of portfolio optimization approaches to electricity market environment, to observe the effects of investors' risk aversion on the portfolio solutions, and to move a step forward portfolio optimization studies published in this field. Power suppliers are considered as key stakeholder while the other important stakeholders are IPPs, state-owned non-profit organizations like municipality or state-owned regulated companies. Target audiences of this paper are composed of policy makers, academicians, researchers, public authorities, power suppliers and electricity market traders. The methods presented in the paper will provide strategic decisions for key stakeholders with different risk aversion levels, and for various instruments to minimize related market risks while maximizing related profits. Additionally, they can be adapted to different market conditions with modifications. In this content, this paper provides an innovative insight and support for consideration of the best management practices.

The major contributions of this paper might be summarized as follows:

1. To the best of our knowledge, this is the first work that investigates and compares the optimal investment decisions for a