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Multi-objective mean–variance–skewness model for generation portfolio allocation in electricity markets

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ABSTRACT

This paper proposes an approach for generation portfolio allocation based on mean–variance–skewness (MVS) model which is an extension of the classical mean–variance (MV) portfolio theory, to deal with assets whose return distribution is non-normal. The MVS model allocates portfolios optimally by considering the maximization of both the expected return and skewness of portfolio return while simultaneously minimizing the risk. Since, it is competing and conflicting non-smooth multi-objective optimization problem, this paper employed a multi-objective particle swarm optimization (MOPSO) based meta-heuristic technique to provide Pareto-optimal solution in a single simulation run. Using a case study of the PJM electricity market, the performance of the MVS portfolio theory based method and the classical MV method is compared. It has been found that the MVS portfolio theory based method can provide significantly better portfolios in the situation where non-normally distributed assets exist for trading.

1. Introduction

Based on trading protocols, the competitive electricity markets (EMs) essentially consist of energy market (day-ahead, hour-ahead, and real-time balancing market) and several contractual instruments, such as forward and future contracts [1]. Forward and future contracts are similar, but future contracts are exclusively of financial type while forward contracts comprise the physical delivery of the energy. In competitive environment, generation companies (GenCos) are required to devise their own strategies on how to optimally allocate their generation capacities to the different markets for profit maximization. Moreover, while deriving the profit based generation strategies, the GenCos are confronted with volatile electricity prices and other uncertainties like congestion in transmission lines, unscheduled generating unit outages, etc. Therefore, while making the trading decision, GenCos' objective is not only to maximize its profit, but also to manage the associated risks and this problem can be viewed as a portfolio optimization.

In the last decade, the comprehensive studies [2,3] on various aspects of risk assessment and management for GenCos in competitive electricity markets have been conducted. Value at Risk (VaR) has been applied to risk assessment in electricity markets [4,5]. For hedging the spot price risks for market participants, different forward contracts with their valuation are proposed in [6–8]. In EMs, statistical studies of hedging strategies using financial instruments have been demonstrated in [9,10]. Moreover, some research papers [11–13] have also discussed the problem of allocating the generation capacities between the spot market and various contracts. Majority of aforementioned works for electricity portfolio optimization have employed the standard portfolio optimization approach, i.e., mean–variance (MV) formulation [14] which is precisely a first step of portfolio management. The MV model is a bi-criteria optimization problem where a rational portfolio choice is based on trade-off between risk and return.

However, the standard MV model is based on the assumption that each asset's return follows a normal distribution, so that asset returns can be portrayed only by their first (mean) and second (variance) central moments of distributions. But, substantial number of studies in finance sector [15–20] argued that the higher moments cannot be neglected unless there are reasons to believe that the asset returns are symmetrically distributed around the mean. Moreover, they point out the importance of skewness in the portfolio management. On the other end, empirical studies [21–23] in competitive electricity markets provide evidence indicating that, because of high volatility, spot price as well as return series exhibit statistically significant levels of positive skewness. To support this argument, a detail analysis of historical return of the spot market and bilateral contracts in PJM electricity market is presented in this paper. This study shows that because of high volatility in spot price, it follows the positively skewed distribution and therefore, GenCos returns do not exactly follow the normal distribution.

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