ELECTRICITY MARKET DESIGN:
FINANCIAL TRANSMISSION RIGHTS

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The Foundations of the New Mexican Electricity Market

Mexico

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The case of electricity restructuring presents examples of fundamental problems that challenge regulation of markets.

- **Marriage of Engineering and Economics.**
  - **Loop Flow.**
  - **Reliability Requirements.**
  - **Incentives and Equilibrium.**

- **Devilish Details.**
  - **Market Power Mitigation.**
  - **Coordination for Competition.**

- **Jurisdictional Disputes.**
  - **US State vs. Federal Regulators.**
  - **European Subsidiarity Principle.**

Order 888, 1996: "Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services by Public Utilities; Recovery of Stranded Costs by Public Utilities and Transmitting Utilities." The Order followed from a lengthy debate about the many details of electricity markets.

> "Today the Commission issues three final, interrelated rules designed to remove impediments to competition in the wholesale bulk power marketplace … . The legal and policy cornerstone of these rules is to remedy undue discrimination in access to the monopoly owned transmission wires that control whether and to whom electricity can be transported in interstate commerce." (FERC, Order 888, April 24, 1996, p. 1.)

- **What did Order 888 anticipate for the development of electricity market design?**
- **What other electricity market design options are available to achieve the objectives of open access and Order 888?**
- **Is it possible to reform Order 888 to achieve the open access objective to remove impediments to competition?**

Can open access not be about market design?

Under Order 888 the FERC made a crucial choice regarding a central complication of the electricity system.

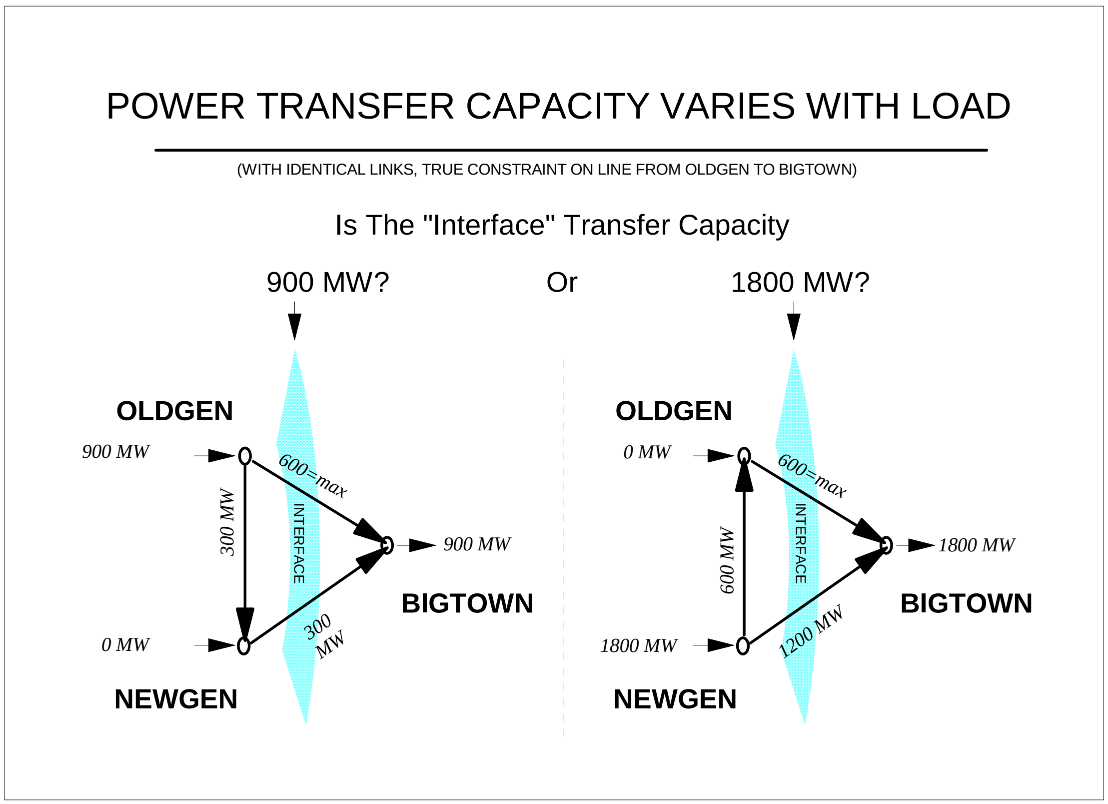
> “A contract path is simply a path that can be designated to form a single continuous electrical path between the parties to an agreement. Because of the laws of physics, it is unlikely that the actual power flow will follow that contract path. … Flow-based pricing or contracting would be designed to account for the actual power flows on a transmission system. It would take into account the "unscheduled flows" that occur under a contract path regime.” (FERC, Order 888, April 24, 1996, footnotes 184-185, p. 93.)

Why is this important?

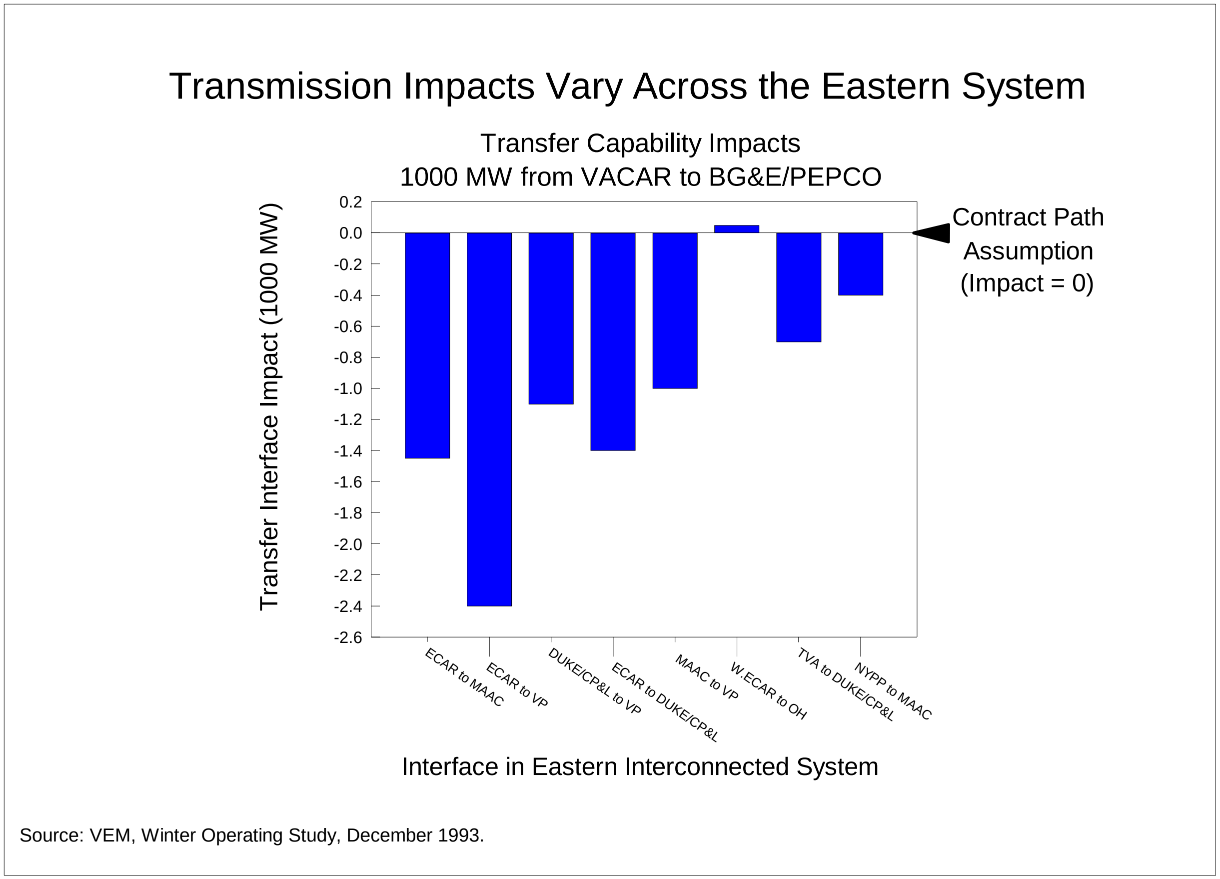
Electric transmission network interactions can be large and important.

- Conventional definitions of network "Interface" transfer capacity depend on the assumed load conditions.

- Transfer capacity cannot be defined or guaranteed over any reasonable horizon.



There is a fatal flaw in the old "contract path" model of power moving between locations along a designated path. The network effects are strong. Power flows across one "interface" can have a dramatic effect on the capacity of other, distant interfaces.



Electricity restructuring requires open access to the transmission essential facility. A fully decentralized competitive market would benefit from tradable property rights in the transmission grid. However, the industry has never been able to define workable transmission property rights:

> "A primary purpose of the RIN is for users to learn what Available Transmission Capacity (ATC) may be available for their use. Because of effects of ongoing and changing transactions, changes in system conditions, loop flows, unforeseen outages, etc., ATC is not capable of precise determination or definition. "
>
> Comments of the Members of the PJM Interconnection, Request for Comments Regarding Real-Time Information Networks, Docket No. RM95-9-000, FERC, July 5, 1995, p. 8.

The problems are not unique to the U. S. They same issue arises in any meshed network, as in Europe and the regulations for European Transmission System Operators [ETSO]:

> "Does the draft Regulation set the right objective when it requires TSOs to compute and publish transfer capacities? ETSO says both yes and no …in many cases the (Net transfer capacity or NTCs) may be a somewhat ambiguous information…The core of the difficulty raised by transfer capacities lies in the fact that they do not obey usual arithmetic: 'it makes no sense to add or subtract the NTC values…' Put it in other ways, in order to compute the maximal use of the network, one needs to make assumptions on the use of the network! This definition is restated and elaborated in ETSO (2001a) (p. 6)."
>
> J. Boucher and Y. Smeers, "Towards a Common European Electricity Market--Paths in the Right Direction…Still Far From an Effective Design," Belgium. September, 2001, pp. 30-31. (see HEPG web page, Harvard University)

Under Order 888 the FERC made a crucial choice regarding a central complication of the electricity system.

> "A contract path is simply a path that can be designated to form a single continuous electrical path between the parties to an agreement. Because of the laws of physics, it is unlikely that the actual power flow will follow that contract path. … Flow-based pricing or contracting would be designed to account for the actual power flows on a transmission system. It would take into account the "unscheduled flows" that occur under a contract path regime." (FERC, Order 888, April 24, 1996, footnotes 184-185, p. 93.)

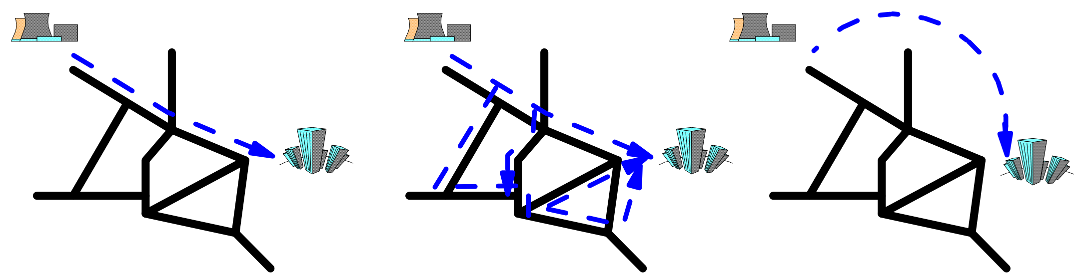
> "We will not, at this time, require that flow-based pricing and contracting be used in the electric industry. In reaching this conclusion, we recognize that there may be difficulties in using a traditional contract path approach in a non-discriminatory open access transmission environment, as described by Hogan and others. At the same time, however, contract path pricing and contracting is the longstanding approach used in the electric industry and it is the approach familiar to all participants in the industry. To require now a dramatic overhaul of the traditional approach such as a shift to some form of flow-based pricing and contracting could severely slow, if not derail for some time, the move to open access and more competitive wholesale bulk power markets. In addition, we believe it is premature for the Commission to impose generically a new pricing regime without the benefit of any experience with such pricing. We welcome new and innovative proposals, but we will not impose them in this Rule." (FERC, Order 888, April 24, 1996, p. 96.)

Hence, although the fictional contract path approach would not work in theory, maintaining the fiction would be less disruptive in moving quickly to open access and an expanded competitive market!

Defining and managing transmission usage is a principal challenge in electricity markets.

Transmission Capacity Definitions

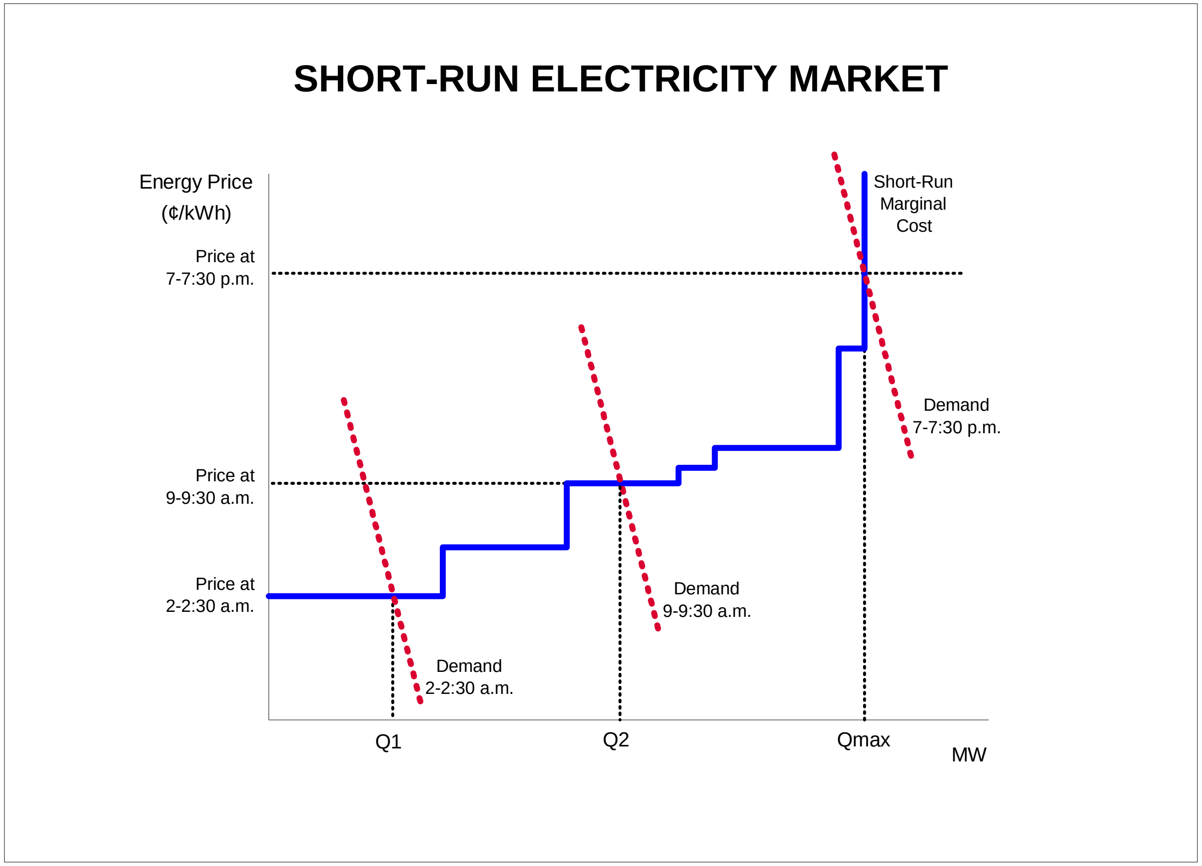
Contract Path → Flow-Based Paths → Point-to-Point



Contract Path Fiction	Parallel Flows	Flows Implicit
OASIS Schedules and TLR	Flowgate Rights FGRs	Financial Transmission Rights FTRs

ELECTRICITY MARKET — Pool Dispatch

An efficient short-run electricity market determines a market clearing price based on conditions of supply and demand balanced in an economic dispatch. Everyone pays or is paid the same price.

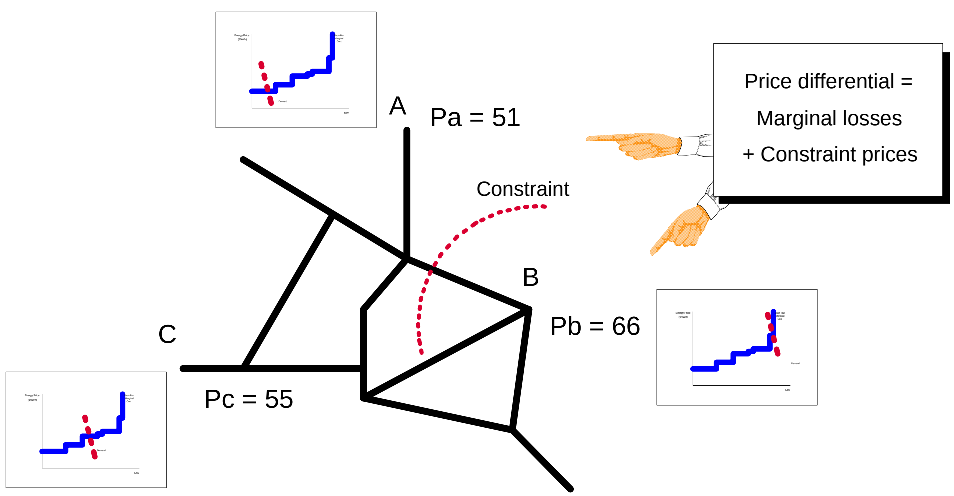


The natural extension of a single price electricity market is to operate a market with locational spot prices.

- It is a straightforward matter to compute "Schweppe" spot prices based on marginal costs at each location. (Schweppe, Caramanis, Tabors, & Bohn, 1988)

- Transmission spot prices arise as the difference in the locational prices.

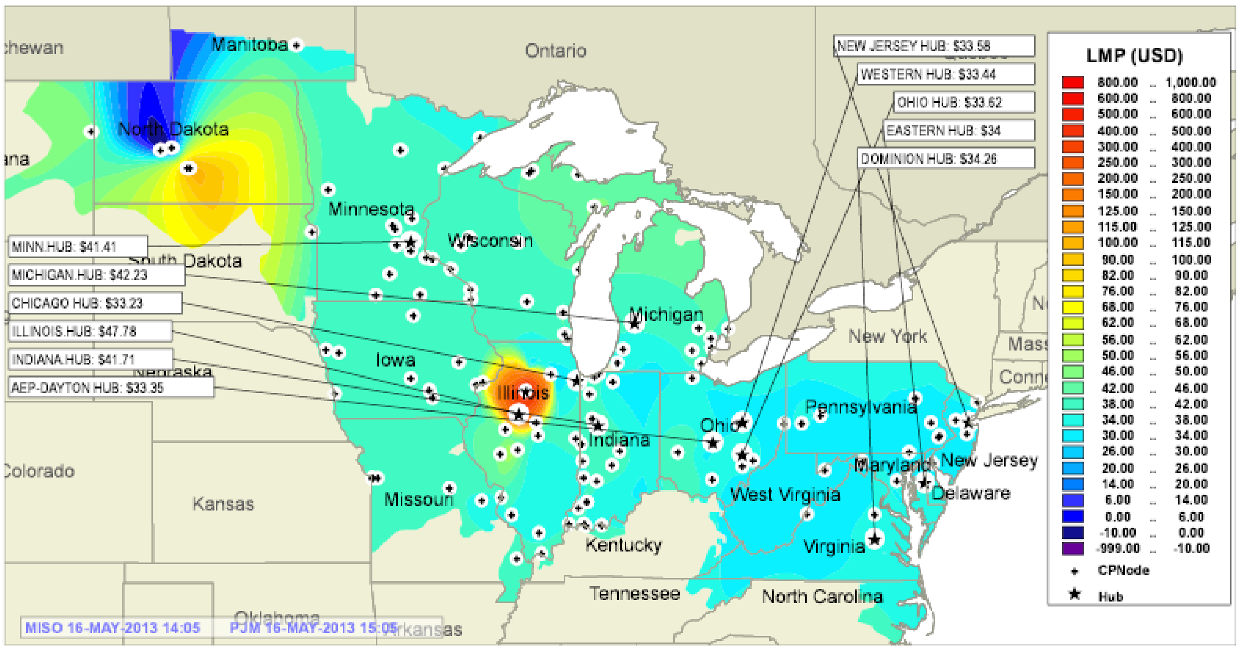
LOCATIONAL SPOT PRICE OF "TRANSMISSION"



Price of "Transmission" from A to B = Pb - Pa = 15
Price of "Transmission" from C to A = Pa - Pc = -4

NETWORK INTERACTIONS Locational Spot Prices

RTOs operate spot markets with locational prices. For example, PJM updates prices and dispatch every five minutes for over 10,000 locations. Locational spot prices for electricity exhibit substantial dynamic variability and persistent long-term average differences.

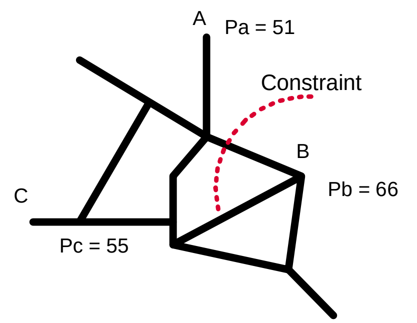


Illinois $529.71, North Dakota -$18.83

From MISO-PJM Joint and Common Market, http://www.jointandcommon.com/ for March 16, 2013, 3:05pm.

A mechanism for hedging volatile transmission prices can be established by defining financial transmission rights to collect the congestion rents inherent in efficient, short-run spot prices. (W. W. Hogan, 2013)

NETWORK TRANSMISSION FINANCIAL RIGHTS

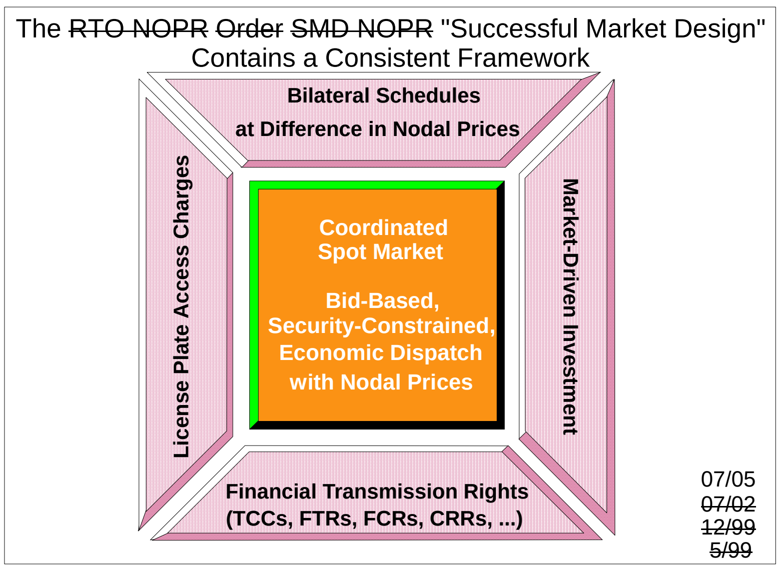


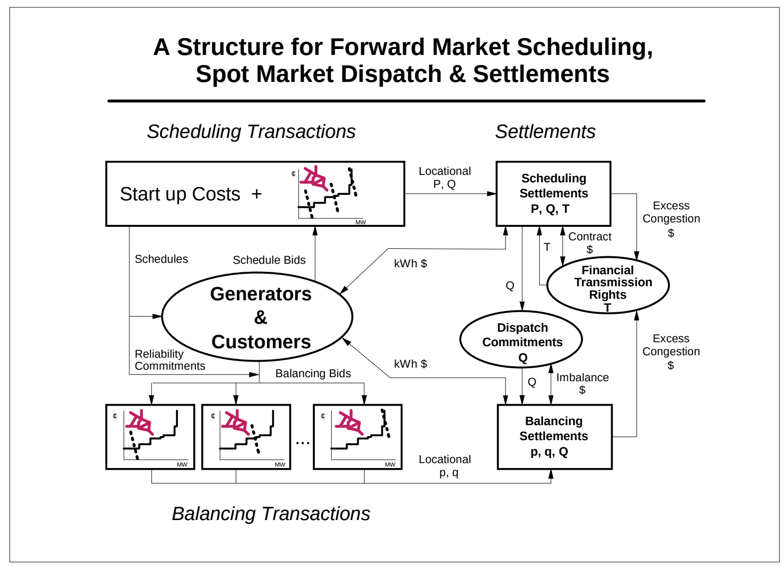
Price of "Transmission" from A to B = Pb - Pa = 15
Price of "Transmission" from A to C = Pc - Pa = -4

- DEFINE TRANSMISSION CONGESTION CONTRACTS BETWEEN LOCATIONS.
- FOR SIMPLICITY, TREAT LOSSES AS OPERATING COSTS.
- RECEIVE CONGESTION PAYMENTS FROM ACTUAL USERS; MAKE CONGESTION PAYMENTS TO HOLDERS OF CONGESTION CONTRACTS.
- TRANSMISSION CONGESTION CONTRACTS PROVIDE PROTECTION AGAINST CHANGING LOCATIONAL DIFFERENCES.

The example of successful central coordination, ~~CRT, Regional Transmission Organization (RTO) Millennium Order (Order 2000) Standard Market Design (SMD) Notice of Proposed Rulemaking (NOPR),~~ "Successful Market Design" provides a workable market framework that is working in places like New York, PJM in the Mid-Atlantic Region, New England, the Midwest, California, SPP, and Texas. This efficient market design is under (constant) attack.

> "Locational marginal pricing (LMP) is the electricity spot pricing model that serves as the benchmark for market design – the textbook ideal that should be the target for policy makers. A trading arrangement based on LMP takes all relevant generation and transmission costs appropriately into account and hence supports optimal investments."(International Energy Agency, Tackling Investment Challenges in Power Generation in IEA Countries: Energy Market Experience, Paris, 2007, p. 116.)





The market equilibrium satisfies a "no arbitrage" condition implies that feasible financial transmission rights must be revenue adequate.

Let y^1 be any other feasible set of net loads, such that there is a u^1 with:

$$L\left(y^1, u^1\right) + \iota^t y^1 = 0,$$

$$K\left(y^1, u^1\right) \leq 0,$$

$$u^1 \in U.$$

Then, assuming concavity for the benefits function, we can show:

$$p^t\left(y^* - y^1\right) \geq 0.$$

If y^1 corresponds the net loads implied by a set of simultaneously feasible financial transmission rights, then the revenues from the current spot market congestion rents must be at least as large as the obligations under the set of FTRs. This result holds for any economic dispatch and any configuration of FTRs. This is unlike any set of physical transmission rights where "Because of effects of ongoing and changing transactions, changes in system conditions, loop flows, unforeseen outages, etc., ATC is not capable of precise determination or definition."

Investment in the transmission grid should create new economic capacity. The allocation of FTRs under a feasibility rule mitigates incentives for inefficient transmission investment. (Kristiansen & Rosellón, 2006)(W. Hogan, Rosellon, & Vogelsang, 2010)

Feasibility Test: The aggregate of all financial transmission rights defines a set of net power injections in the grid. The set of contracts is feasible if these injections and their associated power flows satisfy all the system constraints.

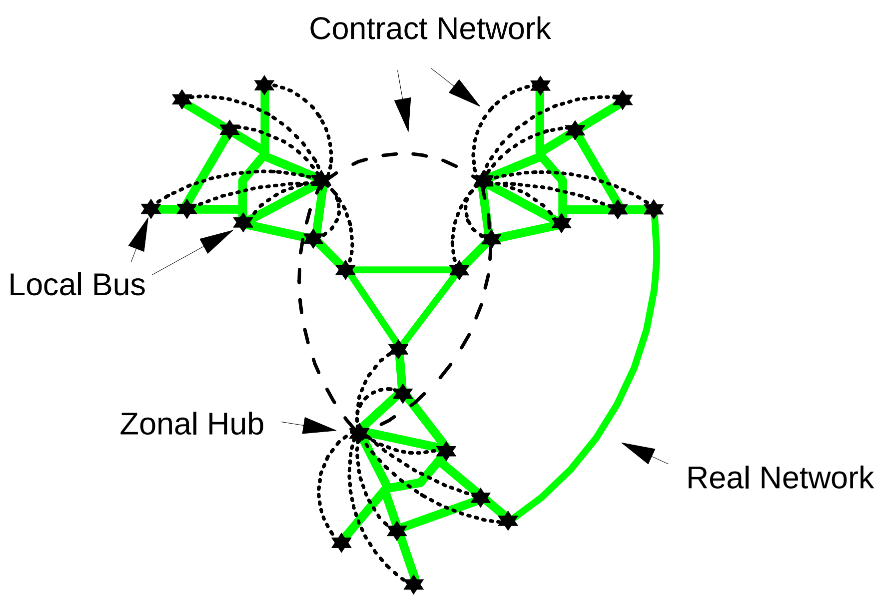
Feasibility Rule: The grid expansion investor selects a set of new financial transmission rights with the restriction that both the new and the old FTRs will be simultaneously feasible after the system expansion.

- If the set of FTRs is feasible then the future payments required for the FTRs will never exceed the congestion revenues collected through the spot market dispatch.
- Future investments in the grid cannot reduce the welfare of aggregate use according to the existing FTRs. Hence, exposure to rent transfers is limited to the spot market.
- (Bushnell & Stoft, 1997). If PTP-FTR obligations initially match dispatch in the aggregate and new FTRs are allocated under the feasibility rule, then the increase in social welfare will be at least as large as the ex post value of new contracts.
- (Bushnell & Stoft, 1996). If PTP-FTR obligations match dispatch individually, then the allocation of FTRs under the feasibility rule ensures that no one can benefit from a network investment that reduces social welfare.

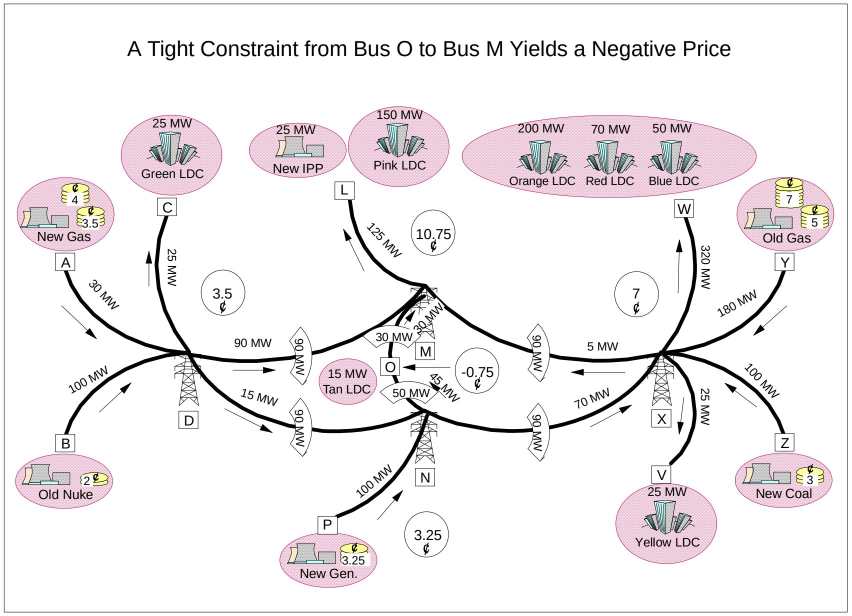
With loops in a network, market information could be transformed easily into a hub-and-spoke framework with locational price differences on a spoke defining the cost of moving to and from the local hub, and then between hubs. This simplifies without distorting the prices.

Contract Network Connects with Real Network

Determine Locational Prices for Real Network; Implement Financial Transmission Rights and Trading on Contract Network



The simultaneous set of transmission congestion contracts defines the "Available Transmission Capacity." Consider the example network with two feasible sets of transmission congestion contracts (TCC) for hub at "O".

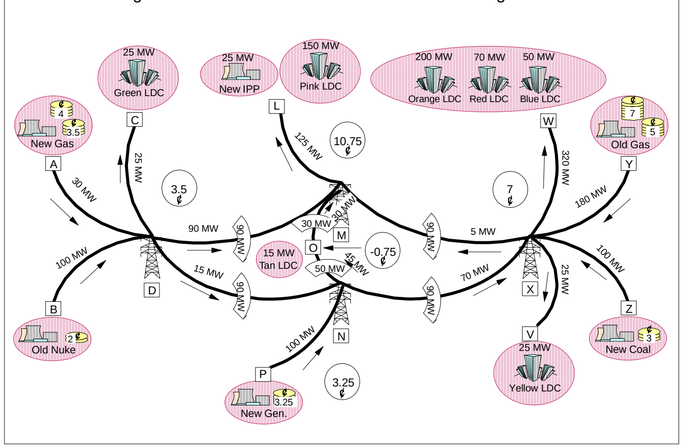


A Tight Constraint from Bus O to Bus M Yields a Negative Price

From-To	TCC 1 (MW)	TCC 2 (MW)
"D-O"	180	160
"O-X"	180	160
"M-O"	30	10
"N-O"	30	70

Either set of TCCs would be feasible by itself in this network. However, subsets of the contracts may not be feasible. Hence, the *definition* of available transmission capacity would be as a simultaneously feasible set of contracts.

The congestion costs collected will always be sufficient to meet obligations under transmission congestion contracts. Excess congestion rents, after paying TCC obligations, could be returned under a sharing formula.



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From-To	TCC 1 (MW)	TCC 2 (MW)
"D-O"	180	160
"O-X"	180	160
"M-O"	30	10
"N-O"	30	70

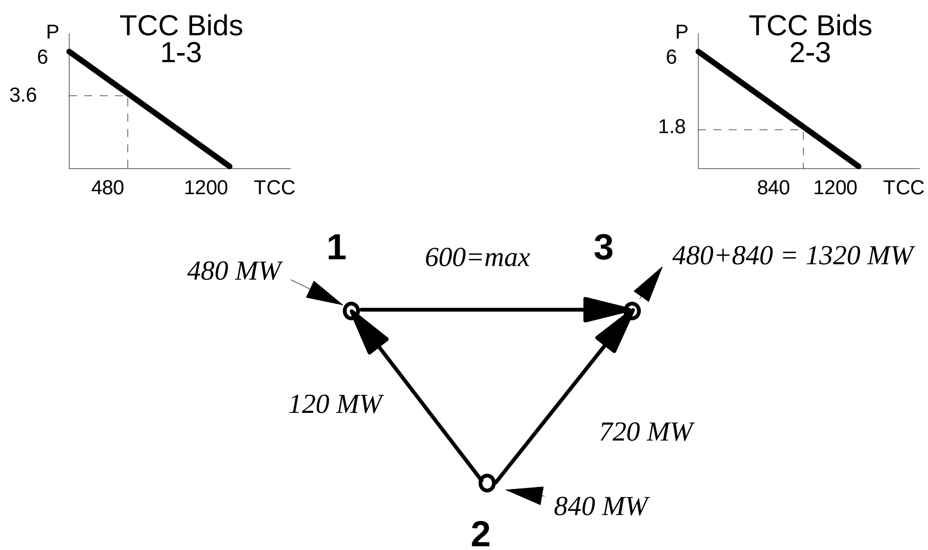
Load at "L"	Bus Prices ¢/kWh					Total Rents $	TCC 1	TCC 2
MW	"D"	"M"	"N"	"O"	"X"			
0	3.50	3.75	3.25	3.50	7.00	6300	6300	5750
50	3.50	5.58	3.25	4.15	7.00	6300	6138	6084
150	3.50	10.75	3.25	-0.75	7.00	10950	1650	1650

TRANSMISSION CONGESTION CONTRACT — Auction

Transmission congestion contracts for the grid could be defined and awarded through an open auction. The collective bids would define demand schedules for TCCs. The concurrent auction would respect the transmission system constraints to assure simultaneous feasibility.

Concurrent Auction of Transmission Congestion Contracts

(WITH IDENTICAL LINKS, CONSTRAINT ON LINE 1-3)

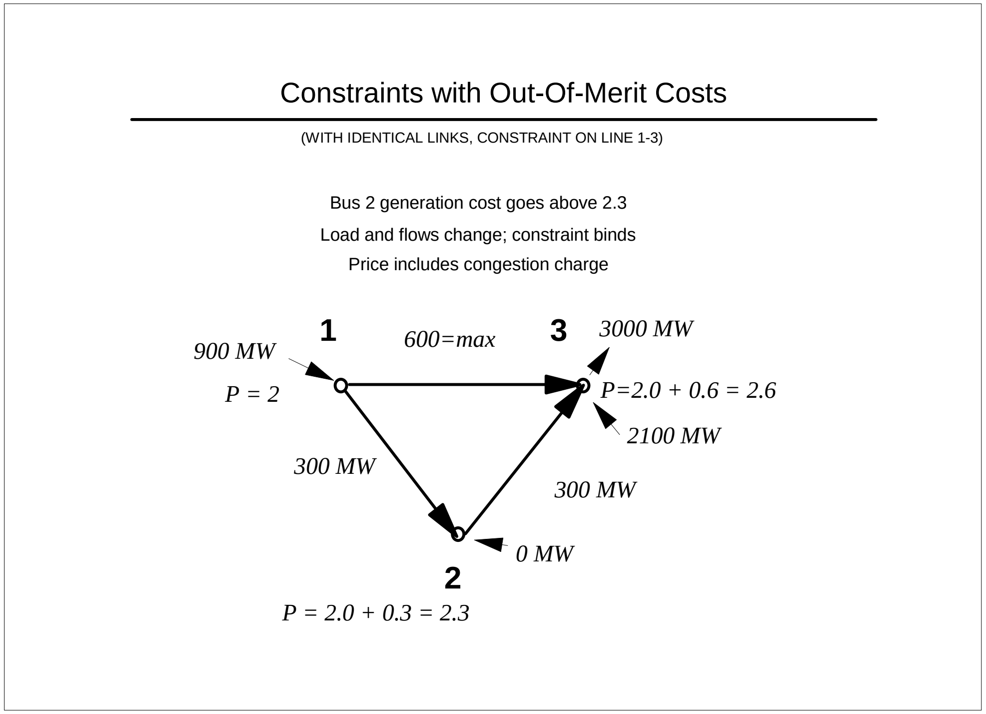


TCCs from 1 -> 3 awarded for 480 MW at price 3.6

TCCs from 2 -> 3 awarded for 840 MW at price 1.8

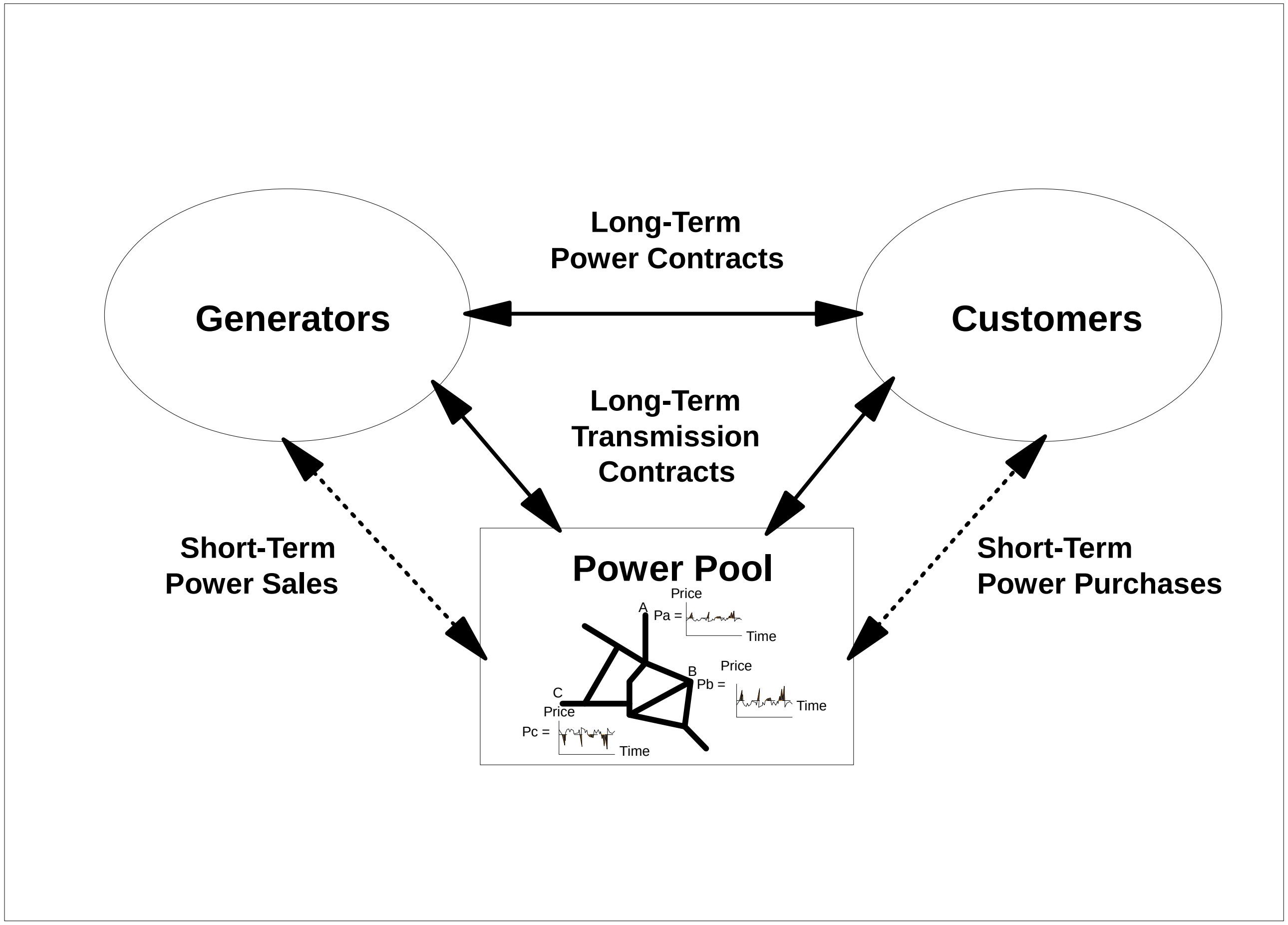
TRANSMISSION CONGESTION CONTRACT — Revenue Adequacy

With spot locational prices, transmission congestion contracts provide price protection. Even with changing load patterns, the congestion revenues collected by the system operator will be at least enough to cover the obligations for all the TCCs.



System Operator Revenues			
	Quantity	Price	$
Bus 1	900	2	($1,800)
Bus 2	0	2.3	$0
Bus 3	2100	2.6	($5,460)
Bus 3	-3000	2.6	$7,800
TCC 1-3	480	0.6	($288)
TCC 2-3	840	0.3	($252)
Net Total			$0

Combining contracts for differences between parties, and financial transmission rights offered by the system operator, the electricity market can support efficient operations, open access, non-discrimination and long term contracts.



Financial Transmission Rights (FTRs), including Transmission Congestion Contracts (TCCs) and Congestion Revenue Rights (CRRs), present a variety of issues.

- **Definitions.**
  - Duration.
  - Obligations vs. Options.
  - Auction Revenue Rights.
  - Sequential Markets.
  - Expansion Rules.

- **Revenue Adequacy.**
  - Theory: Simultaneous Feasibility Ensures Full Funding with Same Grid.
  - Practice: Carve Outs, Outages and Loop Flow Forecasts can Affect Feasibility.

- **Market Performance.**
  - Arbitrage and FTR Prices.
  - Gaming and Credit Risks.
  - Market Power Interactions.

- **Investment and Trading.**
  - Grid Expansion.
  - Continuous Trading: Nodal Exchange.
    (http://www.nodalexchange.com/about_nodal/overview.php)

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