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Gerald B. Sheblé

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Dedicated to my family: Jason, Laura,
Judy, Ron, Mike, Cathy, & Walter

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Preface

The most interesting times are those including massive changes. The electric power industry is in the most turbulent era except for the era when the industry was going from competitive to regulated. The society viewpoint of electricity has fundamentally changed. The nuclear crises as well as the lack of consistent pricing around the world have awakened a sense of distrust of the electric energy monopolies. Schweppe [1988] stated the paradigm precisely: "Electric energy must be treated as commodity which can be bought, sold, and traded, taking into account its time- and space-varying values and costs." Schweppe's work on the application of spatial (spot) prices to the electric power industry, as has been done in other industries [Thompson, 1992; Hillier 1996], is a classic work upon which this work is deeply indebted. However, that work did not truly represent what the spot price of electricity is based. The spot price of any commodity in a free market is based on the perceived value as negotiated through millions of contracts between the consumers and the suppliers. It is the need for a free market that this work builds various auction techniques and bidding techniques to find the best price. The best price is based not only on the supplier costs but also the consumers valuation of that commodity. As with any commodity with special handling and transportation, the price is a function of time and location. Under very restrictive conditions, the spot price will gravitate to the same level in all locations and to the marginal cost. However, any technological changes, any unfair market play, any social or industrial welfare added would drive the price away from the ideal market price. This must be avoided during the transition from a regulated industry to a competitive industry and during the eventual operation as a competitive industry.

This work is written for electric power engineers, economists, and financial planners to include all aspects of competition into the industry. Detailed optimization formulation is provided for those who wish to reproduce the results obtained.

Commodity trading of electricity can be of immense benefit to society and to the industry only if the markets are properly defined and implemented. The history of commodity markets over time (since 400 BC) has shown many market and society crises due to improper market implementation. The benefits of proper price signals are well documented for the expansion of the industry, for the research and development of new technology and processes, and for the continued improvement in the quality of life for our society. The primary advantage I foresee is the joint venture agreements to spread the risk of system outages and of fuel supply uncertainty between the suppliers and the consumers. The proper establishment of the market structure and of the market procedures will require regulation by federal and by state government agencies. Markets are a means to focus controlled greed to the improvement of society. There is much to be accomplished during this transition period. The markets are presently chaotic in nature. The future supply of electricity is not assured. It is only through the simulation and analysis of market structure that the industry can mature into a positive weather vane for democratic societies to succeed.

Organization of Book

This work deals with many topics published by this author with many students: auction basics, auction by transportation, optimal power flow (OPF) linear programming and auctions, comparison with economic dispatch calculation (EDC), auction market simulation for single hour bidding, unit commitment and auctions, ancillary services, auctions and generation bidding, auctions and supportive services bidding, transmission auctions, wholesale market access, and interaction with automatic network control (ANC). Other topics published by this author are not included due to time a space constraints: hydro thermal coordination and multiple auctions, transmission planning and auctions for network expansion, generation planning and auctions for franchises, energy services and auctions for demand expansion. A very interesting topic not covered is valuation of exotic derivatives for risk management. The interested reader will have to search the journal and conference papers for these topics.

Chapter 1 reviews the present state of the industry and the direction this author recommends for auction market implementation.

Chapter 2 on auction basics outlines the different type of auctions available. This chapter should provide an interesting start for those who wish to compare the theory of auctions with the auctions that have actually evolved throughout history.

Chapter 3 presents auctions as transportation and assignment problems based on Linear Programming optimization. Auctions are also posed as price decomposition problems. The auction as an optimization technique is compared with the classical economic dispatch calculation and Dantzig Wolfe equations. Auction techniques can be compared with optimizing a vertically integrated company using optimization through decentralized production. A complete solution with multiple buyers and sellers are then presented with assignment to find a partial equilibrium solution.

Chapter 4 develops economic dispatch, unit commitment, and optimal power flow by linear programming as auction mechanisms. This work is based on LaGrangian Relaxation and Linear Programming as explained in most operations research texts. This chapter outlines the markets for supportive services and the need to bundle such services. This chapter reviews the needs for ancillary services, spinning reserve vs contingency or capacity options. Auctions and generation bidding for multiple contracts, list types and clearing problems are outlined.

Chapter 5 presents the basic tools needed by suppliers and by buyers to function in a competitive marketplace. The use of control theory concepts for modeling bidding strategies is outlined as well as the modeling of competitors based on real-time bids. The basic algorithms for managing cash flow, transaction risks, fuel market scheduling, transaction selection, as well as contract allocation are included. Auction market simulation for single hour bidding by multiple players by control simulation and classical optimization is detailed. The interaction with automatic

network control (ANC), formerly automatic generation control (AGC), for on-line market simulation and training is defined.

Chapter 6 defines the standard operational problems encountered by both GENCOs. The need for multiple hour auctions and relationships similar to a decentralized unit commitment problem is discussed. Auctions for spot prices and forward prices for the next two weeks are minimal information sources. Generation models for fully evolved decentralized markets are segmented and defined. Hedging, comparative analysis, scheduling and capacity options are discussed. Several bidding building techniques are defined.

Chapter 7 reviews the software needs for ESCOs to provide competitive services. Auction implications and generation bidding for multiple contracts, various contract types and clearing problems are outlined. Auctions and energy services bidding, transformation of auction markets to customer contracts, price volatility, forecasting and demand side management by composite market mechanism is provided. Transformation of auction markets to customer contracts, price volatility, forecasting and risk management is outlined. The software needs for ESCOs to provide customer services, spinning reserve, contingency or capacity options are outlined. Auction implications and general bidding for multiple contracts, contract types and clearing problems are outlined. Auctions and energy services bidding to transform auction markets to customer contracts, especially with demand side management, are outlined.

There are many topics not covered. Transmission auctions as an extension to commodity markets have been attempted. The release of information and market power, market share, wholesale market access, probabilistic access while maintaining loss of load probability (LOLP) and expected unserved energy (EUE) are topics central to long term operation and planning of the overall system. Complete operational planning including hydro-thermal coordination and maintenance scheduling are also important. The comparison of classical techniques to multiple auctions, such as water and electricity interdependence, is not mentioned. This is based on the suggested markets proposed by this author for the Brazilian reregulation. The essence of these markets is the equivalent estimation of pseudo prices for fuel and hydro as done in the past for fuel and hydro scheduling. Complete system planing concepts of capital budgeting, portfolio analysis, transmission planning and industrial expansion for multiple or for a single product, generation planning and auctions for franchises, capacity tariffs, auctions for network expansion are left for future work.

This material has been used for a graduate level course in electrical engineering at Iowa State University. The student is assumed to be aware of material from classical optimization for power system operation as found in [Wood, 1996]. The student should also have a firm basis in unconstrained and constrained optimization techniques. This material and material on risk management and financial derivatives are used in a one semester three credit hour course. This is a graduate level course dealing with the economic analysis of power system operation and planning in a de-regulated environment. The objective is to define the alternatives for the new business environment. Algorithmic equivalents are then defined for

select alternatives. Then, algorithmic refinements to alleviate market deficiencies for each of the power system environments will be sought. As with any economic solution, many optimization methods will be included to find solutions. Embedded optimization methods include Linear Programming, Constrained Nonlinear Programming, Network Flow Programming, Integer Programming, and Dynamic Programming. The use of artificial life techniques is very beneficial. I have had the benefit of a course in artificial life techniques designed by Dr. Daniel Ashlock offered for students before taking this course. Background in fuzzy logic is also an additional benefit as most pricing techniques are, at best, fuzzy.

The graduate level course has used the case study technique instead of traditional engineering homework. Students are assigned to a specific company based on their interests. Typically, three companies are sufficient to show the equilibrium solutions. I have limited the company types to GENCOs, ESCOs, and ICAs. The major lectures per topic for this course are shown in the following table.

Lectures	*Topic*
1-2	Review of Corporate Modeling
3	Review of Engineering Economics
4-5	Review of Linear Optimization Fundamentals
6-7	Review of Non-Linear Optimization Fundamentals
8-10	Overview of Micro-economics (theory of the firm)
10-14	Overview of Finance
15-16	Overview of Financial Management
17	Electric Power Industry Structure - Chapter 1
18-19	Industrial infrastructure – Chapter 2
20	Auction by Linear Programming – Chapter 3
21-24	Economic Dispatch, Unit commitment, Optimum Power Flow as Auction - Chapter 4
25	Supportive Services, Bundled or Separate - Chapter 4
26	Forecasting markets, Production Frontiers - Chapter 5
27	Decentralization of production, Vertically Integrated Company Production - Chapter 5
28	Financial Management - Chapter 5
29	Decision Analysis, Value of Information, Value of Perfect Information, and Bidding Possibilities - Chapters 6 & 7 plus handouts
30	Inventory Management & Decisions - Chapters 6 & 7 plus handouts
31	Production Costing, Risk of Production - Chapters 6 & 7 plus handouts
32	Activity Analysis & Multiple Markets - Chapters 6 & 7 plus handouts
33	Input-Output Analysis and Cash Management - Chapters 6 & 7 plus handouts
34	Contracts And Incentives/Yield Management - Chapters 6 & 7 plus handouts
35	Options, Portfolio Analysis - Chapters 6 & 7 plus handouts
36	Capital Budgeting & Investment Programs - handouts

Acknowledgments

The title page of this work has one name on it but the bibliography shows who really contributed to this work. After 15+ years in the electric power industry, I was reluctant to enter the academic world in 1986. Now, after 12+ years, I have found that both worlds are excellent career choices. However, the gratification of working with many excellent graduate and undergraduate students is very rewarding. The experience at Purdue University working with Professors Gerald Heydt and Ahmed El-Abiad has given me a very lofty goal to attain. This research started in 1986 when Leo Grigsby recommended that I become an expert at something worthwhile. Leo, like many others, was convinced that deregulation would not happen. Leo felt that I did not make a sane choice since deregulation should not happen. Leo thoroughly supported my choice and provided enormous support during my tenure at Auburn University. This work at Auburn enabled me to work with many gifted students, most especially George Fahd. I also extend thanks to Professors Charles Gross and Mark Nelms for their comments. After moving to Iowa State University, I was very ably assisted by George Fahd as a post-doctoral student. I have been very fortunate to have Jayant Kumar and Douglas Post as students, as well as Darwin Anwar. At the time of this writing, Chuck Richter has become a very valuable collaborator. I have also been very fortunate to have Somgiat Dekrajangpetch and Kah-Hoe Ng as graduate students. I am grateful to the students with whom I have worked in this area and those students who have helped me in other areas of research. As it has been with my own children, just when they get interesting, they leave to attain their own goals. I am especially indebted to the efforts of Dr. Richter and Mr. Dekrajangpetch in putting this document together. Kah-Hoe Ng assisted with the ESCO chapter. The comments at the beginning of each chapter were the famous last words of several of these students.

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