Power System Economics

Designing Markets for Electricity

S t e v e n   S t o f t

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Cover painting by W. Louis Sonntag, Jr. (1869-1898), *The Bowery at Night*, c. 1895. Early deregulated electricity market with trolleys powered by Westinghouse's AC and shops probably illuminated with Edison's DC. The houses may still be lit by gas. The "Third Avenue Elevated" (1878), whose noise and shadows contributed to the decline of New York's once-elegant theater district, will soon be electrified. (*Uncle Tom's Cabin* was first staged in the Bowery Theatre visible at the extreme left.) Arc lights, brought to New York streets in 1880 by Charles Brush, transformed night life. Sonntag frequently depicted the resulting sense of glamour and excitement. The watercolor was a Gift of Mrs. William B. Miles to the Museum of the City of New York.

For my mother, whose writing inspired me to think I could,
and my father who taught me to test high voltage with one hand behind my back

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Preface

My original purpose in writing this book was to collect and present the basic economics and engineering used to design power markets. My hope was to dispel myths and provide a coherent foundation for policy discussions and market design. In the course of writing, I came to understand there is no received wisdom to present on two key issues: price-spikes and pools. While the majority of the book still holds to my first purpose, Parts 2 and 3 are guided as well by a second. They seek to present the two unresolved issues coherently, answer a few basic questions and highlight some of the gaps in our current understanding.

The price-spike issue is how to design the market to accommodate two demand-side flaws underlying the price-spikes that provide incentives for investment in generation. Part 2 shows that some regulation is required until one flaw has been mitigated. The first regulatory goal should be to ensure the revenue from the aggregate price spike is just sufficient to induce a reliable level of generating capacity. This revenue is determine by (1) the duration of the aggregate price spike which is under the influence of NERC guidelines and (2) the height of the price spike which is regulated by FERC. Currently, neither institution appears aware their policies jointly determine investment.

Part 2 provides a framework for computing the level of investment induced by any combination of NERC and FERC policies. Because many combinations will work, it suggests a second goal. Price volatility should be reduced to levels that might be expected from a mature power market—levels far below those observed in the current markets with their incapacitated demand sides. I hope Part 2 will clarify the regulatory options and the need to fix the market's demand side.

While Part 3 presents the standard principles of bilateral markets, exchanges and pools, it is able to make little progress on the second issue, the power-pool question. An exchange is a widely used form of centralized market—the New York Stock Exchange is an example—while pools are peculiar to power markets. Exchanges trade at one price at any given time and location, while pools pay different prices to different generators according to their costs. The differences in transparency and operation are considerable as may be their performance. Unfortunately, little theoretical or empirical research is to be found, and Part 3 can only raise issues and show the answers are far from obvious.

While three pools operate in the eastern U.S. and PJM has been deregulated for nearly four years, no evaluation of their efficiency has been undertaken. The only national effort, a shoestring operation at the Department of Energy, has been crippled by lack of access to data that FERC could easily obtain from the pools. Pro-pool forces within FERC have, for years, blocked any suggestion to evaluate the performance of pools or their potential benefits. No description of any eastern pool, suitable for economic analysis, can be found within FERC or in the public domain.

Theoretical pool descriptions cover ex-ante pricing while knowledgeable observers indicate the eastern ISOs use ex-post pricing. This is said to be based on a philosophy of controlling quantities in real-time and computing prices after the fact. In practice, it involves proprietary calculations that apparently assume the operator's actions were optimal. I could discover no useful discussion of the theory of this critical issue, so readers of Part 3 must wait for a later edition.

Competitive power markets, like regulated markets, must be designed and designed well. Because of the poor quality of many current designs and the lack of a well-tested standard, this book does not recommend a rush to deregulate. A given deregulation may succeed, but economic theory cannot predict when such a complex political process, once begun, will be out-maneuvered by the forces it seeks to harness. If a market is being designed or redesigned, this book is meant to help; if the decision is to wait, this book is meant to make the wait shorter.

Acknowledgments

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For support and guidance on every challenge, I have turned first to my wife Pamela who has been my creative advisor, editor, and legal counsel. I thank her for her abundant patience and unerring judgement.

But of all those who have contributed to this book, I owe the most to my mother, Dorothy, who brought her artistry to the dull world of power economics. Through three complete drafts, she gently but persistently corrected and shaped, guided and polished. While the quality of my writing still falls far short of my mother's, it delights me to have learned, at last, a little of her art.

Acronyms and Abbreviations

AC	alternating current
ACE	area control error
CA ISO	California Independent System Operator
CFD	contract for differences
CLP	competitive locational price
CR	capacity requirement
DA	day ahead
DOJ	Department of Justice
FERC	Federal Energy Regulatory Commission
FTR	financial transmission right
FTC	Federal Trade Commission
GT	gas turbine generator
HHI	Herfindahl-Hirschman index
ICap	installed capacity
IPP	independent power producer
ISO	independent system operator
ISO-NE	ISO New England
LBMP	locational-based marginal price
LHMC	left-hand marginal cost
LMP	locational marginal price
LRMC	long-run marginal cost
MC	marginal cost
NERC	North American Electric Reliability Council
NYISO	the New York Independent System Operator, Inc.
NYSE	the New York Stock Exchange
NE	Nash equilibrium
OpRes	operating reserve
PJM	Pennsylvania-New-Jersey-Maryland Independent System Operator
PTR	physical transmission right
RHMC	right-hand marginal cost
RT	real time (market)
RTO	regional transmission organization
SMC	system marginal cost
SMV	system marginal value
TR	transmission right
UC	unit commitment
VOLL	value of lost load

Units Used to Measure Electricity

V	volt	The unit of electrical pressure
A	amp	The unit of electrical current
W	watt	Power (Energy per hour)
h	hour	Time
Wh	watt-hour	Energy
k	kilo	1000. Used in kW, kWh and kV.
M	mega	1,000,000. Used in MW and MWh.
G	giga	1,000,000,000. Used in GW.
T	tera	10^{12}. Used in TWh.

Symbols

Units	Symbol	Definition	
	^{e}, *	equilibrium and optimal superscripts	
	$_{peak}$, $_{mid}$, $_{base}$	peakload, intermediate, and baseload generating capacity subscripts	
	$_{1}$, $_{0}$	day-ahead, and real-time subscripts	
	$_{A}$, $_{B}$	bus-A, bus-B subscripts	
\$/MWh	AC_E	average cost of energy for a load slice	
\$/MWh	AC_K	average cost of purchasing and using capacity for a load slice	
\$/MWyear	ARR	annual revenue requirement of a generator	
\$/MWh	CC	cost of providing spinning-reserve capacity.	
none	cf	capacity factor	
none	C	cost of Production	
none	D_{LS}	duration of load shedding	$(L_g > K)$
none	D_{PS}	duration of price spike	$(L_g + OR^R > K)$
none	D_{peaker}	duration of peaker use	$(L_g + OR^R > K_{base})$
none	e	price elasticity of demand	
MWh	E	energy	
\$/MWh	FC	fixed cost	
\$/MWh	F_T	current price of a future for delivery at time T	
MW	g	generation out of service	
none	h	true probability of needing spinning reserves	
none	$\hat{h}$	estimated h	
amps	I	electrical current	
MW	K	installed generating capacity (ICap)	
MW	$\bar{K}^e$	average K in an equilibrium when K is random.	

2 Pages of Symbols Missing