Evaluation of Alternative Market Structure and Compensation Schemes for Incenting Transmission Reliability and Adequacy Related Investments

Final Project Report

Power Systems Engineering Research Center

A National Science Foundation
Industry/University Cooperative Research Center
since 1996

Power Systems Engineering Research Center

Evaluation of Alternative Market Structure and Compensation Schemes for Incenting Transmission Reliability and Adequacy Related Investments

Final Project Report

Research Team Faculty

Shijie Deng, Georgia Institute of Technology
Tim Mount, Cornell University
Shmuel Oren, University of California, Berkeley

Research Team Students

Haibin Sun and Jieyun Zhou, Georgia Institute of Technology
Jaeuk Ju, Cornell University
Kory Headman and Enzon Sauma, University of California, Berkeley

PSERC Publication 08-16

August 2008

Information about this project

For information about this project contact:

Shijie Deng, Ph.D.
Georgia Institute of Technology
School of Industrial and Systems Engineering
Atlanta, GA 30332
Tel: 404-894-6519
Fax: 404-894-2301
Email: deng@isye.gatech.edu

Power Systems Engineering Research Center

This is a project report from the Power Systems Engineering Research Center (PSERC). PSERC is a multi-university Center conducting research on challenges facing a restructuring electric power industry and educating the next generation of power engineers. More information about PSERC can be found at the Center's website: http://www.pserc.org.

For additional information, contact:

Power Systems Engineering Research Center
Arizona State University
577 Engineering Research Center
Box 878606
Tempe, AZ 85287-8606
Phone: 480-965-1643
Fax: 480-965-0745

Notice Concerning Copyright Material

Acknowledgements

This is the final report for the Power Systems Engineering Research Center (PSERC) research project entitled “Evaluation of Alternative Market Structure and Compensation Schemes for Incenting Transmission Reliability and Adequacy Related Investments.” (PSERC project M-11). The project began June 2005 and was completed in June 2007. We express our appreciation for the support provided by PSERC’s industrial members and by the National Science Foundation under grant NSF ECS-0134210 at Georgia Institute of Technology.

The authors thank all PSERC members for their technical advice on the project, especially Xiaoming Feng (ABB), Floyd Galvan (Entergy Corporation), Jonathan Mayo (NYISO), Mark Sanford (GE Energy), and Jianzhong Tong (PJM) who were our industry advisors.

Executive Summary

Incentives for attracting investments in transmission assets are essential to the overall success of the restructuring of the electric power industry. In general, adequate transmission capacity enhances reliability, lowers energy cost as delivered, limits market power of market participants, and provides flexibility to protect against market uncertainties such as load fluctuation, fuel price volatility, and unexpected facility outages.

Various transmission-pricing approaches have been developed for recovering transmission costs and providing incentives for future expansion or enforcement. According to the market-based investment model, a transmission investment usually expands power-transfer capability, and therefore, increases the quantity and variety of transmission rights can be issued to investors. This project tackles problems related to the evaluation of market-based schemes for compensating transmission investments.

I. Power system simulation approach for evaluating transmission reliability and adequacy related investments

First, alternative compensation mechanisms for compensating transmission network investment aimed at improving reliability and adequacy are documented. Then, the evaluation of reliability and adequacy transmission investment is performed through incorporating constraints on the transmission reliability margin (TRM) and the generation reserve margin into a fundamental power system simulation models with a Locational Marginal Price (LMP)-based market structure. Heuristic methods for identifying incremental financial transmission rights (FTRs) resulting from typical network-deepening or network-expanding transmission investment projects are illustrated.

Through a case study, we show that FTR-based compensation scheme does provide financial incentives for reliability and adequacy targeted transmission investments via allocating the incremental FTRs to investors. The magnitude of such incentives depends on the amount of incremental FTRs resulting from the investment. The quantity and value of the incremental FTRs further depend on the bid values, the transmission network topology and the initial configuration of the allocated FTRs. Thus, market-based compensation mechanisms, such as the one rewarding investors with incremental FTRs as tradable instruments for recovering sunk capital costs and hedging market risks, have the potential of adequately compensating the reliability or security constraint-relieving transmission investments.

II. Econometric modeling of the price of financial transmission rights

An econometric modeling framework for simulating the stochastic behavior of congestion costs of electricity in New York State is developed. The basic specification of the model is that the price of electricity in a specified zone (region) is a function of the corresponding load, the price of natural gas and a set of seasonal and daily variables. The estimated multivariate time-series models are then used to predict the average daily prices in various zones in New York for the summer of 2006. Since the estimated models are based on information that is available before the auction to sell the FTRs, it is appropriate to use these models to evaluate the financial risk of purchasing FTRs in the auction.

The financial risk of the FTRs in New York, namely the TCCs, for the summer of 2006 is evaluated from two different perspectives. First, the risk of hedging for a generator comes primarily from uncertainty about the actual daily temperatures next summer. Second, the risk for speculators comes from the combined uncertainty about future temperatures and future prices of natural gas. Through this process, the predicted price differences can be used as a basis for measuring the magnitude and financial riskiness of congestion costs for a specified financial transmission right. This analysis has demonstrated successfully the feasibility of using an econometric model to simulate the financial riskiness of the payout from holding FTRs using only information known prior to the FTR auction.

III. Forward price risk premium and implications for transmission investments

We examine the risk premium present in the electricity day-ahead forward price over the real-time spot price. This study establishes a quantitative model for incorporating transmission congestion into the analysis of electricity day-ahead forward risk premium.

Through simulations with a three-bus study system, it is illustrated that the more frequently transmission congestion happens, the higher the forward prices get at the load buses. Consistent with the implications of the 3-bus model, evidences from empirical studies using the New York electricity market data confirm that there exists a significant statistical relationship between the day-ahead forward risk premium and the shadow price premiums on congested transmission flowgates.

IV. Nonparametric modeling of the Hub-and-Spoke Representation of a Network

We investigated an effective non-parametric approach for identifying proxy trading hubs in an LMP-based market for the purpose of approximating correct incentives for inducing efficient capacity investment in generation and transmission through a small set of financial transmission rights such as FTRs or TCCs. We developed a non-parametric dimension reduction method for modeling the structure of the LMPs at major zones in a bulk power system. Using this model, we can identify and analyze the major factors influencing the LMPs in all zones, which may serve as explanatory variables for the pricing of FTRs.

We have applied this non-parametric model to investigate the electricity day-ahead forward price curve dynamics in the New York power market. This model performs better in forecasting short-term curves of the LMPs than do other existing time series models.

V. Inherent inefficiency of FTR auctions

Empirical studies of FTR (or, TCC) auction data from the NYISO[1] show systematic deviations between the FTR auction clearing prices and the settlement payoffs. Such

[1] Bartholomew E. S, A. S., Siddiqui, C. Marnay, and S.S. Oren "The New York Transmission Congestion Contract Market: Is it Working Efficiently", Electricity Journal, (November 2003), pp. 1-11.

deviations cannot be explained by risk aversion or by risk premiums associated with the correlation between FTRs and non diversifiable risks. As part of this project work, we have demonstrated that even with perfect foresight of the settlement payoffs, the auction clearing prices may deviate from the expected payoffs.

Our theoretical analysis and simulations show that these deviations can be explained by the fact that FTR bids quantities are limited and dispersed over a large number of FTRs since most buyers try to match the FTRs they buy to the energy transactions they wish to hedge. Such quantity limits dampen the efficiency of the auction by allocating part of the flowgate capacities to FTR bids that undervalue them.

Potential uses of the developed analytical tools

Our study documents the alternative market-based compensating schemes for creating incentives for investments in improved network reliability and adequacy. It provides a better understanding on the effectiveness of the FTR-based compensation mechanism. Based on power system simulations reflecting the competitive and volatile market environment together with the physical system operating constraints, our investigation offers a framework for analyzing the proper structure of a long-term forward contract market in a large-scale power system for increasing trading liquidity, valuing transmission assets, and providing efficient incentives for transmission capacity investment. Incentives for transmission investment from energy and capacity markets will also be identified as supplements. Through the system simulation, potential benefits of generation investment for reliability and adequacy purposes at specific locations can be quantified. Reconciling the public goods with market mechanisms, for instance, reliability enhancement may be achieved by incorporating a reliability component into LMP calculation model to create economic incentives for the investments.

The proposed power system simulation framework offers an important tool for evaluating transmission and generation investments which address the reliability and adequacy needs of a power system. For instance, this tool can be used by power merchants to evaluate opportunities in merchant transmission investments; and by system operators/regulators to examine how effective alternative incentive mechanisms are in inducing new investments for improving the system reliability and adequacy levels.

The econometric model component of our project for modeling electricity spot prices and the risk premiums in the forward prices can be commercialized into a module for existing commercial software packages to analyze the key drivers, including transmission congestion factors, which influence the price dynamics of energy and transmission rights.

Siddiqui, Afzal S., Emily S. Bartholomew Chris Marnay and Shmuel S. Oren, “On the Efficiency of the New York Independent System Operator Market for Transmission Congestion Contracts”, Journal of Managerial finance, Vol. 31, No. 1, (2005) pp. 1-45.
Seabron Adamson,Thomas Noe and Geoffrey Parker, “Efficiency of Financial Transmission Rights Markets in Centrally-Coordinated Periodic Auctions, Presented at UKERC Workshop on Financial Methods in Electricity Markets, Oxford UK, July 9-10, 2008

The price models developed in this project could form a basis for developing a method to evaluate a portfolio of FTRs and provide a framework for monitoring the behavior of participants in the FTR markets, which could be adopted by the system operators.

Future work

The identification and allocation of incremental transmission rights under a market setting with a LMP scheme will be investigated concerning configuration, quantity and maturity decisions. Alternative multivariate time-series models for the joint modeling of electricity price, load and temperature can be further investigated to better understand the stochastic behavior of locational marginal prices and the imputed value of FTRs.