In My View
Best Electricity Market Design Practices

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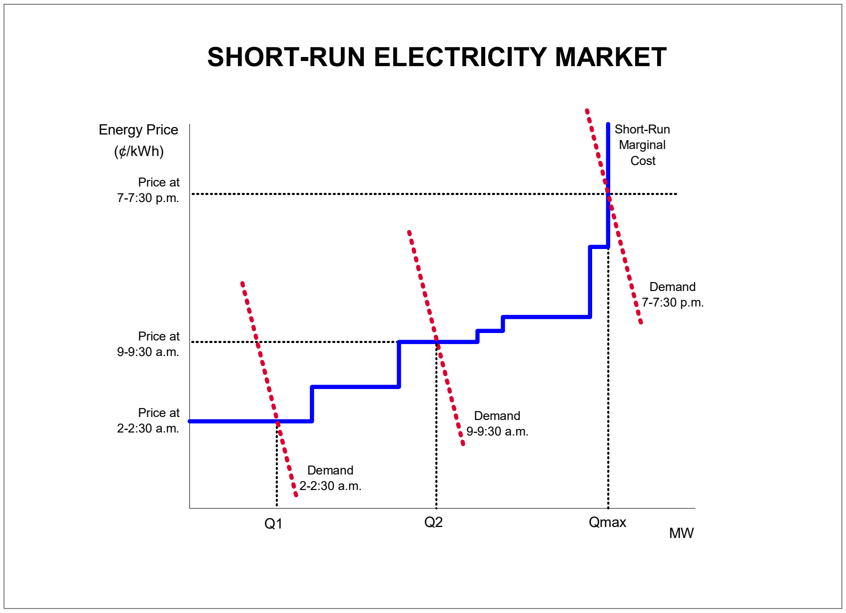
Organized wholesale electricity markets in the United States follow the principles of bid-based, security-constrained, economic dispatch with locational marginal prices. The basic elements build on analyses done when large thermal generators dominated the structure of the electricity market in most countries. Notable exceptions were countries like Brazil that utilized large-scale pondage hydro systems. For such systems, the critical problem centered on managing a multi-year inventory of stored water. But for most developed electricity systems, the dominance of thermal generation implied that the major interactions in unit commitment decisions would be measured in hours to days, and the interactions in operating decisions would occur over minutes to hours. As a result, single period economic dispatch became the dominant model for analyzing the underlying basic principles.

Figure 1: Spot Market



The structure of this analysis integrated the terminology of economics and engineering. As shown in Figure 1: Spot Market, the increasing short-run marginal cost of generation defined the dispatch stack or supply curve. Thermal efficiencies and fuel cost were the primary sources of short-run generation cost differences. The introduction of markets added the demand perspective, where lower prices induced higher loads. As demand shifted over the day, prices would rise and fall. The rents earned by generators, in the periods when prices were higher than dispatch costs, would provide the contribution for covering the cost of investment. With the accompanying simplifying assumptions, this efficient dispatch and pricing model would have been all that would be needed to support operating and investment decisions. Over thirty years ago, Schweppe and his colleagues showed how this basic efficient market could be expanded to include the effects of transmission and the associated locational prices.

Extension of this model to include multi-part bids, look-ahead, and multi-period optimization presented no major challenges in principle.

The road to success with this market design was littered with prominent failed attempts to avoid the basic analysis and dismiss the special characteristics of security-constrained economic dispatch. Eventually, the expensive failures demonstrated the importance of the basic principles and good market design. Not every electricity market in the world has made this transition. However, it is clear that if open access and non-discrimination principles set the constraints, there is only one market design that meets the test, and the critical elements of this efficient market design have been adopted by every organized wholesale market in the United States.

Practical application of the basic principles has been highly successful, but not always perfect. A major problem developed with implementation details that tended to depress the spot energy price, particularly during periods of constrained capacity. The defect of the twin absences of demand participation and explicit scarcity pricing created the missing money problem and the search for alternatives, usually some form of long-term capacity payment, to restore the economics of investment. These alternative approaches typically postulated some traditional generating capacity type to serve as the benchmark for the cost of new entry to identify and pay the missing money.

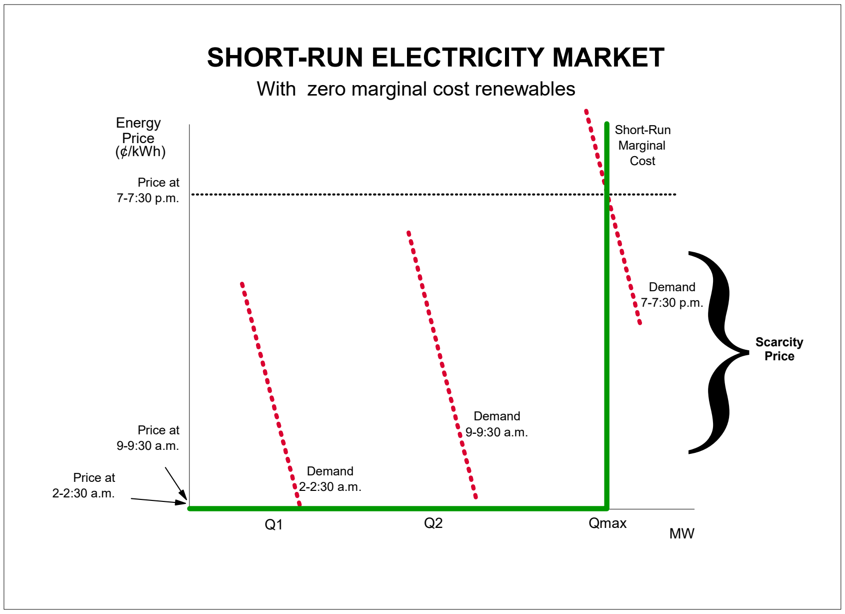
The early and growing penetration of renewables has been driven by mandates and subsidies. At some point, the likely importance of these top-down approaches will diminish for at least one of two reasons. The cost of the subsidies and mandates will be too great, and political economy will shift away from this approach. Or, the cost of renewables will decline to the point where they are fully economic without the mandates and subsidies, which will then atrophy and disappear. Hence, the interesting question is how can economically efficient renewables alter the fundamentals and how will this dictate changes in the basics of efficient electricity market design.

Going forward, the increasing role of intermittent renewables and the technological potential of distributed energy resources, especially including demand participation, might seem to turn over the assumptions of thirty years ago and call for an entirely new approach. From this perspective, large scale thermal generation, with relatively high short-run operating costs, will be replaced by capital intensive but low or zero variable cost resources. Distributed demand participation will be ever more important in managing overall system balance and security. The result will be a much less important role for spot markets and the associated spot locational marginal prices. Hence, so the argument goes, new revenue models will be required and the fundamentals of the basic electricity market will have to change.

Despite the appeal of this logic, it depends on implicit assumptions that are both wrong and point in the wrong direction for market reform. One implicit assumption is that the basic analysis cannot accommodate a world with a large fraction of energy supplied by zero variable cost renewable energy. The argument is that zero-variable-cost supply will produce low spot prices which could never support efficient investment.

The flaw in the argument is revealed by looking again at the implied spot market. Consider the extreme case in Figure 2. The short run supply curve, or dispatch stack, is now replaced with a green supply that is completely zero variable cost renewables. In most hours, the implied efficient price is zero, and demand participation would expand to take advantage of the free energy. In some hours, when the available capacity is fully utilized, the price rises to limit demand. In these periods, the short-run price is entirely determined by the scarcity value. But in all other respects, the analysis of basic principles is the same as it is for the Figure 1: Spot Market. The dispatch quantity changes over time, but the spot price is always equal to the short-run variable cost, including the marginal cost of scarcity. Efficient spot prices are part of the solution derived from basic principles. And with greater reliance on zero-variable-cost resources that can change availability over short horizons, the scarcity component of spot pricing becomes ever more important. In the extreme case, scarcity pricing is the only short-run incentive that matters.

Figure 2: Renewable Only Spot Market



Another implicit assumption of the flawed argument is that demand participation can be managed without efficient pricing mechanisms. Under the current supply configuration with large thermal generators it is possible to imagine centralized control without the benefits of spot prices. But even for the present case, it is a commonplace for system operators to observe how much better the system works when locational prices provide the right incentives and reinforce the choices of economic dispatch. Moving to greater reliance on distributed resources—many and small—and demand participators—many and small—leads inexorably to a greater need to have real-time spot prices that send the right price signals. Central control of distributed resources would not be feasible, and prices must provide the needed incentives. Failure to provide the right price signals will lead to distributed decisions that would undermine efficient operations.

Hence, increased arrival of renewables and greater reliance on distributed resources both point to fundamentals that reinforce rather than invalidate the fundamental logic of electricity spot market operation and pricing. This overview reveals that the problem lies not in the fundamentals of market design, but rather in the flaws of implementation that have led to the distracting focus on capacity markets and other ad hoc approaches for correcting the defects of the spot market implementation. There are a number of small and large changes in spot market implementation that have been long needed, and these reforms will be even more important for the future electricity system.

First and foremost is better scarcity pricing. The example of the Electric Reliability Council of Texas (ERCOT) market stands out as guiding the way. Embedded in the original spot market analysis, an assumption was that demand participation would handle the needed scarcity pricing. But there is a chicken-and-egg problem: without scarcity pricing there is not enough incentive for demand participation. A missing element is in the pricing of operating reserves, i.e. the short-term capacity set aside to deal with unexpected changes over the next dispatch intervals. This necessarily administrative construct can be addressed with the Operating Reserve Demand Curve, based on the value of lost load and the probability that load will be curtailed. As in Texas, this creates the right incentives for generation to be available, and through the associated energy price sends the virtuous signal to demand participation and distributed resources to respond to the needs of efficient dispatch. This separates scarcity pricing from the exercise of market power, adjusts the implied scarcity price over all hours, provides good incentives without requiring the system operator to declare an emergency, and provides an alternative to the administrative determination of long-term capacity payments.

A second reform would be to give greater attention to multi-period dispatch and pricing. In particular, ramping constraints can and do limit the ability to respond to short-term changes in net demand that will be of increasing importance with the expansion of intermittent resources. This sometimes goes under the heading of flexibility requirements. However, much of the problem in practice relates to actual dispatch models using something close to a single period formulation with the associated prices. This inherently ignores the value of ramping. The computational problems of a multi-period dispatch are relevant, but should not be determinative. With a multi-period dispatch that is longer than the range of the ramping constraints, spot prices in all periods can reflect the value of ramping flexibility and provide market rewards for the generators and demand participants that can and do respond, without the need to discriminate by creating special categories of dispatch resources.

One of the simplifying assumptions of the basic spot-market model is that everything is so flexible that there are no costs to startup, no minimum run times, and so on. Some markets are premised on the assumption that these real-world complications are so minor that they can be ignored. But ignoring these complications becomes more important in a system where the remaining thermal resources are transformed from base-load facilities that are always running to dispatched resources that keep changing output to meet the system requirements. In this model of the future, the costs of startup and minimum load complicate the pricing analysis and lead to the requirement for uplift payments to ensure participation in the dispatch. A natural extension of the basic analysis of efficient spot prices is found under the heading of Extended Locational Marginal Prices (ELMP) that preserve as much as possible of the basic pricing arguments and minimize the need for uplift payments. Although approximations of this pricing reform have been in use for many years, the more general application is receiving increased attention with the increased penetration of intermittent resources. Furthermore, implementation of ELMP in spot-markets interacts in a natural way with the need for multiperiod dispatch and pricing, so the reforms can proceed together.

The central role of the real-time spot market design is one of the key findings of the analysis of the fundamentals of electricity markets. The associated locational pricing model resolved the long-standing dilemma of how to charge for the opportunity costs of transmission, provides the foundations for financial transmission rights (FTRs), and creates the benchmark for the design of day-ahead markets that must be compatible with real-time pricing. The forward markets allow for reconfiguration of FTRs and the introduction of virtual bidding for day-ahead financial contracts that will be settled against the real-time spot price. The value of these prominent features of best practice in existing electricity markets has been well established in actual implementation. The reconsideration of these best practices in light of the increase in intermittent generation and distributed resources reinforces the importance of the fundamentals.

The problem is not the underlying structure of the theory of electricity spot markets. The basic model works in theory and performs well in practice. But the practical implementations have employed certain short-cuts, or averted eyes from the basics, and created imperfect market implementations that seem on their face to be incompatible with the needs of the electricity markets of the immediate future.

The argument here is that the fundamentals continue to point in the same direction. The defects in practical short-term markets are not minor issues that can be ignored. But a comprehensive rethinking of the market design is not required. What is required is to recognize the importance of the fundamentals, and the need to continue to improve on the market designs already in place. The expansion of intermittent and distributed resources makes this more urgent, but it would be a good idea in any event. The big mistake would be to continue to create new products and new subsidies in the futile attempt to replace market incentives with central procurement diktats. The proper challenge is to take the fundamentals seriously, and follow where they lead: get the prices right.

Bio

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For Further Reading

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