Math Model Explains High Prices in Electricity Markets

By Sara Robinson

In 1996, in the hope of reducing its historically high electricity prices, California became the first U.S. state to vote to open its energy markets to competition. Following electricity reform efforts in other countries, the state planned to undo the different functions of the old regulated monopolies, introducing competition for power generation and retail delivery.

California's venture, however, turned into a disaster of immense proportions, and became the poster child of an anti-power-grid campaign, weighing in with an alternative perspective on restructuring. In a recent opinion piece, Cho and Meyn's conclusion was awful.
Electricity Markets

1996, with wholesale prices hovering around $15 per megawatt-hour. California's demand for electricity peaks in the summer months, when air conditioners are in use. The state's demand is increased by importing hydropower from the Pacific Northwest. In the summer of 2000, however, hydropower was less abundant than usual because of a drought. At the same time, prices of natural gas and nitrogen oxide pollution permits were unusually high, driving up the operating costs of gas-powered generators.

In an already precarious situation, these events combined to create a perfect storm, with wholesale power prices soaring to levels nearly 500% higher than those of the previous summer. California had throughout most of the state were shielded from the price fluctuations, but the utilities were paying as much as $170 per megawatt-hour, ten times the average wholesale rate that was implicit in the fixed retail rate for consumers.

Only the San Diego Gas and Electric Company, which had already recovered its stranded assets, and was thus exposed to the rate freeze, was able to raise retail prices. In July, San Diego customers began receiving electric bills two to three times higher than those of previous summers. In response to the ensuing howls of protest, the state stepped in and reinserted the retail cap. Still, the federal government had to use emergency funds to help some residents pay their inflated utility bills.

As winter approached, demand for electricity leached, but the power shortages and high prices continued unabated. On November 1, 2000, FERC issued a preliminary order concluding that the inflated power prices were "unjust and unreasonable," and thus in violation of the Federal Power Act that FERC is mandated to uphold. The order suggested several "remedies" for the situation, including replacement of the $250 per megawatt-hour cap with a "soft" cap of $15 per megawatt-hour; bills two to three times higher than those of previous summers. In response to the ensuing howls of protest, the state stepped in and reinserted the retail cap. Still, the federal government had to use emergency funds to help some residents pay their inflated utility bills.

Nonetheless, FERC implemented the soft cap. In January 2001, prices zoomed to new highs, averaging $290 per megawatt-hour, and chronic shortfalls of available power forced statewide rolling blackouts. Through March, and by April, one state utility—Pacific Gas and Electric Company—had declared bankruptcy. Critics (including the independent subsidiary of PG&E's parent company, POKE Corporation, proliferated enormously during the crisis (from generators it owned), and Southern California Edison testified on the brink. Finally, the state itself intervene in the market, purchasing long-term power contracts, albeit at inflated rates, on behalf of the Utilities. "This was the major factor in stabilizing the wholesale market," Wolak says. Shortly afterward, FERC extended the soft cap on wholesale power prices across the West.

Economists' Perspective on the Crisis

California's power problems, Wolak suggests in a paper titled "Lessons from the California Electricity Crisis" (Electricity Journal, August 2003), stemmed primarily from some critical miscalculations by California's utilities, combined with extremely poor oversight by regulators. In the resulting environment, even a company with a small market share could drive up prices by withholding supply. Starting in the summer of 2000, that ability was enhanced by the diminished competition from hydro-power plants outside the state.

Several groups of economists (that include Borenstein, Joskow, and Wolak) performed studies comparing the actual prices in California's markets with those predicted by models under the same supply/ demand conditions. The actual market prices were significantly higher than the models' predictions. At the same time, data indicated that the number of power plants offline for maintenance or emergency repairs was substantially higher than normal. The reasons, taken together, are evidence that companies were indeed exercising market power during the crisis, Wolak says.

Market power was a problem because of the utilities' failure to hedge, by purchasing power in advance to deliver at a future date, Wolak says. Joskow suggests that a lack of forward contracting was a key issue, but that the blame on the state's regulatory agency, rather than the utilities. Under the restructuring agreement, all power transactions had to go through the Power Exchange. A generator that had contracted to sell a specified amount at a particular price would still have to bid in the power market for the right to produce that power. Through side payments, the effective payment from the utility to the generator would be the contracted price. Such a contract reduces a generator's incentive to withhold capacity to inflate wholesale prices, Wolak notes, because the generator has already sold the power. Moreover, if the generator bids high in the Power Exchange, it risks losing out in the auction and thus not being allowed to sell its power. In that situation, the generator would have to purchase power at market prices to meet its contract. Compounding these problems was the failure of regulators to understand the problems plaguing the market and offer appropriate remedies. It is this, Wolak believes, that turned market glitches into a full-fledged crisis. Regulatory problems are also preventing other electricity markets from delivering on their promise of lower prices.

Borenstein, in his paper, advocates a combination of long-term contracting andmaking prices does not contribute to the problems in California and elsewhere. In California, retail prices were fixed, and in other US markets, consumers pay a time-averaged price for power or, at best, prices for peak and off-peak times. With exposure to real-time fluctuations in power prices, consumers would have the incentive to conserve during peak times. This would lower the production capacity needed to meet peak demands, Borenstein writes, and would reduce prices for long-term contracts. Such measures are not popular, however. The idea of real-time pricing "is a regulatory failure because it is technologically feasible to do this," Wolak says. "State pub-

Ramp-up constraints for power plants, combined with inelastic demand, might make any decentralized approach inherently inefficient, even in the absence of the exercise of market power by participants.

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Electricity markets will not implement retail pricing plans that charge customers according to the hourly wholesale price.”

An Engineering Perspective

Without disputing that the issues cited by the economists were in play in the California power crisis, Meyn says he can not wholely agree with their conclusions.

"Why should high prices imply the exercise of market power?" he asks. Such conclusions, Meyn says, are based on intuition obtained from observing gross manipulation by Enron and others, and on decades of analysis of static models.

For Meyn, the fundamental explanation for the problems in California and elsewhere lies in the engineering constraints on power markets. In March 2004, at a workshop on power networks at the Institute for Mathematics and its Applications at the University of Minnesota, Meyn questioned whether a lack of long-term contracts and market manipulation could completely explain the collapse of California’s market. He hypothesized that the ramp-up constraints for power plants, combined with the miscalculation of the ancillary power sources ramp-up, with the auxiliary power sources ramping up faster than the primary one. Any excess power produced can be dumped at any time without cost, a simplifying assumption, the researchers note, because real costs are nonlinear. There is always a social cost of not meeting demand and incurring a blackout.

Starting from the premise that society benefits from the consumption of electricity, the researchers first solve for a policy that maximizes the total social value: the sum of the profits of the generators and the social value for the consumers. (For readers versed in control theory: This required solving a multidimensional singular control problem.) This policy represents what a centralized controller of a power market would ideally try to achieve.

The theoretical goal for decentralized markets, however, is to optimize through the actions of individuals, without a central controller. Toward this end, the researchers show the existence of an equilibrium price functional for which both consumers and generators arrive at the same policy decisions in a decentralized market. They prove that this equilibrium is unique, and that it coincides with the centralized social optimum. Choo and Meyn go on to show that even when their statistical assumptions on demand are relaxed, an equilibrium price functional, if it exists, must be of the form obtained for the model with Brownian demand.

Remarkably, the prices corresponding to this unique equilibrium are, on average, so high that a consumer would incur a negative benefit from participating in the market. Prices will be prone to volatile even without manipulation. Meyn says, because the unpricability of demand and the slow response of supply mean there will always be times when demand approaches the available supply and prices soar.

In the model, generators are assumed to be price-takers, meaning that a single generator’s actions cannot affect the price. When generators do have market power, however, the basic problem becomes more pronounced, Meyn says. If there is a real-time demand response to high prices, the problem disappears for the most part because demand would approach supply only rarely, in a fashion where the supply fails suddenly due to an outage or storm, prices could again explode.

Steven Strogatz, an applied mathematician at Carnegie Mellon University, considers the paper “a significant step forward,” both for its mathematical contributions and for the issue it raises. The next step for mathematicians, he says, will be to understand all the simplifying assumptions in the model to see if any of them are not justified. “Is this a problem we have to worry about, or is there something in the real market that is different than the model?” he asks.

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