



Integrated Financial and Operational Risk Management in Restructured Electricity Markets

Final Project Report

Power Systems Engineering Research Center

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Power Systems Engineering Research Center

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Executive Summary

In the restructured electric power industries, how to manage the extremely high price volatility in the electricity wholesale markets has been a crucial factor to the smooth and viable business operations of all parties, including independent power producers, system operators and load serving entities and the likes. Compounded with the price risk, quantity or volumetric risk that arises from demand uncertainty due to weather conditions and load migration, presents major challenges and opportunities for the above mentioned market participants. The financial exposures to these two sources of risk that could result in severe financial losses are amplified by the positive correlation between load and price, which prevails in electricity markets. Therefore, managing these risks is essential to the financial success of participants in the electricity industry.

This project investigates the integration of financial and operational risk management mechanisms to facilitate market operations and enhance market efficiency in the restructured electricity industry. Financial and operational hedging strategies utilizing existing standard and prospective instruments have been studied. This work has developed methods for pricing such instruments and assessing their effectiveness.

I. Electricity Price Curve Modeling and Forecasting

We established a novel non-parametric approach for the modeling and analysis of electricity price curves by applying the manifold learning methodology—locally linear embedding (LLE). The prediction method is based on manifold learning, and reconstruction is employed to make short-term and medium-term price forecasts. Our method not only performs accurately in forecasting one-day-ahead prices, but also has a great advantage in predicting one-week-ahead and one-month-ahead prices over other methods. The forecast accuracy is demonstrated by numerical results using historical price data taken from the Eastern U.S. electric power markets.

II. An Equilibrium Pricing Model for Weather Derivatives in a Multi-commodity Setting

We developed an equilibrium-pricing model for weather derivatives in a multi-commodity setting. The model is constructed in the context of a stylized economy where market participants optimize their hedging portfolios, which include weather derivatives that are issued in a fixed quantity by a financial underwriter. The demand of weather derivatives resulting from hedging activities of buyers and the supply by the underwriters are combined in an equilibrium-pricing model under the assumption that all participants maximize some risk-averse utility function. We analyzed the gains due to the inclusion of weather derivatives in hedging portfolios and examined the components of that gain attributable to risk hedging and to risk sharing.

III. Hedging Quantity Risks with Standard Power Options

We analyzed the quantity risk in the electricity market, and explored several ways of managing it. The research also addressed the price and quantity risk hedging problem of a load serving entity (LSE), which provides electricity service at a regulated price in electricity markets. Exploiting the correlation between consumption volume and spot price of electricity, we derived an optimal zero-cost hedging function characterized by

the payoff as a function of spot price. How such a hedging strategy can be implemented through a portfolio of forward contracts and call and put options was also illustrated.

IV. Optimal Static Hedging of Volumetric Risk

We developed a static hedging strategy for an LSE or a marketer whose objective is to maximize a mean-variance utility function over net profit, subject to a self-financing constraint. Since quantity risk is non-tradable, the hedge consists of a portfolio of price-based financial energy instruments, including a bond, a forward contract and a spectrum of European call and put options with various strike prices. The optimal hedging strategy, which varies in contract timing, is jointly optimized with respect to contracting time and the portfolio mix under specific price and quantity dynamics, and the assumption that the hedging portfolio, which matures at the time of physical energy delivery, is purchased at a single point in time. Explicit analytical results are derived for the special case where price and quantity have a joint bivariate lognormal distribution.

V. VaR Constrained Hedging of Fixed Price Load-Following Obligations

We developed a self-financed hedging portfolio consisting of a risk free bond, a forward contract and a spectrum of call and put options with different strike prices. A popular portfolio design criterion is the maximization of expected hedged profits subject to a Value-at-risk (VaR) constraint. Unfortunately, that criterion is difficult to implement directly due to the complicated form of the VaR constraint. We show, however, that under plausible distributional assumptions, the optimal VaR constrained portfolio is on the efficient Mean-Variance frontier. Hence, we proposed an approximation method that restricts the search for the optimal VaR constrained portfolio to that efficient frontier. The proposed approach is particularly attractive when the Mean-Variance efficient frontier can be represented analytically, as is the case, when the load and logarithm of price follow a bivariate normal distribution. We illustrate the results with a numerical example.

Potential uses of the developed analytical tools

In order to show the practical usage of the model discussed in this project, we have developed a graphic **User Interface** for industry members to investigate the hedging performance of the optimal portfolios suggested by our model. We implemented the model developed in Oum, Oren, Deng 2006 as an illustration. Our intention is that, with real market data inputted and utility functions specified by the industry users, the interface could provide the corresponding payoff functions, the positions of forward contracts and options, and the performance of hedging the price and volumetric risks.

Future work

On the side of hedging with financial instruments, a credit limit constraint, which limits the amount of money that can be borrowed to construct the portfolio, needs to be considered in future extension of our work. A dynamic hedging strategy rather than the static approach is likely to improve the hedging performance and should also be considered. On the other side, we would like to incorporate a broad range of demand-side management programs into the analytic framework and investigate the impact of these programs in hedging the price and volumetric risks. The valuation and role of other tools, for example, “out-of -money” power plant should also be explored.