Transmission Congestion: The Nodal-Zonal Debate Revisited

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The original one-zone congestion pricing system proposed for the New England independent system operator (ISO) created inefficient incentives for locating new generation.[2] To counter these price incentives, the proposal imposed limiting conditions on new generation construction. Following the Federal Energy Regulatory Commission's (FERC) rejection of the resulting barriers to entry for new generation in New England, there developed a debate over the preferred model for managing and pricing transmission congestion.[3] One zone was not enough, but perhaps a few would do? Or should New England go all the way to a nodal pricing system?

> **Fact:** A single transmission constraint in an electric network can produce different prices at every node. Simply put, the different nodal prices arise because every location has a different effect on the constraint. This feature of electric networks is caused by the physics of parallel flows. Unfortunately, if you are not an electrical engineer, you probably have very bad intuition about the implications of this fact. You are not alone.

> **Fiction:** We could avoid the complications of dealing directly with nodal pricing by aggregating nodes with similar prices into a few zones. The result would provide a foundation for a simpler competitive market structure.

There are many flaws in this seductive simplification argument.[4] In reality, the truly simple system turns about to be a market that uses nodal pricing in conjunction with a bid-based, security-constrained, economic dispatch administered by an independent system operator. Purchases and sales in the balancing spot market would be at the nodal prices. Bilateral transaction would be charged for transmission congestion at the difference in the nodal prices at source and destination. Transmission congestion contracts would provide price certainty for those who pay in advance for these financial "firm" transmission rights up to the capacity of the grid. The system would be efficient and internally consistent.

The most obvious flaw in the zonal argument is in its very definition. If the nodal prices are not materially different, then there is no need to aggregate into zones. The nodal prices would already be simple to use in the market. Apparently the move to aggregate nodes into zones is really an effort to treat fundamentally different locations as though they were the same.

If market participants had no market choices, then there would not be much effect of such zonal aggregation, other than a certain amount of cost shifting. But a central objective of market restructuring is to give market participants as many choices as possible. Further, we expect that market participants will respond to profit incentives. If we don't "get the prices right," the market actors will respond to the prices and make choices that at best would significantly raise costs and at worst would dangerously compromise reliability.

There are many ways that things can go wrong. In the Pennsylvania-New Jersey-Maryland Interconnection (PJM), the 1997 experiment with a zonal pricing system collapsed as soon as the system became constrained. Responding to the incentives of zonal pricing, generators self-scheduled themselves to run rather than respect the transmission constraints. To protect reliability, the system operator had to suspend the market and essentially revert to command-and-control procedures whenever the system became constrained. Happily, in 1998 PJM replaced the zonal approach with nodal pricing and eliminated the artificial incentives to game the security constraints. The nodal pricing system is working well, supporting rather than undermining reliability.

In Australia, a zonal pricing system has greatly complicated the ability to offer transmission rights that match the real capability of the system. The same physical laws that govern nodal pricing make it impossible to define a complete set of zonal transmission rights, or to guarantee that generators can always participate in the market. By contrast, with a nodal pricing system such as in New Zealand, point-to-point transmission contracts can be defined in a natural way that is inherently consistent with the pricing regime and the real capacity of the grid. Just such a system of transmission contracts is operational with nodal pricing in PJM, and plays a central role in the recently FERC approved nodal pricing system for the New York ISO.[5] (Note: FERC explicitly objected to a proposed zonal aggregation for loads, calling for any metering changes needed to apply a full nodal pricing system.)

Similar experiences revealing the hidden complications of zonal pricing can be found from England to California, with different ad hoc rules applied to create more and more complex structures to fight against the choices of market participants confronted with administrative prices. Often it is hard to recognize the connections among the isolated ad hoc decisions, or to see the root of the problem in offering choices without getting the prices right. New England is not alone, but it could learn from the mistakes of others.

The real impact of zonal pricing is to create more administrative rules, poorer incentives for investment, demands to pay generators not to generate power, and proposals to "socialize" the higher costs by using the taxing power of the ISO. This is not the way of a market. It creates more problems than it solves.

Furthermore, there really are no major complications in implementing nodal pricing, once you look closely at what is required. The fears are misplaced, and the benefits are real and substantial.

Consider some of the arguments:

Is transmission congestion a small problem? No. On close inspection, few systems are really unconstrained. And when the constraints bind, the effects can be very important. Transmission congestion costs can easily exceed generation costs at the margin. The incentive effects have major commercial implications. Before the fact, zonal advocates argued that PJM would consist of at most only a few zones and constraints would be rare. In the event, the PJM market environment saw significant constraints in 15-20% of the hours in the first six months of operation, often under conditions that would be important in capturing commercial profits. And the number of zones needed to respect the commercially significant price differences in PJM has been more like one hundred than the promised few.[6] Zonal pricing is not simple.

Are nodal prices produced by a black box? No. Given the dispatch, the prices are easy to calculate, explain and audit. There is ample operational experience to dispel the notion that nodal pricing is too hard. The engineers know how to do it, and have been doing it for years. The nodal prices have always been there; we just haven't used them for market transactions.

Doesn't nodal pricing preclude transmission price certainty? No. To be sure, we do not know in advance what the spot price will be, just like in any market. But those who want transmission price certainty can acquire transmission congestion contracts. And those who do not want to pay in advance for price certainty, and want to rely on the spot market, cannot socialize the costs by making others pay for the congestion they create.

The list of misconceptions about the pricing debate is longer. Given the fundamental underlying differences in marginal costs, it is not so easy to define the zonal price. It is not an easy matter to set or later change the zonal boundaries. The inherent averaging of zonal prices tends to remove incentives for energy efficiency or distributed generation. And so on. Perhaps the most oft-repeated point of confusion has to do with the impact of zonal aggregation on the ability to exercise market power.

Won't zonal aggregation mitigate market power? No. Real elimination of the physical constraints would reduce market power. But administrative aggregation into zones simultaneously increases and obscures market power. Under the zonal approach, favored generators could take advantage of the real physical constraints, but their higher charges would be socialized and averaged over all system users.

Isn't a simpler system possible? Yes. The nodal pricing approach is completely consistent with a hub-and-spoke description of the market. One or more trading hubs can be established. The transmission charge for moving along the spokes, to and from the hub, is just the difference in the locational price and the hub price. This approach captures most of the intended simplification of the zonal model without embracing the hidden defects of aggregation. There is no mystery here. The hub-and-spoke approach is the system now working in PJM.

There is nothing unusual in nodal pricing. It is the natural system that falls out of an analysis of competitive market marginal-cost pricing principles in the context of the physics of the electric network. Nodal pricing does not solve all problems in electric market design, but it turns out to be important in dealing with some of the most intractable problems created by the special nature of the electric grid. If zonal aggregation is commercially attractive, it presents a business opportunity for its advocates and need not be imposed by the ISO. But practical experience and theoretical analysis both support the conclusion that for the independent system operator, nodal pricing is the simplest system that actually works in the context of a market with choices and flexibility.

Get the prices right, and it is much easier to rely on the market.

Endnotes.

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[1] Supporting papers and additional detail can be obtained from the author. William W. Hogan is the Lucius N. Littauer Professor of Public Policy and Administration, John F. Kennedy School of Government, Harvard University, and Senior Advisor, Putnam, Hayes & Bartlett, Inc. This paper draws on work for the Harvard Electricity Policy Group and the Harvard-Japan Project on Energy and the Environment. Many individuals have provided helpful comments, especially Robert Arnold, John Ballance, Jeff Bastian, Ashley Brown, Michael Cadwalader, Judith Cardell, John Chandley, Doug Foy, Hamish Fraser, Geoff Gaebe, Don Garber, Scott Harvey, Stephen Henderson, Carrie Hitt, Jere Jacobi, Paul Joskow, Maria Ilic, Laurence Kirsch, Jim Kritikson, Dale Landgren, William Lindsay, Amory Lovins, Rana Mukerji, Richard O'Neill, Howard Pifer, Susan Pope, Grant Read, Bill Reed, Joseph R. Ribeiro, Brendan Ring, Larry Ruff, Michael Schnitzer, Hoff Stauffer, Irwin Stelzer, Jan Strack, Steve Stoft, Richard Tabors, Julie Voeck, Carter Wall and Assef Zobian. The author is or has been a consultant on electric market reform and transmission issues for British National Grid Company, GPU Inc. (and the Supporting Companies of PJM), GPU PowerNet Pty Ltd, Duquesne Light Company, Electricity Corporation of New Zealand, National Independent Energy Producers, New York Power Pool, New York Utilities Collaborative, Niagara Mohawk Corporation, PJM Office of Interconnection, San Diego Gas & Electric Corporation, Transpower of New Zealand, Westbrook Power, Williams Energy Group, and Wisconsin Electric Power Company. The views presented here are not necessarily attributable to any of those mentioned, and any remaining errors are solely the responsibility of the author. (http://ksgwww.harvard.edu/people/whogan).

[2] The use of zones for collecting transmission fixed charges is not the issue here. The focus is on managing transmission congestion. For a critique of the previously proposed one-zone congestion pricing system, see Peter Cramton and Robert Wilson, "A Review of ISO New England's Proposed Market Rules," Market Design, Inc., September 9, 1998.

[3] Federal Energy Regulatory Commission, New England Power Pool Ruling, Docket No. ER98-3853-000, October 29, 1998.

[4] William W. Hogan, "Nodes and Zones in Electricity Markets: Seeking Simplified Congestion Pricing," in Hung-po Chao and Hilliard G. Huntington (eds.), Defining Competitive Electricity Markets, Kluwer Academic Publishers, 1998, pp. 33-62. Steve Stoft, "Transmission Pricing in Zones: Simple or Complex?", The Electricity Journal, Vol. 10, No. 1, January/February 1997, pp. 24-31.

[5] Federal Energy Regulatory Commission, New York ISO Ruling, Docket Nos. ER97-1523-000, OA97-470-000 and ER97-4234-000, January 27, 1999.

[6] William W. Hogan, "Getting the Prices Right in PJM: What the Data Teaches Us,:" (sic), Electricity Journal, August-September, 1998, pp. 61-67.