PSERC

Market Mechanisms for Competitive Electricity

Final Project Report

Power Systems Engineering Research Center

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Power Systems Engineering Research Center

Market Mechanisms for Competitive Electricity

Final Report

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Power Systems Engineering Research Center

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Executive Summary

This project is concerned with the design and analysis of market mechanisms and instruments that support competitive operation of electric power systems. The project emphasizes the interaction between the economic and technical aspects of competitive electricity markets. Our research focused on several specific topics.

- Theoretical and experimental studies of alternative auction structures and their implications for participants' behavior and the efficient operation of the system.
- How market rules in conjunction with system characteristics influence market power.
- Congestion management and transmission pricing.
- Design and analysis of financial instruments for asset valuation and risk management in electricity markets.
- Understanding price formation and market operation.
- Optimal unit commitment algorithms for competitive electricity.
- Design of demand-side contracts.

This report provides brief summaries of our research reports and publications addressing the various topics outlined above, classified by subject area with annotated references to published results.

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1 Introduction

This project is concerned with the design and analysis of market mechanisms and instruments that support competitive operation of electric power systems. The project emphasizes the interaction between the economic and technical aspects of competitive electricity markets. Research activities focused on several specific topics.

- Theoretical and experimental studies of alternative auction structures and their implications for participants' behavior and the efficient operation of the system.
- How market rules in conjunction with system characteristics influence market power.
- Congestion management and transmission pricing.
- Design and analysis of financial instruments for asset valuation and risk management in electricity markets.
- Understanding price formation and market operation.
- Optimal unit commitment algorithms for competitive electricity.
- Design of demand-side contracts.

This report provides brief summaries of research reports and publications addressing the various topics outlined above, classified by subject area with annotated references to published results.

2 Theoretical and Experimental Analysis of Electricity Auctions

We have completed a theoretical study of the efficiency properties of auctions based on load slice vs. time slice approaches. This work led to the conclusion that load slice approaches have superior theoretical properties with respect to inducing efficient dispatch when bidders try to cover their start-up costs through energy-only bids. We have also designed an experiment that will test this conclusion by comparing the two approaches in an environment where bidders are faced with start-up costs. Experimental studies of alternative auctions have focused so far on basic aspects of auction design that take into consideration transmission constraints but not intertemporal costs. The following are detailed summaries of the experimental and theoretical work done on this subject.

Markets for Electric Power: Experimental Results for Alternative Auction Institutions

John Bernard, Robert Ethier, Timothy Mount, William Schulze, Ray D. Zimmerman, Deqiang Gan, Carlos Murillo-Sanchez, Robert J. Thomas, and Richard Schuler
PSERC Document 98-03 (July 27, 1998)

The objective of this paper is to present experimental results for testing the performance of different auction mechanisms related to the introduction of competitive markets for the generation of electricity. The research is based on the concept of smart markets introduced by Vernon Smith and a simulation model (PowerWeb) of a realistic bulk power system. There are unique physical aspects associated with the supply of electricity (e.g., required instantaneous matching of supply and demand, unintended congestion of parallel transmission routes, and maintenance of system stability in response to disturbances). As a result, traditional theories of efficient markets and auction structures developed for other commodities may not be efficient if applied without alteration to markets for electricity. Conversely, current utility rules of operation developed for a centrally-planned regime may not be appropriate in a competitive environment. The research has not yet addressed the issues of multiperiod operations (unit commitment) and multidimensional markets (ancillary services), and considers only real power in a single time period. The main objective is to test three alternative auction mechanisms when market power is a potential problem. This situation occurs when limits on transmission lines are binding to form a load pocket in which demand is met by a few (in this case two) generators.

Alternative Auction Institutions for Purchasing Electric Power: An Experimental Examination

John Bernard, Ray Zimmerman, William Schulze, Robert J. Thomas, Timothy Mount, and Richard Schuler
PSERC Document 98-08 (July 27, 1998)

This paper reports on research being conducted by a combination of economists and electrical engineers at Cornell University who are examining potential auction institutions

for restructured markets for electric power. As it is a report on developing results and analysis, the discussion remains general throughout. The research follows two related but independent strands. The first looks at the performance of various alternative auction mechanisms under different market sizes. The setting is a single-sided auction with multiple units being offered and a vertical, multiple unit demand. This was conducted in the absence of a network, the equivalent of a system where transmission of electric power is lossless and costless. The second research strand investigates a realistic network environment using a single auction institution. This smart market experimental platform has the added benefit of being web-based. One group size has been studied, with the group containing a subset operating in a load pocket enabling simultaneous analysis of different market situations. Analysis of the market effects of load pockets is of major importance, especially in the U.S. northeast. Three pilots have been conducted in this framework, and the most interesting aspects of our findings are recorded here.

Multi-Unit Auctions with Complementarities: Issues of Efficiency in Electricity Auctions

Wedad J. Elmaghraby
PSERC Document 98-14 (September 29, 1998)

As auction-based mechanisms for dispatch are emerging in previously regulated electricity supply industries, it is important to understand the effects of auction rules and structure on efficiency. This paper addresses exactly this relationship in a complete information framework by asking which auction structures are sufficient to guarantee that electricity demand is satisfied in a least-cost manner.

Capturing Non-Convexities in Multi-Unit Electricity Auctions

Wedad J. Elmaghraby
PSERC Document 98-15 (September 29, 1998)

As electricity auctions are being created around the world in newly deregulated electricity supply industries, several questions regarding the design of these auctions are being raised. This paper analyzes the ability of various electricity auction mechanisms to satisfy demand while attaining productive efficiency, i.e., minimizing total generation costs. Four possible auction mechanisms are considered and their performance is evaluated under three demand scenarios. Only a horizontal sequential auction is found to support an efficient equilibrium bidding strategy in all three demand scenarios.

The Efficiency of Multi-Unit Electricity Auctions

Wedad J. Elmaghrabi and Shmuel S. Oren
PSERC Document 98-12 (October 4, 1998)

This is a theoretical analysis examining efficiency properties of alternative electricity auction designs when fixed start-up costs are taken into consideration. Using a complete information, game-theoretic model, we analyze the performance of different electricity

auction structures in attaining efficiency (i.e., least cost dispatch). We find that an auction structure where generators are allowed to bid for load "slices" outperforms an auction structure where generators submit bids for different hours in the day. The results of this analysis led to the development of an experimental design that will test the load slice versus the time slice approach within the framework of PowerWeb.

Generation Supply Bidding in Perfectly Competitive Electricity Markets
George Gross (gross@ece.uiuc.edu) and David Finlay
PSERC Document 00-41 (2000)

This paper reports on the development of a comprehensive framework for the analysis and formulation of bids in competitive electricity markets. Competing entities submit offers of power and energy to meet the next day's load. We use the England and Wales Power Pool as the basis for the development of a very general competitive power pool (CPP) framework. The framework provides the basis for solving the CPP dispatcher problem and for specifying the optimal bidding strategies. The CPP dispatcher selects the winning bids for the right to serve load each period of the scheduling horizon. The dispatcher must commit sufficient generation to meet the forecasted load and reserve requirements throughout the scheduling horizon. All the unique constraints under which electrical generators operate including start-up and shut-down time restrictions, reserve requirements and unit output limits must be taken into account. We develop an analytical formulation of the problem faced by a bidder in the CPP by specifying a strategy that maximizes his profits. The optimal bidding strategy is solved analytically for the case of perfect competition. The study in this work takes into account the principal sources of uncertainty—the load forecast and the actions of the other competitors. The formulation and solution methodology effectively exploit a Lagrangian relaxation based approach. We have conducted a wide range of numerical studies; a sample of numerical results are presented to illustrate the robustness and superiority of the analytically developed bidding strategies.

Analytical Framework for Strategic Bidding in Competitive Electricity Markets
George Gross (gross@ece.uiuc.edu)

We are investigating extensions to our work on the formulation of strategic bidding in competitive electricity markets. We have developed the formulation of optimal strategic bids in perfectly competitive markets in which the unique characteristics of the electric power production system are explicitly represented. This formulation uses a decision analytic framework that does not represent the interaction between competing players. The scope of our activities is on the study of strategic bidding in a more general setting. One area of investigation is the enlargement of the set of bidders. In addition to supply-side bidders, demand-side bidders are allowed to offer blocks of capacity for removing load from the system. The modeling of these additional players and the formulation of incentives for their participation in the markets are being investigated. Another topic of investigation is the relaxation of the perfect competition assumption. Since many of the

markets in operation are not implementations of perfect competition, the representation of this more realistic situation is important.

Additional documentation of work performed in this subject area

Wedad Elmaghraby, "Multi-unit Auctions for Electric Power with Nonconvex Costs", Ph.D. Thesis, University of California at Berkeley, 1998.

Wedad Elmaghraby and Shmuel S. Oren, “The Efficiency of Multi-Unit Electricity Auctions”, *The Energy Journal*, 20(4), 1999, 89-116.

W. J. Elmaghraby, “Multi-Unit Auctions with Dependent Valuations: Issues of Efficiency in Electricity Auctions,” December 2001.

3 Studies of the Causes and Implications of Market Power in Electricity Markets

In this subject area we have employed experimental and theoretical approaches to investigate how market rules and congestion influence market power in electricity markets and how market power can be quantified to better reflect dynamic and locational effects. The following are detailed summaries of the experimental and theoretical work done on this subject.

Market Power: A Dynamic Definition

Fernando L. Alvarado
PSERC Document 98-07 (July 27, 1998)

Market power refers to conditions where the providers of a service can consistently charge prices above those that would be established by a competitive market. There are many well-known definitions of market power, including indices intended to quantify the degree of market concentration of energy supplies. Market power assessment within electric power markets requires the consideration of the ever-changing network conditions that result from congestion. This paper explores the effect of changes in network congestion conditions on one of these indices, the Herfindahl-Hirschman Index. Results indicate that congestion can lead to drastically different values of this index at various locations. Furthermore, when ownership of facilities is dispersed, this can greatly complicate the assessment of market concentration. The paper also explores several topics on strategic behavior possibilities.

Energy Auctions and Market Power: An Experimental Examination

Ray D. Zimmerman, John C. Bernard, Robert J. Thomas and William Schulze
PSERC Document 98-19 (October 2, 1998)

Testing auction mechanisms experimentally in a controlled environment provides an inexpensive means for evaluating their relative merits. The first part of this paper focuses on the comparison of three different auctions with regard to market efficiency and pricing, given scenarios with two, four and six competitors. Though the uniform price, last accepted offer auction was superior overall, the number of competitors proved to be a more significant factor in determining auction performance. Significant exploitation of market power was observed in the duopoly case. The second part of the paper focuses on a transmission network with six sellers in which network constraints give rise to market power opportunities. Experimental evidence based on tests with student and expert subjects show exploitation of this strategic advantage. Several other scenarios are described in which the transmission network creates market power.

Analytic and Experimentally-Derived Estimates of Market Power in Deregulated Electricity Systems: Policy Implications for the Management and Institutional Evolution of the Industry

Richard E. Schuler
PSERC Document 98-21 (October 13, 1998)

Previous experimental and game-theoretic analyses of deregulated electricity markets suggest that communities having four or less effective suppliers (either because of transmission constraints or load characteristics; retail customers facing suppliers; or marketing agents having more than seventy percent of the region's market) are likely to experience prices well above competitive levels. While state regulatory bodies may be able to forestall the onset of retail wheeling and non-regulated retail energy pricing until a single supplier does not dominate initial market shares, it is more difficult to mute the exercise of market power by generators serving electrically-isolated load pockets. And in both instances, if the accrual of some excess profits by initial, non-regulated suppliers are not tolerated, then little incentive will have been provided for competitors to enter the market and for more efficient technologies to evolve. Estimates are provided in this analysis of the circumstances for and the extent and duration of the exercise of market power. When combined with the present absence of incentives to build transmission lines that would reduce bottlenecks and the existing utilities' insistence upon full recovery of stranded costs through line charges and access fees, the powerful incentives to develop distributed generation are highlighted.

Market Power and Price Volatility in Restructured Markets for Electricity

Tim Mount
PSERC Document 98-22 (November 12, 1998)

The restructured market for electricity in the UK experienced a systematic pattern of price spikes associated with the use of market power by the two dominant generators. Partly in response to this problem, the share of capacity owned by any individual generator after restructuring was limited in Victoria, Australia. As a result, a much more competitive market resulted with prices substantially lower than they were under regulation. Nevertheless, an erratic pattern of price spikes exists and the price volatility is a potential problem for customers. This paper argues that the use of a uniform price auction for electricity markets exacerbates price volatility. A discriminatory price auction is proposed as a better alternative that would reduce the responsiveness of price.

4 Congestion Management and Transmission Pricing

This continues to be an important subject and research on this topic is regaining momentum as a result of new empirical findings regarding the performance of the PJM and California systems. Efforts by NERC to revamp the Transmission Load Relief protocols and new interests in formation of for-profit transmission companies is motivating research in this area. Following is a description of research results that propose a new approach to intrazonal congestion management.

Priority Network Access Pricing for Electric Power

Shijie Deng and Shmuel Oren
PSERC Document 98-16 (September 29, 1998)

We propose a priority-pricing scheme for zonal access to the electric power grid that is uniform across all buses in each zone. The Independent System Operator (ISO) charges bulk power traders a per unit ex-ante transmission access fee based on the expected option value of the generated power with respect to the random zonal spot prices. The zonal access fee depends on the injection zone and a self-selected strike price determining the scheduling priority of the transaction. Interzonal transactions are charged (or credited) with an additional ex-post congestion fee that equals the zonal spot price difference. The unit access fee entitles a bulk power trader to either physical injection of one unit of energy or a compensation payment that equals the difference between the realized zonal spot price and the selected strike price. The ISO manages congestion so as to minimize net compensation payments and, thus, curtailment probabilities corresponding to a particular strike price may vary by bus. We calculate the rational expectation equilibria for a three and four node system and demonstrate that the efficiency losses of the proposed second best scheme relative to the efficient dispatch solutions are modest.

Additional documentation of work performed in this subject area

Oren Shmuel S., "Transmission Pricing and Congestion Management", Proceedings of the EPRI Conference on Innovative Pricing, Washington DC, (June 17-19, 1998).

Deng Shieji and Shmuel S. Oren, "Priority Network Access Pricing for Electric Power," In Proceedings of the Bulk Power Systems Dynamics and Control Conference IV - Restructuring, Santorini, Greece,August 24-28, (1998).

Oren Shmuel S., contributor to *Unlocking the Benefits of Restructuring: A Blueprint for Transmission*" by Shimon Awerbuch, Leonard Hyman and Andrew Vesey, Public Utilities Reports Inc., (Nov. 1999.)

Deng, Shijie and Shmuel S. Oren, "Priority Network Access Pricing for Electric Power," *Journal of Regulatory Economics*, Vol. 19, No. 3, (2001) 239-270.

5 Financial Instruments in Competitive Electricity Markets: Applications and Valuation

Our work in this area produced new price models that capture unique features of electricity spot prices. Using these models we have characterized and developed pricing formulas for exotic derivatives that have broad applications in risk management, asset valuation as well as the design and pricing of demand-side contracts. The following are detailed summaries of the work done in this subject area.

Exotic Electricity Options and the Valuation of Electricity Generation and Transmission Assets

Shijie Deng, Blake Johnson and Aram Sogomonian
PSERC Document 98-13 (September 29, 1998)

This paper presents and applies a methodology for valuing electricity derivatives by constructing replicating portfolios from electricity futures and the risk free asset. Futures-based replication is argued to be made necessary by the non-storable nature of electricity, that rules out the traditional spot market, storage-based method of valuing commodity derivatives. Using the futures-based approach, valuation formulae are derived for both spark and locational spread options for both geometric Brownian motion and mean-reverting price processes. These valuation results are, in turn, used to construct real options based valuation formulae for generation and transmission assets. Finally, the valuation formula derived for generation assets is used to value a sample of assets that have been recently sold, and the theoretical values calculated are compared to the observed sales prices of the assets.

Combining Financial Double Call Options with Real Options for Early Curtailment of Electricity Service

Shmuel S. Oren
PSERC Document 98-17 (September 29, 1998)

In a competitive electricity market, customers can ensure a fixed electricity price and benefit from their flexibility to curtail loads by purchasing forward electricity contracts bundled with financial options that reflect their "real options". This paper describes a "double call" option and derives the value of that option under the assumption that forward electricity prices behave as a geometric Brownian motion. It is shown that a forward contract bundled with an appropriate double call option provides a perfect hedge for customers who can curtail loads in response to high spot prices and who are able to mitigate curtailment losses with sufficient lead time.

Short-Term Generation Asset Valuation

Chung Li Tseng and Graydon Bartz
PSERC Document 98-20 (October 5, 1998)

In this paper we present a method for valuing a power plant over a short-term period using Monte Carlo simulation. The power plant valuation problem is formulated as a multi-stage stochastic problem. We assume that there are hourly markets for both electricity and the fuel used by the generator, and their prices follow some Ito processes. At each hour, the power plant operator must decide to run or not to run the unit so as to maximize expected profit. A certain lead time for the commitment decision is necessary to start up a unit. The commitment decision, once made, is subject to physical constraints such as minimum uptime and downtime constraints. The generator's start-up cost is also taken into account in our model. In this paper, the Monte Carlo method is employed not only in forward-moving simulation, but also backward-moving recursion of dynamic programming. We demonstrate through numerical tests how the physical constraints affect a power plant's value.

Managing Transmission Risk: The Theory of Spatial Hedging and Arbitrage

Rajesh Rajaraman and Fernando L. Alvarado
PSERC Document 98-27 (December 2, 1998)

This report shows how one may manage or eliminate transmission risk using relatively few liquid futures markets. The idea can be used to detect arbitrage opportunities and for partial hedging. Rigorous formulas are derived; numerical examples are shown; and "rules of thumb" for risk management are presented.

Stochastic Models of Energy Commodity Prices and Their Applications: Mean-Reversion with Jumps and Spikes

Shijie Deng
PSERC Document 98-28 (December 6, 1998)

In this paper, we present several mean-reversion jump diffusion models to describe energy commodity spot prices. We incorporate multiple jumps, regime-switching and stochastic volatility in these models. Prices of various energy commodity derivatives are obtained under each model. We show how the electricity derivatives can be used to evaluate generation and transmission capacity. We also show, for our price models, how to determine the value of investment opportunities and the threshold value above which a firm should invest.

Using Weather Derivatives to Improve the Efficiency of Forward Markets for Electricity
Timothy Mount
PSERC Document 01-26 (October 24, 2001)

The analysis in this paper demonstrates that a combination of 1) a forward contact, with fixed price for both base land and peaking power; and 2) a collar option for the number of hot days in a summer is an effective way to reduce the risk of purchasing electricity in a spot market. The main advantages are: 1) the effectiveness of price signals is strengthened by making peaking power expensive; and 2) the correlation between payouts from the weather option and high prices is increased.

Additional documentation of work performed in this subject area

Shmuel S. Oren, "Integrating Real and Financial Options in Demand-Side Electricity Contracts", *Decision Support Systems*, Vol. 30, (2001) 279-288. Also in Proceedings of the 32nd Hawaii International Conference on Systems Sciences, Maui, Hawaii (January, 1999).

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Shijie Deng, Blake Johnson and Aram Sogomonian, "Exotic Electricity Options and the Valuation of Electricity Generation and Transmission Assets", *Decision Support Systems* (30)3 (2001), pp. 383-392. Also in Proceedings of the 32nd Hawaii International Conference on Systems Sciences, Maui, Hawaii (January, 1999).

Kamat, Rajnish and Shmuel S. Oren, "Exotic Options for Interruptible Electricity Supply Contracts," *Journal of Operations Research*, Vol. 50, No 5, (September-October) 2002 pp 835-850.

Rajnish Kamat, *Market Mechanisms in Deregulated Electricity Markets*, Ph.D. Thesis, University of California at Berkeley, 2001

Deng, Shijie and Shmuel Oren S., "Incorporating Operational Characteristics and Startup Costs in Option-Based Valuation of Power Generation Capacity", *Probability in Engineering and Information Sciences*. (Accepted for publication August 2002).

6 Understanding Price Formation and Market Operation

Since 1998, price spikes in wholesale electricity markets have drawn considerable attention by market participants and policy-makers. Our research has explored the occurrence of and reasons for the price spikes. The following are detailed summaries of the work done in this subject area.

The June 1998 Midwest Electricity Price Spike
George Gross (gross@ece.uiuc.edu)
Dinner Presentation at IAB meeting

We have studied the background for and the events of the Midwest electricity market during the week of June 22 - 26, 1998. Bulk electricity prices reached a high of $7,500/MWh on June 25. Our study focused on the impacts of both system planning and system operations on market activities. In particular, the effect of the interconnected system reliability and the deployment of the NERC transmission line loading relief actions were examined. In the market analysis, focus was on the requirements for risk management and mitigation. The June events constitute a sequence of highly unusual occurrences in the still maturing electricity markets. The relatively low reliability margins in the Midwest, the onset of a heat wave early in the summer of 1998, the maintenance schedule in effect, the large amount of nuclear capacity on outage, the impacts of severe storms on generation and transmission, the default of some players, and the inexperience of others, combined to create market panic which, through a price spiral, resulted in this dramatic price spike. The lessons learned are being studied with a view of using them in the development of analytical models for the bulk electricity markets.

Are Price Spikes Predictable, Reproducible and Avoidable?
Timothy Mount
PSERC Document 00-10 (October 5, 2000)

These are the Power Point slides used by Prof. Mount from Cornell University for the PSERC Internet Seminar on October 3, 2000. The primary objective of this seminar was to present two different but related areas of research on the volatility of spot prices for electricity. These areas are 1) an analysis of actual price behavior in the PJM market, and 2) a series of economic experiments to test how market structure affects price volatility.

Experimental Tests of Competitive Markets for Electric Power
Simon Ede, Timothy Mount, William Schulze, Robert J. Thomas, and Ray Zimmerman
PSERC Document 00-26 (March 7, 2001)

Testing the performance of electricity markets using Powerweb has already shown that relatively inexperienced players can identify and exploit market power in load pockets. When transmission constraints are not binding, however, auctions with six players have been shown to be efficient. There is evidence from operating electricity markets that

prices can be driven above competitive levels when the largest supplier controls less than 20% of total installed capacity. This is accomplished by causing price spikes to occur. In experiments, uncertainty about the actual load and paying standby costs, regardless of whether or not a unit is actually dispatched, contribute to volatile price behavior. The objective of this paper is to investigate characteristics of a market that affect price volatility. The tests consider three different sets of rules for setting price when there are capacity shortfalls, and the following four market structures:

1. Load is responsive to price
2. Price forecasts are made before market settlement.
3 A day-ahead market and a balancing market auction.
4. Suppliers are paid actual offers (a discriminatory auction).

7 Unit Commitment in Competitive Electricity Markets

Under this heading we have explored various adaptations of unit commitment algorithms to the new realities of a deregulated power industry. In particular, we have explored how spinning reserve requirements could be made price responsive. Rigid reserve requirements encourage "hockey stick" bidding that create price spikes. This phenomenon can be mitigated by allowing reserves requirements to be responsive to price. Incorporating such responsiveness into a unit commitment framework is challenging since it leads to an equilibrium problem that is harder to solve than the typical optimization problem. Another challenge in designing unit commitment algorithms for a deregulated industry is the incorporation of transmission constraints in the algorithm. The following describes some modest efforts attempting to expand the scope of unit commitment methods to deal with those challenges.

Price-Based Adaptive Spinning Reserve Requirements in Power System Scheduling
Chung-Li Tseng, Shmuel S. Oren, Alva J. Svoboda, and Raymond B. Johnson
PSERC Document 98-18 (September 29, 1998)

In a deregulated electricity market, such as the California system, spinning reserves must be explicitly identified as an ancillary service and priced. Additionally, scheduling coordinators who match suppliers and demands may either self-provide spinning reserves, or rely on the Independent System Operator (ISO) to provide reserves at the spot price. The deregulated market structure makes explicit the implicit softness that has always been recognized in the reserve constraints: additional reserves may have value even when a minimum reserve requirement has been met. In this paper we formulate the spinning reserve requirement (SRR) as a function of the endogenously determined marginal values of reserves. The spinning reserve requirement depends, according to a non-increasing response function, on a price/value signal. We present three power system scheduling algorithms in which this price/value signal is updated at each iteration of a dual optimization. Game theory is used to interpret the proposed algorithms. Numerical test results are also presented.

A Transmission Constrained Unit Commitment Method
Chung-Li Tseng, Shmuel S. Oren, Carol S. Cheng, Chao-an Li, Alva J. Svoboda and Raymond B. Johnson.
Proceedings of the 31st Annual Hawaii International Conference on System Sciences, Maui, Hawaii, January (1998), pp. 71-80. For a copy, contact Shmuel Oren at oren@ieor.berkeley.edu. It was also published in Decision Support System. It can be downloaded from http://www.ieor.berkeley.edu/%7Eoren/pubs/commit.pdf.

This paper presents a transmission-constrained unit commitment method using a Lagrangian relaxation approach. The transmission constraints are modeled as linear constraints based on a DC power flow model. The transmission constraints, as well as the demand and spinning reserve constraints, are relaxed by attaching Lagrange multipliers.

In this paper we take a new approach in the algorithmic scheme. A three phase algorithm is devised including dual optimization, a feasibility phase, and unit decommitment. A test problem involving over 2,500 transmission lines and 2,200 buses is tested along with other test problems.

8 Design of Demand-Side Contracts

Market designs for competitive electricity markets are including mechanisms by which customers can offer their loads as demand resources. These demand resources can be quite valuable in maintaining system reliability when the system is experiencing tight generation reserves or transmission constraints. The following are detailed summaries of the work done in this subject area.

Designing Cost Effective Demand Management Contracts Using Game Theory

Morat Fahrioglu and Fernando Alvarado
PSERC Document 99-05 (June 10, 1999)

Demand relief from customers can help a utility solve a variety of problems. There exist all sorts of different demand management programs that utilities use. A critical issue is the incentive paid to the customer to participate in demand management programs and provide load relief. The utility has to design cost effective yet attractive demand management contracts. The main goal is to get load relief when needed. If the contracts are designed to be cost effective, they can help the utility reduce costs. Customers sign up for programs when the benefits they derive in the form of up-front payments and interruption payments exceed their cost of interruption. In order to design such contracts, mechanism design under the revelation principle is adopted from game theory and applied to the interaction between a utility and its customers. The idea behind mechanism design is to design an incentive structure that encourages customers to sign up for the right contract and reveal their true value of power (and thus, the value of power interruptibility).

Using Utility Information to Calibrate Customer Demand Management Behavior Models

Morat Fahrioglu and Fernando Alvarado
PSERC Document 99-06 (June 16, 1999)

In times of stress, customers can help a utility by means of voluntary demand management programs if they are offered the right incentives. The incentives offered can be optimized if the utility can estimate the outage or substitution costs of its customers. This report illustrates how existing utility data can be used to predict customer demand management behavior. More specifically, it shows how estimated customer cost functions can be calibrated to help in designing efficient demand management contracts.