

**MARKET MECHANISMS AND DECOMPOSITION
FOR COORDINATION OF
TRANSMISSION LINE LOADING RELIEF
ACROSS MULTIPLE REGIONS**

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The development of rules for reliability and rules for markets confront a familiar human condition -- the desire for mutually inconsistent things.

- **What Do We Want?**
 - Multiple control areas with different approaches to scheduling and coordination.
 - Maximum opportunities and flexibility for choice, trading, and commerce.
 - Minimum commercial interference.
 - Maximum economic efficiency.
 - More, not less, reliability.

- **What Do We Have?**
 - An interconnected grid where everything affects everything else, fast.
 - Conflicting agendas and ideologies.
 - Too many good ideas.

Evidence of the current confusion appears in parallel activities that tend to be discussed in isolation, but where there is substantial overlap in alternative approaches for the same core problem: rationing use of scarce transmission capacity. Furthermore, the approaches tend to be mutually inconsistent.

- **OASIS.** The central FERC requirement for transmission scheduling and coordination, which offers itself as an innocuous information protocol but is in fact a restrictive and flawed market model.
- **NERC Security Coordinators.** A response to the flaws of OASIS, driven by the fears that the reality of the grid would not accommodate the fictions of the simplistic model.
- **ISOs.** A range of approaches and institutions for providing the many services that are necessary to make the grid function, including security coordination.
- **CRT.** The FERC capacity reservation tariff initiative for transmission property rights and trading to integrate reliability and commercial market activities.

The challenge is to support market transactions while preserving reliability.

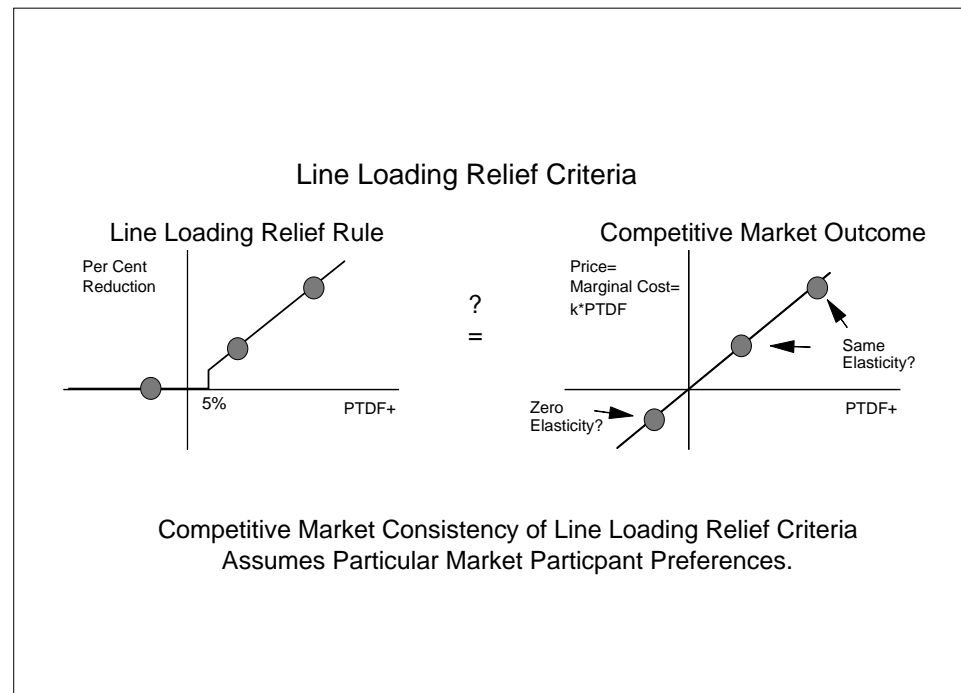
The FERC mandated method of scheduling and coordinating transmission usage was adopted despite its transparent fallacies because it was familiar, and FERC did not know what else to do. An old lesson repeated: "You can't beat something with nothing."

- **Contract Path.** The OASIS rules presume and perpetuate the "contract path" fiction that has little to do with what actually occurs in the transmission grid.
- **Problematic Estimates of Available Transmission Capacity.** The method requires a "squaring of the circle" by estimating something which in principle is not well defined.
- **Incentives to Under-Estimate.** The transmission owners off the contract path get some of the problems but none of the money.
- **Incentives to Over-Schedule.** The transmission owners on the contract path get all of the money but only some of the problems.

This solution is less than the least common denominator. It is broken, and needs to be fixed.

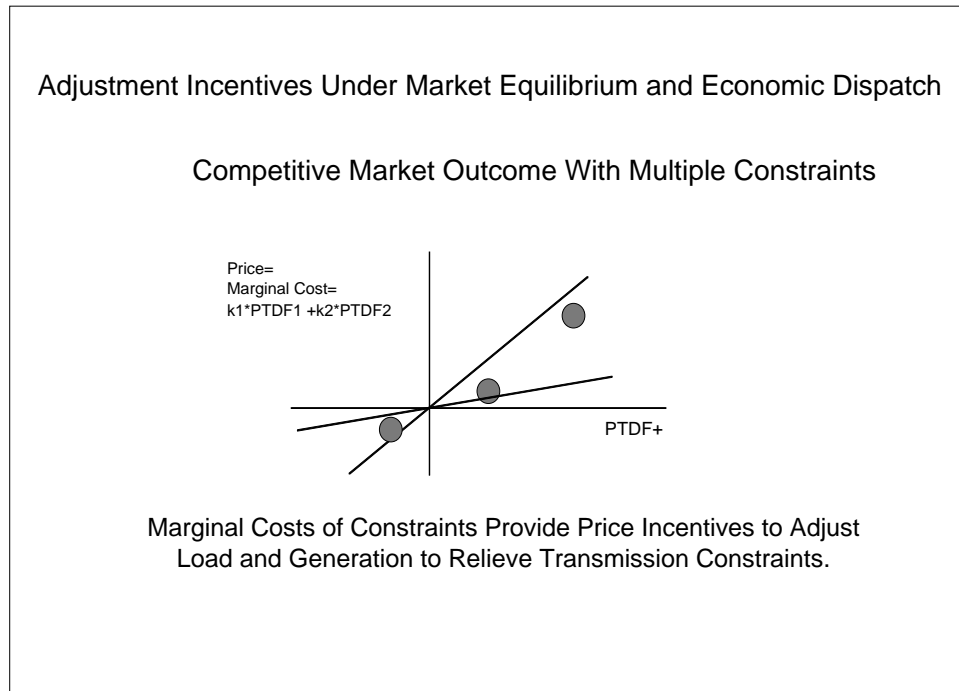
Faced with the imminent problems of reliability, NERC put in place a system of security coordination to control use of the grid within the limits of an OASIS-driven contract path system excluding explicit consideration of commercial activities. "A solution and a problem."

- **Twenty Three Security Coordinators.** Coverage of interconnected grid.
- **Tagging Debate.** Transaction oriented system with tags to identify source and sink.
- **Flowgates, Derated System, and Power Transfer Distribution Factors.** Used to identify network effects of transactions for curtailment analysis
- **Single Constraint: The Critical Path.** Methodology based on relief of a single constraint on actual flows.
- **Transaction Adjustment Criteria.** No commercial criteria; guided by objectives of equity and sharing the responsibility for adjustment. Limited connection to requirements of a market.



Independent System Operators are in place with a variety of responsibilities. Functions include the role of security coordinator for their region, but the rules are different for internal and external transactions. The more developed systems integrate reliability with support of the market.

- **Multiple Contingency Constraints.** Less reliance on derated systems and lower estimates of transmission capacity.
- **Multiple Paths and Power Distribution Factors.** Recognize in principle and in practice that there will be multiple constraints that limit transmission usage.
- **Security Constrained, Bid-Based Economic Dispatch.** Familiar principles of power system control adapted to bid-based systems that support market interactions.
- **Congestion and Locational Pricing.** Prices reflect marginal costs and the impact on transmission congestion. Market transactions adjust to relieve transmission constraints.



A challenge is to define a set of security rules and institutions that support commercial transactions in a market setting.

- **Curtailement Complaints.** The security coordinator administrative approach of priority categories and non-market curtailment rules is inefficient, lowers effective transmission capacity, and creates its own new set of problems. (Rajaraman and Alvarado 1998)
 - Poorly defined transmission rights that are difficult to trade. Poorly estimated PTDFs and flowgate limits that derate the grid.
 - Limited opportunities to pay to avoid curtailment, the usual market response.
 - Curtailment seldom includes curtailing the real load, which means generation must still be found. This shifts the task of managing transmission congestion.
- **Purchase and Sales Through Security Coordinators.** Paying for counterflow to relieve transmission congestion would be efficient.
 - Buying high and selling low to move power against the flow. If everyone is not paying for transmission congestion, where does the money come from?
 - If the those causing congestion are charged for the use of the system, this reverses the flow of money and leaves the virtual ISO with congestion rents.

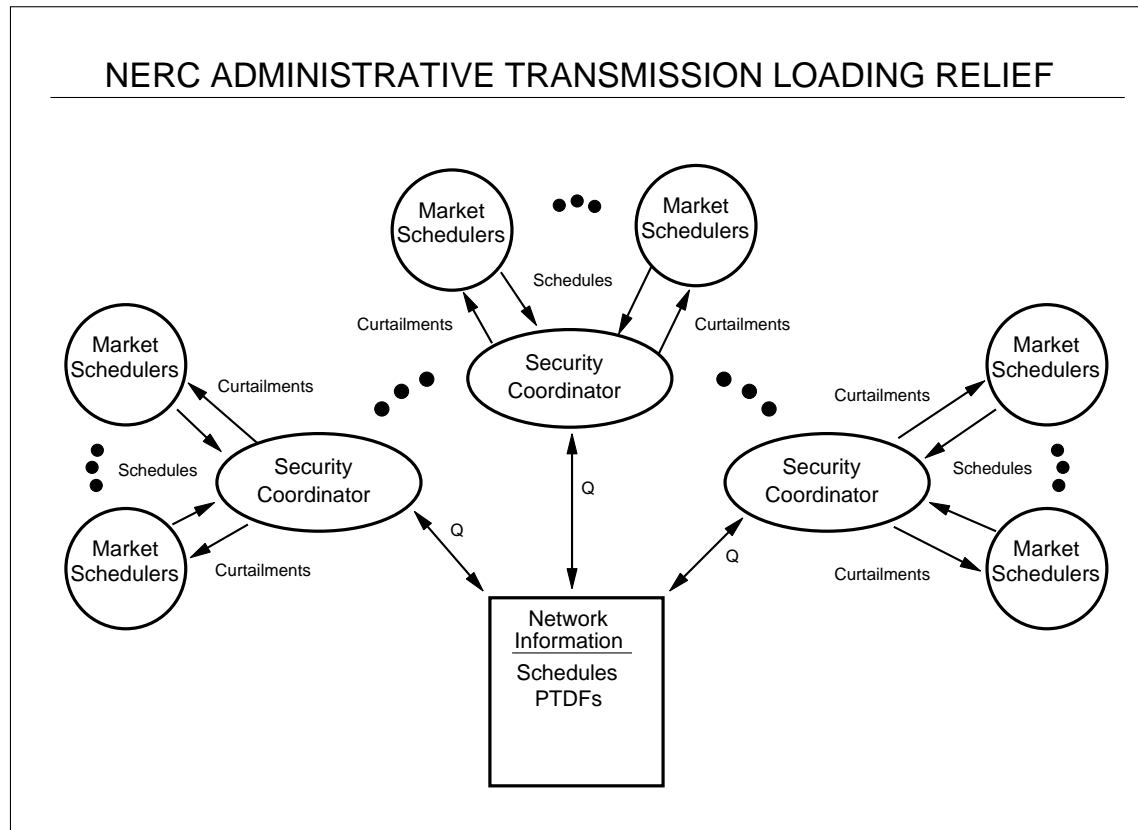
Key problems remain that have no easy answers. Part of the task is to address these problems within a coherent and consistent framework. Part of the task is to muddle through while we work on the framework, without making things worse than they are, or worse than they were.

- **Coordinating Multiple Control Areas.** With many interacting control areas and different systems making independent and decentralized decisions, the only solution may be to lower the effective transmission capacity and impose restrictive rules. Is it possible to have many approaches on one grid?
- **Decomposition Rules and Grid Oversight.** There are theoretical difficulties decomposing decisions across parts of an interconnected grid. The work of Kim and Baldick (1997) as applied by Boucher, Dekelver and Smeers (1998) provides an approach based on connecting variables. A clever idea without contingency constraints, but the intended limited information exchange expands proportionally when contingencies are considered. It may be necessary that security coordinators or their functional equivalents have a de facto view of the entire grid.
- **A Super ISO or a Virtual ISO?** A single ISO for an entire grid is not appealing, but the idea came out of the closet at the FERC ISO conference in April 1998. The information and transaction costs seem imposing, although they have not been examined. Would it be possible to create a virtual ISO that involved tiered-trading within and between control areas? (Cadwalader, Harvey, Hogan and Pope 1998)

TRANSMISSION COORDINATION

Administrative Coordination

The existing NERC system exchanges quantity information about scheduled loads to determine the impact on the grid. Administrative rules and priorities determine schedule curtailments.



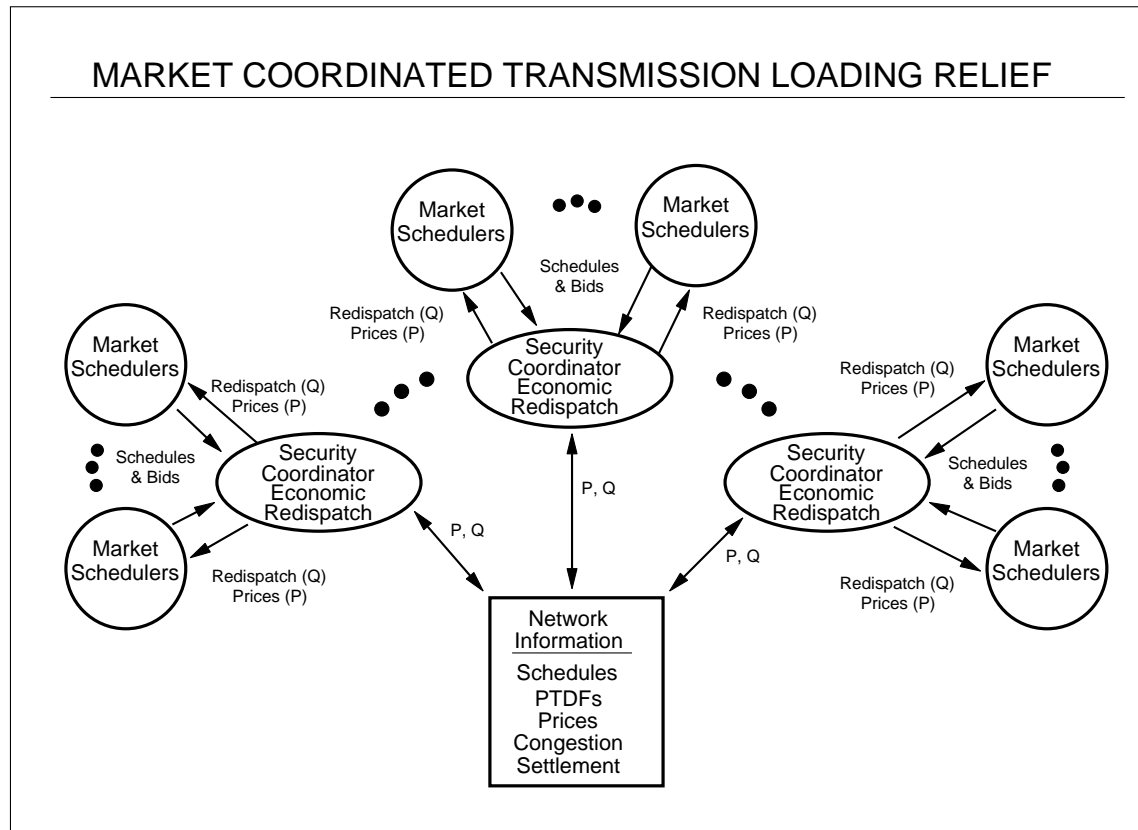
Movement to greater use of market forces would require expansion of the NERC transmission loading procedures.

- **Prices.** The use of markets implies pricing and the associated incentives. Participants must have economic information and face real prices to induce market support of transmission loading relief.
- **Schedules, Bids and Economic (Re)Dispatch.** The ISO framework of schedules supplemented by incremental and decremental bids provides the opportunity to use security constrained economic dispatch to redispatch schedules and respect security limits to achieve efficient transmission loading relief.
- **Iteration.** Regional security coordinators could exchange information about both schedules and prices in an iterative process to establish a mutually consistent redispatch for transmission loading relief.
- **Settlements.** A system-wide settlements system could handle payments between and among the regional security coordinators.
- **Integration of Markets and Reliability.** The supposed dichotomy between markets and reliability is false. And the implied separation between reliability (ISOs) and short-term markets (Power Exchanges) is counterproductive. At best, the false separation is expensive. At worst, it is dangerous. Both markets and reliability can be improved if the essential interactions are recognized and integrated.

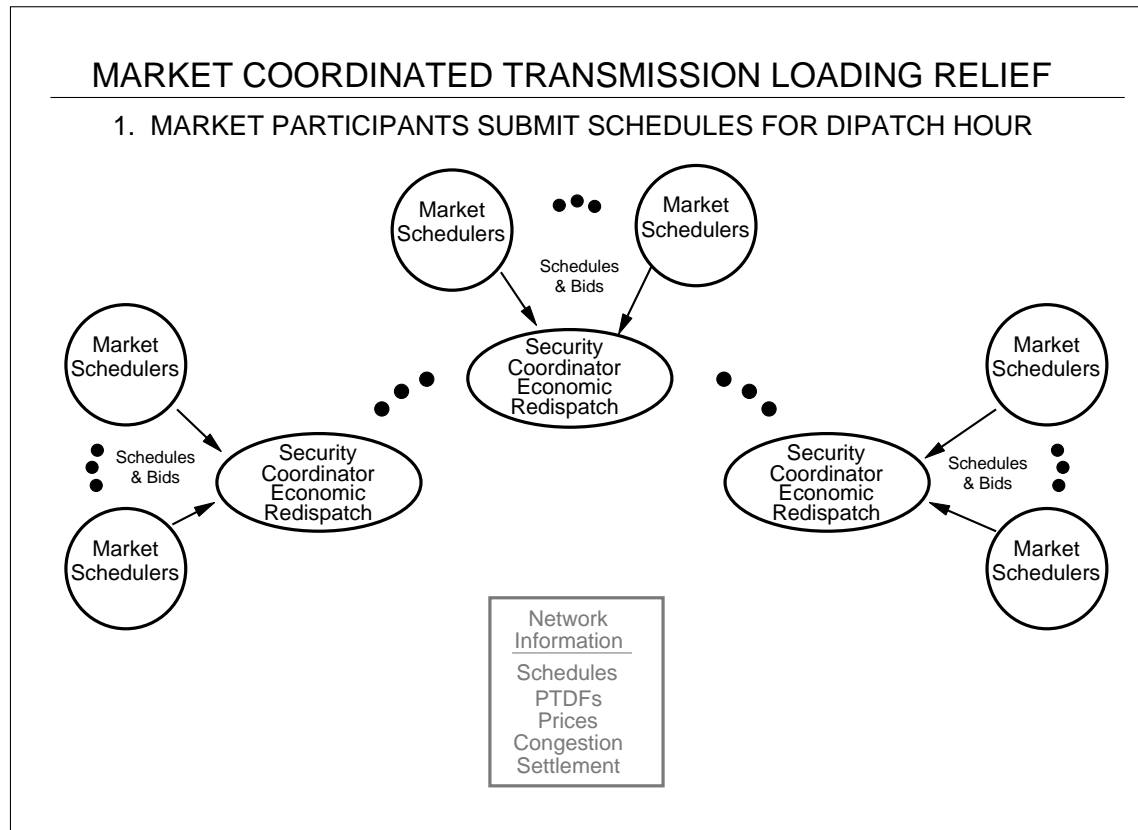
TRANSMISSION COORDINATION

Market Coordination Overview

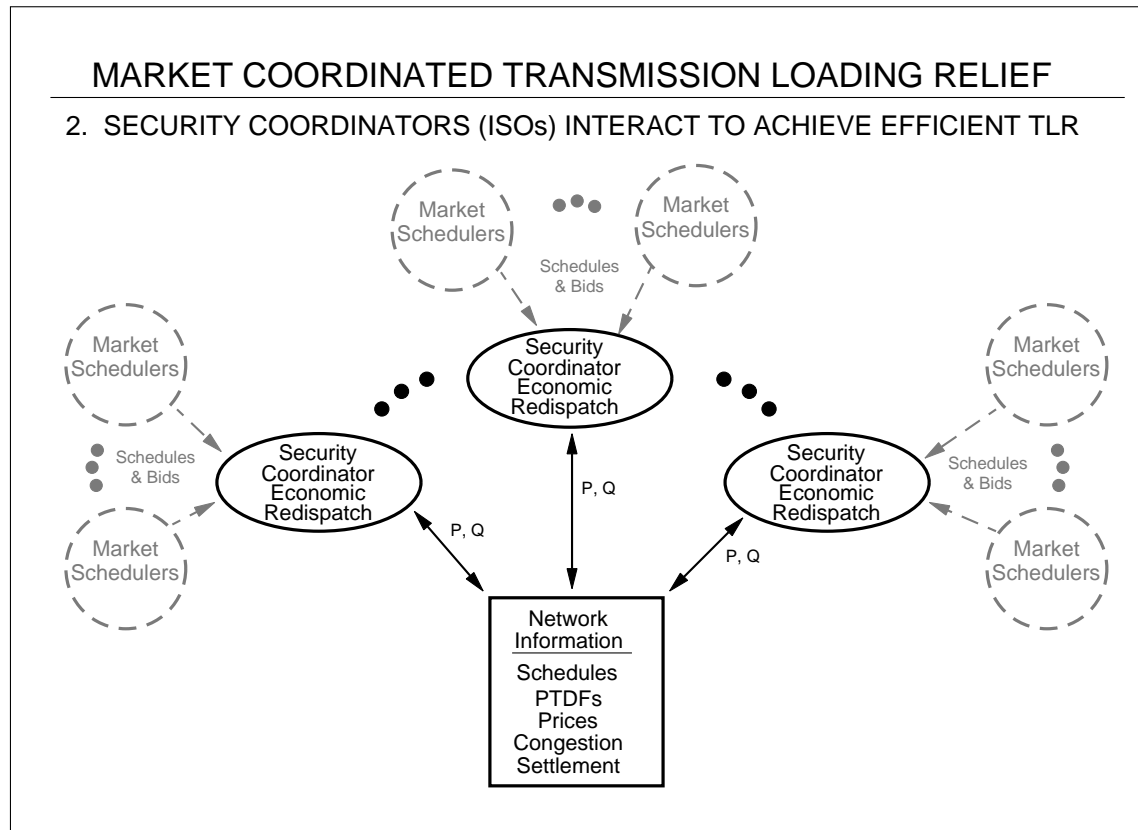
A market oriented system would require information on scheduled loads, bids and prices to determine an economic redispatch of the system.



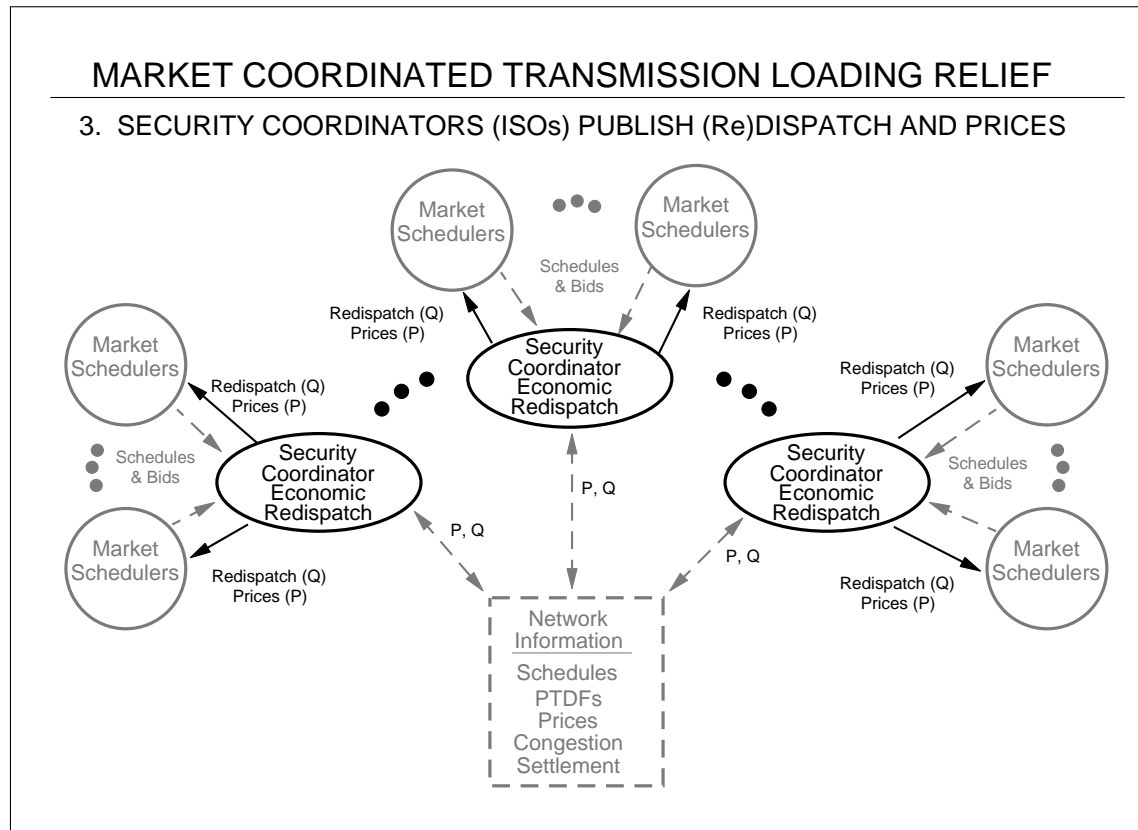
A market oriented system would begin with market participants submitting both schedules and bids to adjust those schedules.



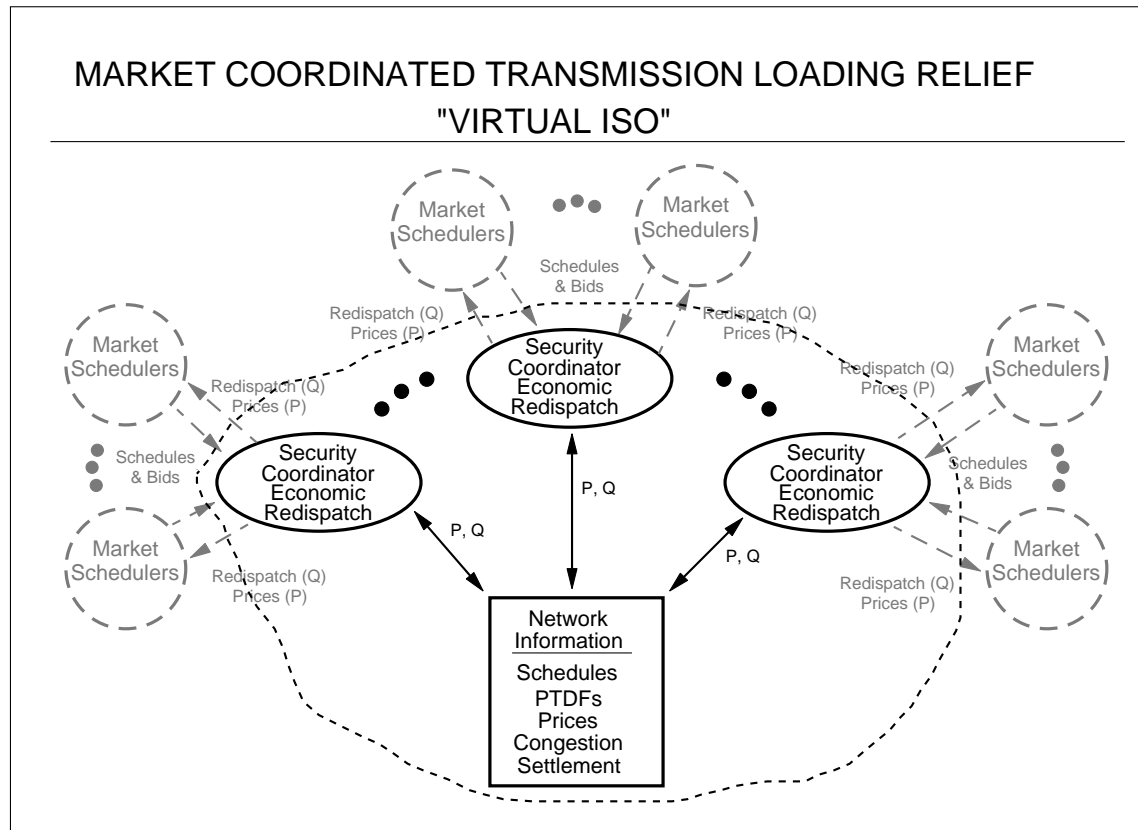
Given the schedules and bids, the security coordinators (ISOs) would interact to find an efficient market solution that balanced the system and relieved transmission constraints.



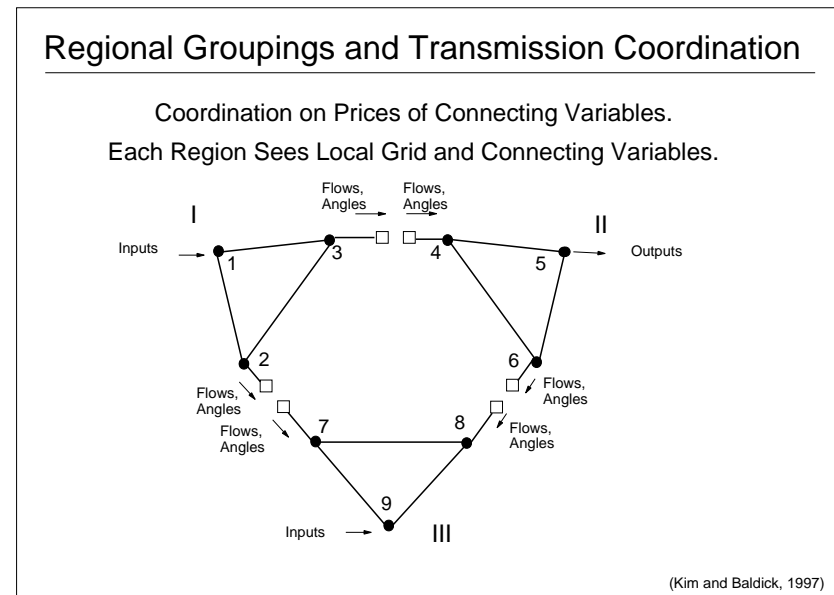
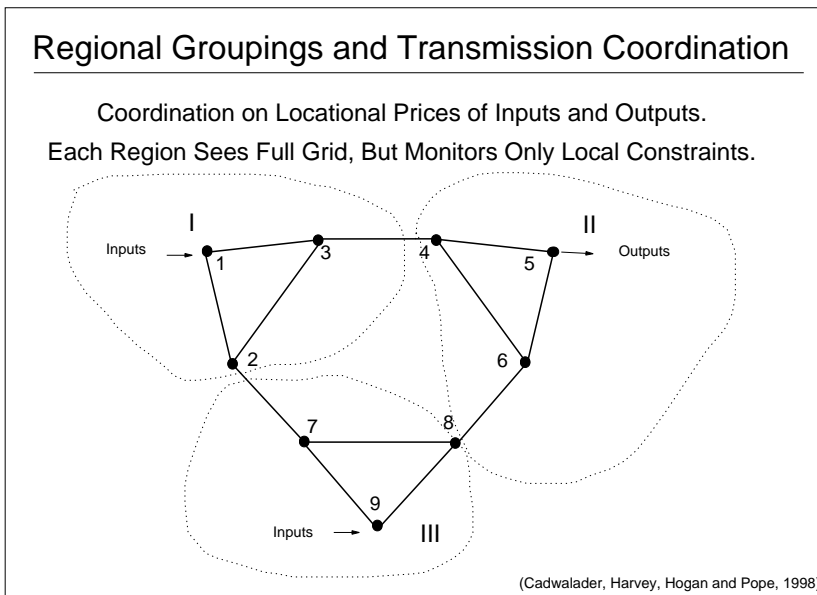
Finally, security coordinators inform the market participants of the (re)dispatch for the hour and the prices that will apply for balancing charges, transmission congestion charges, and settlements.



Through repeated exchange of information in a common data base, the regional security coordinators would solve their local problems to update the schedules and price estimates. A consistent solution would be an overall market equilibrium as though obtained by a "virtual ISO." Need to identify the required information flows and the rules for updating.



Alternative approaches to network representation yield different approaches to regional decomposition and coordination. Coordinating on locational prices of inputs and outputs (Cadwalader et al.) and coordinating on connecting variables (Kim and Baldick).



TRANSMISSION COORDINATION

Coordination on Scheduled Inputs

(Cadwalader, Harvey, Hogan and Pope) A market coordination approach could rely on economic (re)dispatch by each of the regional security coordinators. The regional problem would be:

Given schedules and prices from all regions, each region uses local bids and constraints to choose a redispatch across the grid to

Maximize [Net Benefit of Local Market Schedulers as Reflected in Bids]
+ [Profit from Redispatch Purchase and Sale at Locational Prices in Other Regions]
- [Congestion Cost from Redispatch Requested in All Regions]

Subject to:

Maintain System Balance with Redispatch

&

Meet Local Transmission Constraints Monitored by the local Security Coordinator.

Each Region Produces Estimates of:

1. Schedule Adjustments Across the Grid.
2. Locational Prices within the Region.
3. Congestion Cost Impact of any Redispatch on the Local Constraints.

Iteration to a consistent solution yields a market equilibrium with coordinated transmission loading relief.

A market coordination approach based on scheduled inputs and a full model of the grid is an incremental step that should be within reach.

- **Familiar (Re)Dispatch Problem.** The form of the market equilibrium problem that would be presented to the regional ISOs is the same as the problem now solved in balancing schedules and bids within the region along with trades in and out of the region, using a model of the full grid. The NERC TLR administrative procedure requires exchange of quantity information. The change for coordination across regions would be to add price information.
- **Precedent for Pricing TLR Across Regions.** The use of locational prices to charge for congestion from outside the region has already been proposed by the Pennsylvania-New Jersey-Maryland Interconnection (PJM) Energy Committee as a first step towards integrating market operations and TLR. Participants outside PJM would be able to avoid PJM TLR curtailment by paying for the congestion they create within PJM.
- **Principal Obstacle is the False Separation of Markets and Reliability.** The history of FERC policy and NERC policy has reinforced the fallacious argument that there should be a sharp separation between reliability and markets. Given the strong and complex interactions in electric networks, this continuing attempt to prevent what is obviously accepted elsewhere in the world -- integration of the short-term balancing and congestion relief decisions under the familiar principles of economic dispatch -- is a first-order policy problem.

TRANSMISSION COORDINATION Coordination on Connecting Variables

(Kim and Baldick) A market coordination approach could rely on economic (re)dispatch by each of the regional security coordinators. The regional problem would be:

Given connecting prices and quantities for contingency-based flows, angles and voltages from neighboring areas, each region chooses a redispatch on its sub-grid to

Maximize [Net Benefit of Local Market Schedulers as Reflected in Bids]
- [Payments for Connecting Flows and Other Variables at Current Prices]

Subject to:

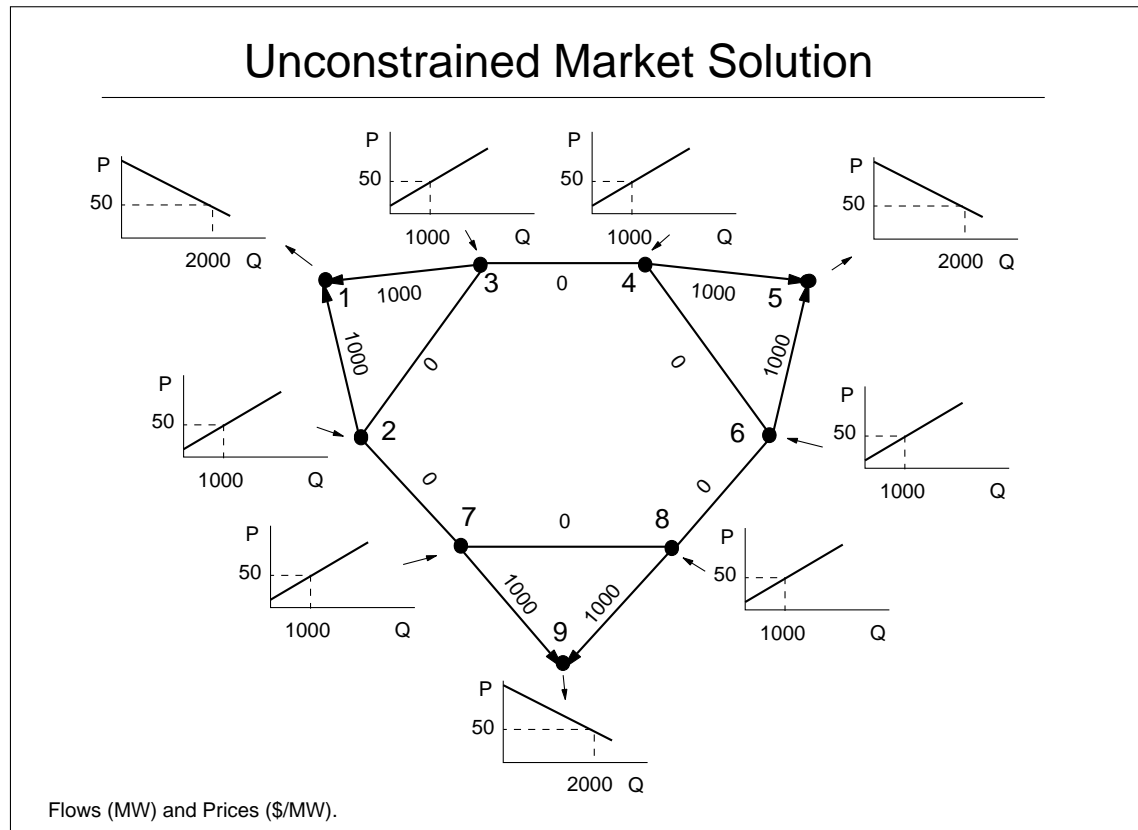
Maintain Regional System Balance with Redispatch
&
Meet Local Transmission Constraints Monitored by the local Security Coordinator.

Each Region Produces Estimates of:

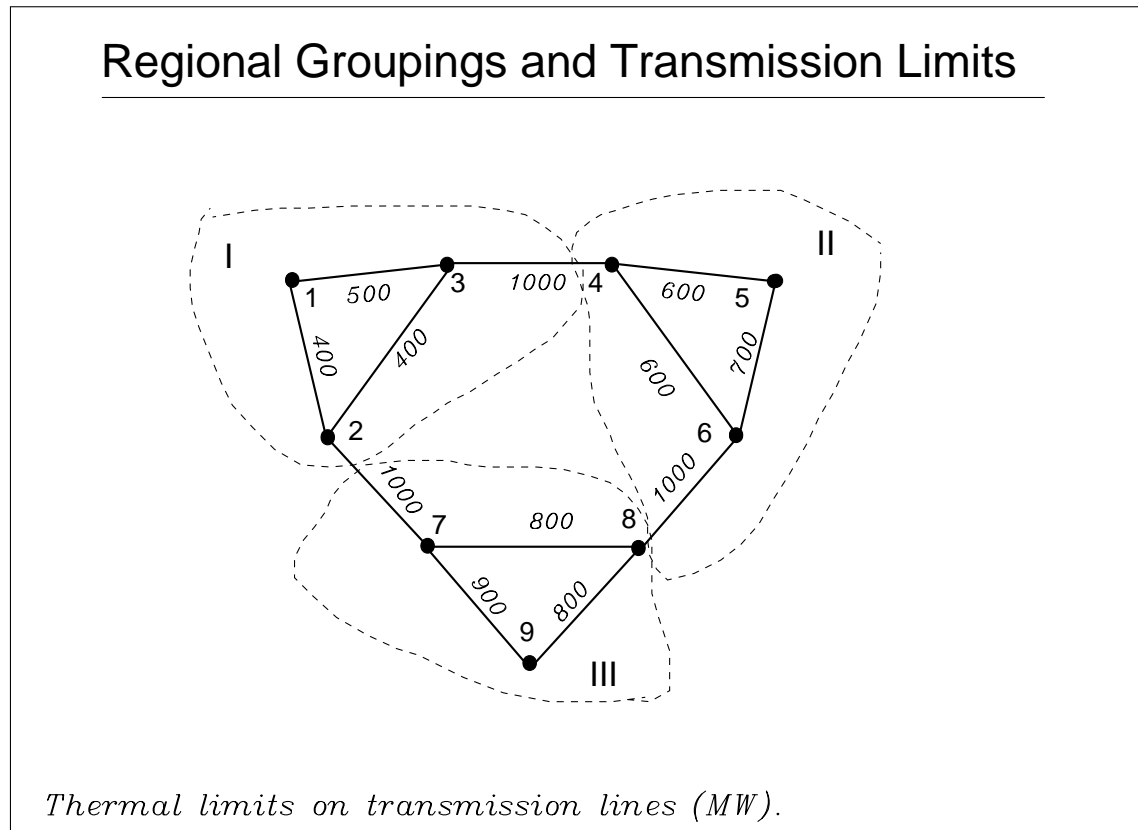
1. New Estimates of the Connecting Variables.
2. Regional Prices for the Connecting Variables.
3. Regional Economic Dispatch.

Iteration to a consistent solution yields a market equilibrium with coordinated transmission loading relief.

An example network with nine locations and provides an illustration of a "virtual ISO" operating by coordinating inputs across the full grid. The unconstrained solution provides a starting point.



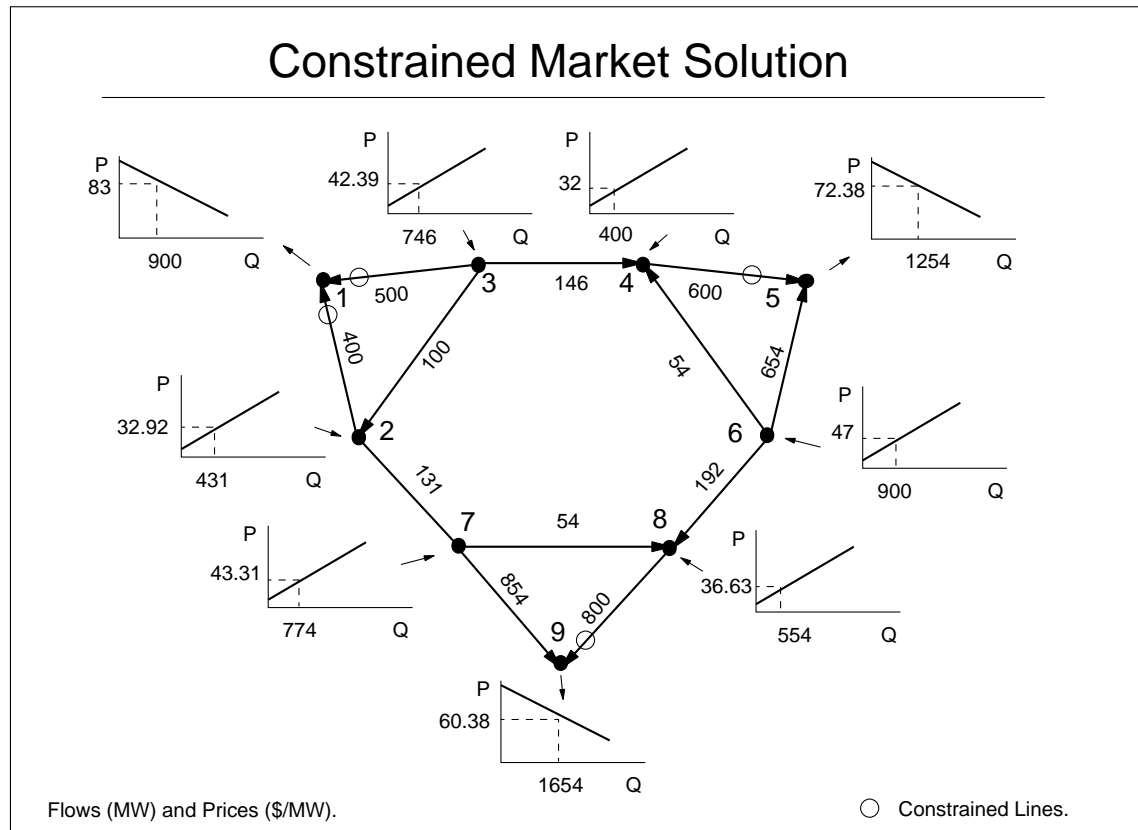
Three security coordinators or ISOs coordinate the operations within each region and exchange information with each other. Each ISO sees the flows on the full grid, but monitors only its own transmission constraints.



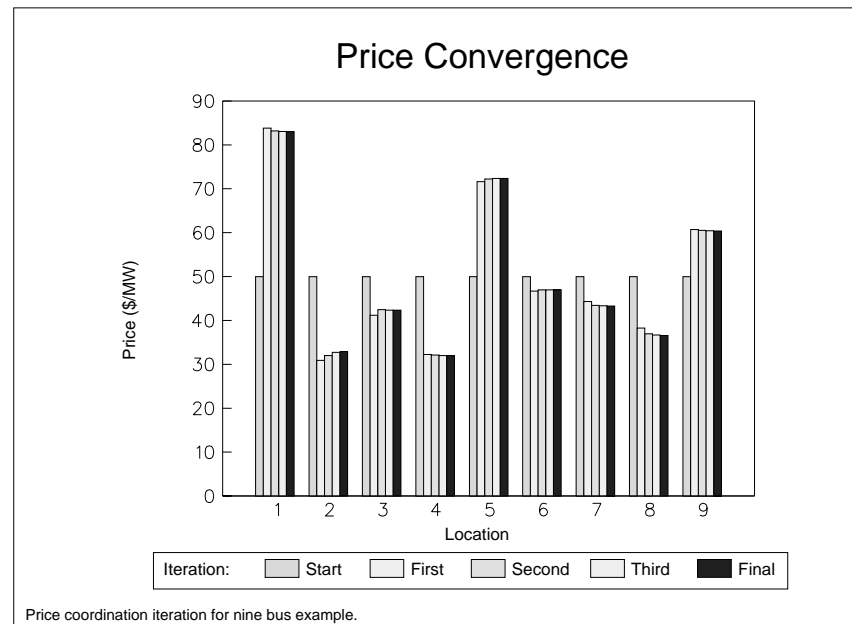
TRANSMISSION COORDINATION

Market Coordination

Through the exchange of information, the ISOs find a constrained solution for the full system that is an overall market equilibrium. Payments could be handled through a settlements process.



If the "local" constraints and bids are the most important, convergence to a good solution could occur in a relatively few steps. For the example problem, with coordination across locational prices of loads, one cycle through the three ISOs gave a good approximation of the final solution.



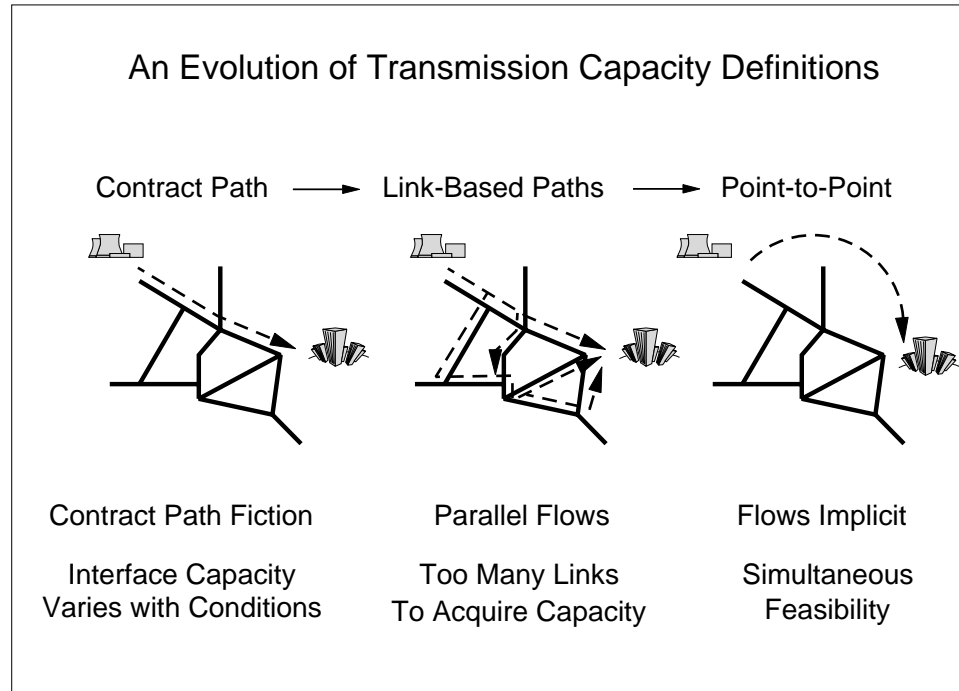
Baldick, Kim, Chase and Loo (1998) report similar fast convergence in a test without contingency constraints for a 2578 line representation of the Texas ERCOT system and coordination on connecting variables.

The "virtual ISO" model provides a target for development of transmission loading relief processes. There would be many implementation issues, such as:

- **Drawing the Boundaries.** Analysis of the coordination mechanisms suggests that a regional aggregation should be better when the looped impacts across the boundaries are reduced relative to the looped impacts within the region. The best form of interconnection would be radial, with no distant impacts on constraints and prices.
- **Network Modeling.** Coordination across all inputs and outputs requires the security coordinators or ISOs to represent both their own regional network and the external system. This a familiar problem and a challenge. Coordination on connecting variables is unfamiliar and would require a redesign of economic dispatch models.
- **Incompatible Systems and Transitions.** If not all security coordinators cooperate in the system, methods would be required to represent or isolate the missing systems. The two frameworks suggest the direction of the necessary approximations.
- **Gaming and Honest Revelation.** The coordination frameworks assume the regional security coordinators do not game the process by providing misleading estimates or strategic changes in schedules for local advantage. This would be a reasonable assumption for market models based on ISOs charged to use a bid-based, security constrained, economic dispatch. This resolution of gaming problems would not be available for market models that would give market participants an opportunity to respond to interim coordination and price information.

The FERC CRT proposal is a critical innovation in moving to point-to-point rights in place of the contract path approach. This would connect with the settlements process among regions.

- **Point-to-Point Transmission Capacity Rights.** Abandoned contract path and link-based approaches for tradeable point-to-point rights. Handles all constraints
- **Physical vs. Financial Rights.** Industry response emphasized the difficulty of trading rights and matching with physical transmission use. Alternative interpretation emphasized financial contracts.
- **Coordinated Trading of Rights.** Transmission right trading requires coordination to respect network interactions. A role for the ISOs?
- **PJM Implementation.** The CRT is alive and working in the PJM implementation with Fixed Transmission Rights to receive congestion payments. Proposed in New York with equivalent transmission congestion contracts.



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 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, Ross Baldick, John Ballance, Jeff Bastian, Ashley Brown, Terry Callender, Judith Cardell, John Chandley, Jose Delagdo, Doug Foy, Hamish Fraser, Geoff Gaebe, Don Garber, Stephen Henderson, Carrie Hitt, Jere Jacobi, Paul Joskow, Maria Ilic, Laurence Kirsch, Jim Kritikson, Dale Landgren, William Lindsay, Amory Lovins, Paul McCoy, Rana Mukerji, Richard O'Neill, Andy Ott, Robert Pike, Howard Pifer, Grant Read, Bill Reed, Joseph R. Ribeiro, Brendan Ring, Larry Ruff, Michael Schnitzer, Yves Smeers, Hoff Stauffer, Irwin Stelzer, Jan Strack, Steve Stoft, Richard Tabors, Sam Thomas, Robert Thompson, Julie Voeck, Carter Wall, Steve Walton, 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, Trans Power of New Zealand, 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>)