TRANSMISSION CAPACITY RIGHTS FOR THE CONGESTED HIGHWAY: A CONTRACT NETWORK PROPOSAL

WILLIAM W. HOGAN

Thornton Bradshaw Professor of Public Policy and Management
John F. Kennedy School of Government
Harvard University

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Submitted to the Federal Energy Regulatory Commission
in response to

NOTICE OF PUBLIC CONFERENCE AND REQUEST FOR COMMENTS
ON ELECTRICITY ISSUES

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(April 12, 1991)
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Center for Business and Government
John F. Kennedy School of Government
Harvard University
Cambridge, Massachusetts 02138

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EXECUTIVE SUMMARY

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The fundamental problems of transmission pricing and access policies require a generic review. This paper outlines one generic transmission approach that could play an essential role in further development of efficient, competitive markets. The new ingredient is a viable long-term transmission capacity right defined within a contract network that respects the special problems of electric power networks. A contract network extends the concept of a contract path to address the problems of loop flow and congestion in electric power transmission systems. A contract network option provides a well-defined, internally consistent framework for assigning long-term capacity rights in a complicated electric transmission network.

The special circumstances of electricity markets lead to three essential ingredients for the design of the new electricity market: greater reliance on competition; spot markets for efficient operations; and long-terms contracts defining rights and financial hedges. Competition should control the process wherever practical. The most important requirement for competition is to minimize or eliminate any barriers to entry. New or competing generators should have easy

entry to the market to provide contestability. Wholesale customers should have access to alternative generators, suppliers and brokers when economically appropriate. The market should provide the proper signals and incentives such that mutually acceptable contracts between users of the system are economically efficient for the system as a whole.

In an electricity system, operating an efficient spot market for energy and transmission is a key to providing both access and the proper economic incentives. At the same time, the demands of system control and reliability require central dispatch of power plants to meet load while respecting the constraints of the transmission grid. These requirements combine naturally in the continuation of traditional practices for economic dispatch of power plants coupled with the innovation of allowing market-based bids for power to replace engineering estimates of costs.

The existing mechanisms for central economic dispatch provide the information needed to calculate short-run marginal costs that reflect the payments for energy inputs, the availability of power plants and the constraints of the transmission system. This central dispatch must be preserved. With the proper design of incentives for bidding, this same dispatch process will replicate the results of a competitive market for which the marginal costs would be equal to the market-clearing prices. All energy could be brought and sold at these market clearing prices.

Efficient short-run transmission usage prices are implicit in the differences in these spot-market prices across locations. These price differences always include the effect of marginal transmission losses. In addition, faced with transmission constraints, these market prices will include sometimes substantial differences that reflect the costs of system congestion. The resulting transmission loss and congestion prices provide the necessary signals for efficient use of the existing electricity system and the proper incentives for efficient investment to locate new

generating plants or expand the transmission grid.

The existence of a spot market based on demand bidding and central economic dispatch would provide a principal ingredient needed to assure access to the electricity market. Subject to minimal technical requirements and credit guarantees, any generator, supplier, broker or wholesale customer should have access to the grid and be allowed to buy and sell power in the spot market. The operation and central control of the grid should be limited to the technical but not the commercial operation of the market.

As with other industries, an efficient spot market in electricity must combine with long-term contract arrangements for both energy and transmission. These contracts should define rights and responsibilities and share price and other financial risks as the parties agree. Energy contracts between customers and generators can insure generator cash flow and provide the required support for financing new projects. Furthermore, long-term energy contracts provide an option for customers seeking greater price stability. Buyers and sellers would have the option of relying on the spot-market with the possibility of highly volatile prices. However, buyers and sellers would also have the option of agreeing on separate bilateral financial payments that hedge against any changes in prices in the spot market. Furthermore, in the presence of the spot market, the long-term energy contracts are limited to financial hedges and do not constrain the operation of central economic dispatch by requiring application of specific generating plants for specific customers. Actual purchase and sale of power would be provided through the spot market, with payments under the contract returning agreed compensation for fluctuations in the spot price.

Although long-term energy contracts can arise naturally through bilateral negotiations

built around the operation of an electricity spot market, corresponding contracts defining transmission rights and payments must work through the monopoly grid operator. The technical conditions of electric power transmission require that the central grid operator recognize and incorporate the interactions of different users of the system. In the short run these interactions lead to efficient transmission usage prices. In the short run these interactions lead to efficient transmission usage prices. In the long-run, the central grid can operate a market in transmission capacity rights. Just as with long-term energy contracts, these transmission rights would be limited to financial hedges and would not constrain the technical operation of central dispatch.

The financial payments for transmission rights would provide the natural compensation for the fluctuations in spot prices. However, unlike the long-term contracts with generators, the definition of rights and the computation of the associated financial payments for transmission requires the participation of the central grid. Fortunately, the necessary payments could be determined automatically in the calculation of the short-run marginal costs associated with the optimal economic dispatch for the spot market. Hence the central grid could provide the technical operation of the spot market and act as a clearinghouse for payments under long-term transmission capacity rights.

Creation and use of the financial transmission capacity rights would provide the normal mechanism for capturing the benefits of the transmission grid. By distributing the revenues obtained from short-run transmission usage back to the holders of transmission capacity rights, we would leave the costs of the transmission system to be collected from a set of fixed charges under long-term contracts. Combined with short-run marginal cost prices, the fixed charges are economically efficient as the other half of a two-part tariff and would fall naturally to the

recipients of the transmission rights. Customers who wish to reduce the costs of congestion implicit in payments in the electricity spot market would have an incentive to invest in transmission expansion and reinforcement. Such investment would create new transmission capacity. The right to the financial benefit of that new capacity could be assigned to the customer who agreed to pay the investment cost. Those who invest in long-term transmission capacity rights would not face the possibility of later paying congestion costs induced by other users of the system. This provides the complementary long-term financial assurances found in the companion long-term energy contracts. These long term contracts provide the necessary analogy to property rights to promote economically efficient incentives for long-term investment in both generation and transmission.

TRANSMISSION CAPACITY RIGHTS FOR THE CONGESTED HIGHWAY: A CONTRACT NETWORK PROPOSAL

William W. Hogan[1]

As competitive markets in electricity generation are emerging, increasing pressure is placed on providing expanded transmission service. [2]

INTRODUCTION

As the Federal Energy Regulatory Commission (FERC) reviews basic issues in the development of the electricity market, it asks for guidance on the development of transmission policies that would provide more open access to the grid and on the need for a generic review: "Should the Commission address transmission pricing and access issues on a case-by-case or a generic basis?" Given the fundamental and central nature of the problems of transmission pricing and access policies, a generic review and reform would be appropriate. This paper outlines a generic transmission approach that could play an essential role in further development of efficient, competitive markets. The new ingredient is a viable long-term transmission capacity right defined within a contract framework that respects the special problems of electric power networks.

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[1] Thornton Bradshaw Professor of Public Policy and Management, Kennedy School of Government, Harvard University, and Director, Putnam, Hayes & Bartlett, Inc., Cambridge, MA. I benefitted greatly from comments by Charles Cicchetti, William Lindsay, Steve Mitnick, Joe Pace, Howard Pifer, Thomas Parkinson and Ellen Roy. The idea of using contract networks for defining long-term rights grew out of intensive discussions with Sarah Johnson, Thomas Parkinson, Larry Ruff, and Michael Schnitzer. For a more comprehensive collection of acknowledgements and citations, see W. Hogan, "Contract Networks for Electric Power Transmission," Energy and Environmental Policy Center, Harvard University, Discussion Paper E-90-17, September 1990. The author is a consultant on electric transmission issues for Duquesne Power and Light Company, the British National Grid Company, and Electricorp of New Zealand. The views presented in this paper are not necessarily attributable to any of those mentioned, and the remaining errors are solely the responsibility of the author.

[2] Federal Energy Regulatory Commission, "Notice of Public Conference and Request for Comments on Electricity Issues," Docket No. PL91-1-000, April 12, 1991, p.2.

TRANSMISSION ACCESS PROBLEMS

Gridlock threatens the electric transmission highway. Without clear rights-of-way, congestion reduces the effective capacity of the transmission network. Those caught in the traffic jam or forced to stand on the roadside clamor for reform before traffic halts for all but a privileged few in the express lane. Just a sample of typical problems illustrates the cost of congestion:

- **Cooperative Company:** A utility joins with smaller partners to build a new transmission line. The partners assume that their investment entitles them to unrestricted use of a pro rata capacity increment to move power between any two places connected to the new line. The operator argues that other network reliability constraints will restrict the ability to use the new transfer capability and these limits will depend on system load conditions in ways that are difficult to define in advance. The resulting disputes threaten to compromise the efficient use of the new transmission increment and leave the utility last in the priority queue.
- **Weak Wheeler**: A utility regularly loses its ability to honor transmission ("wheeling") rights over its system during periods of heavy congestion; the lines fill up with loop flow from interconnected utilities engaging in bulk power transactions scheduled along other contract paths. Reportedly a relatively modest investment to upgrade transmission lines would increase wheeling capacity. However the wheeling utility would gain little as the increased capacity would be absorbed in turn by increased loop flow that provides no revenue for the wheeling utility. Hence the transmission

investment is not made, thereby foreclosing attractive long term power contracts.

- **Big Buyer:** A utility's power purchases were curtailed by voltage problems during a period of heavy system load despite the availability of adequate generating capacity under long-term contracts. Unfortunately the long-term contracts covered plants at distant sites that depend on bulk transmission to move the power. "At the time we signed the contracts, all the studies indicated that there would be adequate transmission capacity," but the studies did not anticipate the current load patterns which clog the system. The resulting congestion imposes higher costs without compensation. In this case the free riders bump off the paying passengers.

As outlined below, in each case the problems can be traced in part to a lack of an adequate definition of a transmission capacity right. Everyone sees the need for something new.[3] From Britain with its national grid and competitive market innovations to the United States with its Balkanized grid and traditional regional pools, the electric utility industry is searching for new rules of the road.[4] Progress has been slow and halting, stumbling over the special complexities of transmission networks. Further advances would seem to require a change in the terms, and terminology, of the transmission debate.

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[3] For example, see the discussion of transmission issues woven throughout the "1990 Electric Utility Executives' Forum," Public Utilities Fortnightly, Vol. 125, No. 11, May 24, 1991, pp. 62-110; or the Special Report, "Transmission...A Continuing Controversy," Public Utilities Fortnightly, July 19, 1990, p. 12.

[4] For a review of the many reform proposals, and a discussion of remaining problems, see Federal Energy Regulatory Commission, The Transmission Task Force's Report to the Commission. Electricity Transmission: Realities, Theory, and Policy Alternatives, Washington, DC, October 1989.

Competition and Access

The old traffic rules developed in a different era and with a different vision of the purposes of the transmission grid. Earlier when the few owners were also the only users of the grid, these members of the transmission club could manage the traffic with no more than gentlemen's agreements. When the principal uses of the grid were for reliability and capacity sharing, the club members could rely on informal exchanges to absorb or balance the costs of sporadic congestion. Now, however, new opportunities have arisen and new players are anxious for admittance to the club. Uncomfortable with the informal rules, these new participants want a better definition of the entrance rights and membership fees.[5]

The new emphasis on transmission grew out of the economic shifts of the last two decades. Previously unexpected regional pockets of excess generating capacity developed that can now help other need locales which lack adequate power resources. In other cases, even where regional capacity is adequate, shifts in relative energy prices have created economic incentives to move cheaper power, spurred on by stringent environmental requirements that make remote generation even more attractive.

The accompanying growth of competition is creating a constituency of vigorous third parties anxious to use the transmission system. Most forecasts anticipate that a large fraction of new power generation over the next decade will come from non-traditional sources, including both independent power producers and utilities operating outside their own service territory. In

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[5] "Furthermore, clear rules-of-the-road must exist for transmission access to assure the technical integrity of the grid, particularly as bulk power markets become more competitive. Such rules will be crucially important to maintaining reliability and economic/engineering efficiency of increasingly complex intersystem transmission grids. These rules will become more critical as the informal agreements that currently sustain cooperation are superseded by open rivalry between utilities that control transmission." C.G. Stalon and R.H.J.H. Lock, "State-Federal Relations in the Economic Regulation of Energy," Yale Journal on Regulation, Vol. 7, No. 2, Summer 1990, p. 471.

order to finance and build new generation, these new suppliers will need firm access to the transmission grid. Until now, while the numbers have been small, the few requests for transmission access and power wheeling could be handled as special cases. However, the grid operators will need to rewrite the rules as the new plants become more than a token appendage to the system.

There is little doubt that more changes are coming. The FERC policies on both mergers and power sales have emphasized the concern with market power and the importance of transmission access in mitigating both the appearance and the reality of such market power. For example, the UPL-Pacificorp merger approval foundered until transmission access was promised for any requesting electric utility.[6] The FERC's requirement for a "no fault" assurance of transmission access as proposed in the Public Service Company of Indiana power sale underscored the reliance on firm transmission rights for third parties as the sine qua non of flexible pricing and light-handed regulation.[7]

Transmission access reform is in the air. According to one respected expert, "the 50-year old debate ... is behind us." Simply put: "Government will mandate third-party access to transmission." Only the "appropriate terms" are at issue.[8]

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[6] "Utah Power & Light, Pacificorp, and PC/UP&L Merging Corporation," Opinion No. 318, issued October 26, 1988, Docket No. EC88-2-000, 45 FERC 61,095.

[7] Federal Energy Regulatory Commission, Opinion No. 349, Public Service Company of Indiana, Inc., Docket no. ER89-672-000 and ER89-672-001, 51 F.E.R.C. P61,367 (1990), at 62,194-62,198.

[8] R. Pierce, "Who Will Mandate Access to Transmission: FERC or the Courts?", Public Utilities Fortnightly, March 29, 1990, pp. 28-29.

Access and Reliability

What terms would be appropriate? The prospect of free-wheeling open access to the transmission grid alarms many of the current members of the transmission club. The "free" part is a matter of special concern. Fear of being stuck with the bill for the free lunch has spawned numerous fine distinctions to separate the "good" wheeling that promotes competition and rewards economic efficiency from the "bad" wheeling that degrades reliability or moves dollars rather than power.

Of course, it is difficult to separate good access from bad access, or to separate the calls for reasonable transmission limitations designed to protect reliability from unreasonable barriers designed to protect vested interests. Furthermore, the policy-makers have heard it all before elsewhere in the defense of heavy regulation and limited access in the cases of airlines, trains, trucks, telephones, natural gas, and so on. The instinct of many reformers is to get the prices right, provide access to the transmission system, and let the new competitors enter.

In the broad policy debate, therefore, natural suspicion arises when utility industry executives and system operators (the insiders' insiders) warn of the complexity of the transmission grid and the dangers of open access. Pressed by the desire to move ahead, it is easy to dismiss the arcane features of transmission grids -- including loop flow, reactive power compensation, frequency control and contingency analyses -- as mere operational details. Given the experience in other industries, it is tempting to assume that these details can be ignored for purposes of the grand policy design.

In the case of electric power transmission, however, the details do matter and they have a potentially dramatic impact on the character of possible reforms. The detail in electric power

transmission may not be so easy to dismiss -- much that seems obvious isn't.

Consider a few facts that are well known to the club members, but often unfamiliar to others:

- The ubiquitous contract path for power transactions, typically defined as a series of transmission "lines" on which capacity is available, is a legal fiction. Due to the phenomenon of loop flow, the actual power flow will deviate from the contract path, sometimes significantly, by traveling across all parallel paths. This interferes with other fictitious contract paths. In a congested system, the real costs and benefits of transmission, with the associated winners and losers, may bear little resemblance to the assumptions of the compensation scheme embodied in the contract path.

- Because of loop flow, the transmission grid is only as strong as its weakest parallel path. It is easy to construct examples where use of a small power plant connected to a "weak" transmission line can prohibit use of large power plants connected to "strong" transmission lines. Hence, traditional anti-trust market-share analysis is compromised. The associated Herfindahl index calculations of market power in power markets are at best incomplete and at worst, meaningless.

- The "transfer capacity" of a transmission grid is not well-defined in the usual sense. The short-hand qualifier used by system engineers is "*according to studies*," as in "*according to studies*, the transfer capacity is 1500 MWs." The long-hand version is

"*under the assumed range and location of generation and loads for use of the transmission system, as envisioned by the system engineers for the prospective life of the proposed firm transmission right,* the transfer capacity is 1500 MWs." However, if the loads and the patterns of flow change, as they surely will over a period of more than even a few years, the transfer capacity will change as well, and could increase or decrease.

- **o** Since the transfer capacity cannot be defined, it cannot be guaranteed easily. As ready examples attest, users who planned for long-distance power sales under one set of loads and operating conditions can find these sales foreclosed later when loop flow from other contract paths clogs the grid.

- **o** In the short run the marginal cost of transmission congestion is greater than the average cost, sometimes much greater. When congestion costs are implicit, as well as in most cases where congestion costs are recognized explicitly, the usual compensation is based upon average costs. As is true in other areas of utility pricing, compensation for congestion based on average costs provides the wrong incentives for operation and investment decisions. For transmission, the resulting incentives for locating new generation are biased towards increasing total costs.

Each of these facts creates real problems that complicate any guarantee of transmission access. And this short list does not exhaust the difficulties in defining rights or finding the

appropriate prices. For example, thermal limits on individual transmission lines dominate discussions of transmission availability. However, thermal limits on individual lines create only one, and perhaps not the most important, constraint on power flows. System contingency and voltage limitations constrain power flows even when individual lines might appear to have substantial excess capacity. No broadly accepted market has emerged yet to price these scarce resources.

None of these problems is fatal in itself. And they all have solutions. Inside the transmission club, when the volume of power sales was small and congestion was minor, the informal rules and approximations sufficed. However, with many new entrants in a congested system, it will not be possible both to guarantee reliability and allow major players to operate as though the accepted fictions are economic facts. Transmission reform must face the facts.

Constraints on Transmission Reforms

The bulk of the existing transmission reform proposals duck these issues. Most are far more concerned with related but different problems such as recovering fixed costs or billing erstwhile free riders. As for the special constraints of networks, the reform proposals characteristically invoke one of a few popular incantations to make the problems of congestion disappear. For instance, the proponents of the "voluntary" transmission proposals typically take comfort in the retention of ultimate control by transmission owners who would approve access and respect the facts of the complicated network constraints. However, the rules are not articulated, and the critics find little here to distinguish the voluntary proposals from the insiders' club of old.

The competing proponents of "mandatory" transmission proposals remove the dilemma by assuming that utilities will be required to build ever more transmission capacity. This approach would overcome the facts by restoring the fiction. Then there would be no congestion and the deviations from reality would again be truly negligible. Even though the "best" solution might save on transmission construction by allowing for a little congestion, a policy of overbuilding transmission to eliminate congestion is seen by some as a cheap way of avoiding the problems of defining new rules and administering use of the transmission highway.

For example, the existing FERC policy to limit market power relies heavily on expanding transmission capacity wherever there is congestion. The FERC "no fault" provision is constructed around the threat to reject any explanation for a failure to expand transmission capacity. If the threat were likely to work, and congestion truly would disappear, then there would be much to recommend such a device which would avoid immersion in the details. But if congestion is more difficult to overcome, it may be necessary to look to the details in order to untangle the policy choices.

Unfortunately, expanding transmission capacity is easier said than done, and it may be a long time before we enjoy such happy abundance. At a minimum, existing congested transmission systems will complicate the transition to a new electricity market. For the foreseeable future, therefore, the transmission grid needs new rules that replace a reliance on the familiar fictions with a respect for the unfamiliar facts.

Another appealing approach often suggested as a seemingly simple way to respect the facts is to submerge the transmission problem in an independent transmission grid that buys and sells power. Then transmission would be implicit, the grid operator would know the facts, and

the new club would be open equally to all. For instance, this is the essence of the current British approach with the National Grid Company and its common dispatch of all generating plants. But as long as the grid operator is not making the plant investment decisions, this buy-sell model only hides the problem. For instance, if the grid imposes a common transmission charge, including a uniform allocation of "out-of-merit" dispatch costs, the new loads and new generators will not see the correct economic incentives.[9] New plants will be built in the wrong locations, too far from the loads. Or if the grid buy-sell prices reflect the locational differences arising from transmission constraints, the possibility of significant fluctuations in the implicit transmission cost will increase the risks for new investment. New plants will be built in the wrong locations, too close to the loads.

Although the actual generation and transmission outcome will be consistent with some set of buy-sell prices reflecting the contemporaneous operating conditions, the incentives of the buy-sell model are not geared toward long-term investment. Yet the decisions on construction of new facilities, both generation and transmission, encompass the big stakes.

In addition to advancing the development of the market for power sales from existing facilities, a primary goal of transmission reform should include provision of correct incentives for location of new facilities. The new rules should redefine long-term transmission rights to respect the facts and provide a foundation for bankable long-term contracts. At a minimum, these rights should preserve the priority of system reliability, accommodate the incentives for efficient generation dispatch in the short-run, reduce the risks of long-term investments, and be credible to investors in the face of the complexities of power transmission.

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[9] "Out-of-merit" dispatch cost is the term-of-art referring to increased power generation costs imposed by transmission congestion constraints.

This is a beginning, but more will be required. Fear of new transmission reforms arises in part because of real concerns with any overt tampering with the dispatch process. Arguably the current system dispatch and reliability procedures aren't (severely) broken and don't need to be fixed (much). We are blessed with a highly reliable system and the utility dispatchers have well-established methods for achieving efficient use of the available plants subject to the many constraints. Furthermore, the simple reality is that any reform which depends upon revising dispatch procedures, and thereby raising the specter of a threat to reliability, faces a huge obstacle. It would be far easier to proceed with a transmission reform that would be compatible with either the current or some new dispatch practice.

CHANGING THE TERMS OF ACCESS: A CONTRACT NETWORK

Progress in defining the "appropriate terms" for transmission requires a new vision with new terms to define the meaning and use of transmission capacity rights in the face of congestion. A capacity right that is consistent with efficient short-term usage of the transmission system will be an essential ingredient of a new transmission regime. With a well-defined capacity right, **Cooperative Company** could negotiate agreements with its partners that incorporate the real constraints on the capacity created by a new transmission line connected within a larger network. **Weak Wheeler** could participate in a joint venture to expand its transmission capacity without fear that the new capability would be usurped by free riders. **Big Buyer** would be able to arrange long-term purchases with predictable economics that would not fluctuate wildly with changing load patterns.

Objectives

The principal electricity sector. This objective includes a mandate to operate and maintain the electricity system to acceptable standards of safety, environmental protection and reliability. Support of economic efficiency requires a balance of measures that both accommodate proper use of the existing electricity system and provide incentives for innovation and adaptation to the changing needs of the economy.

A market maintains natural pressures for cost control while providing the incentives and the opportunities for discovering and meeting the diverse needs of customers. A goal is to capture these long-run benefits without an undue increase in the cost of using the existing electricity system.

Operation of a market replaces traditional central planning with a greater reliance on agreements among parties through contracts. These contracts will determine market access, customer rights and obligations, and pricing. Economic efficiency improves when the system allows a wide choice of contract forms without constraining system operations. Any reform of the system design should help customers enter into mutually acceptable contracts to share financial risks within the technical limits of efficient operation of the system.

At the same time, it would be preferred that the transmission protocol provide a reasonably intuitive model that fits within the progression of utility institutions. Here an outline of the contract network concept demonstrates that workable reform is possible with explicit attention to the details of the constraints that create congestion in transmission networks. The contract network concept provides one tool for accommodating transmission reform that confronts the special complexities without requiring wholesale fixes in parts of the system that aren't

broken.

Supporting a Market

These objectives and the special circumstances of electricity markets lead to three essential ingredients for the generic design of a new electricity market: greater reliance on competition; spot markets for efficient operations; and long-term contracts defining rights and providing financial hedges.

First, competition should control the process wherever practical. The most important requirement for competition is to minimize or eliminate any barriers to entry. New or competing generators should have easy entry to the wholesale market to provide contestability. Wholesale customers should have access to alternative generators, suppliers and brokers when economically appropriate.[10] The market should provide the proper signals and incentives such that mutually acceptable contracts between users of the system are economically efficient for the system as a whole.

In an electricity system, operating an efficient spot market for energy and transmission is a key to providing both access and the proper economic incentives. At the same time, the demands of system control and reliability require central dispatch of power plants to meet load while respecting the constraints of the transmission grid. These requirement combine naturally in the continuation of traditional practices for economic dispatch of power plants coupled with

[10] The emphasis on wholesale customers respects FERC's jurisdiction and distinguishes the analysis from the separate consideration of the quite different issues of retail access, wheeling and competition. Furthermore, in the case of requirements customers, open access even in wholesale markets raises questions of stranded investment, backup service, and other complexities required for a transition from the exiting practices. These complexities go beyond the focus of the present discussion.

the innovation of allowing market-based bids for power to replace engineering estimates of costs.

The existing mechanisms for central economic dispatch provide the information needed to calculate short-run marginal costs that reflect the payments for energy inputs, the availability of power plants and the constraints of the transmission system. These estimates incorporate all the system interactions and thereby subsume the complications of loop flow within the calculated marginal costs. This central dispatch must be preserved. With the proper design of incentives for bidding, this same dispatch process will replicate the results of a competitive market for which the marginal costs would be equal to the market-clearing prices. All energy should be bought and sold in the short run at these market clearing prices.

Short-run transmission usage prices are implicit in the differences in these spot-market prices across locations. These price differences always include the effect of marginal transmission losses. In addition, faced with transmission constraints, these market prices will include sometimes substantial differences that reflect the costs of system congestion. The resulting transmission loss and congestion prices would provide the necessary signals for efficient use of the existing electricity system and the proper incentives for efficient investment to locate new generating plants or expand the transmission grid.

The existence of a viable spot market based on demand bidding and central economic dispatch would provide a principal ingredient needed to assure access to the electricity market. Subject to minimal technical requirements and credit guarantees, any generator, supplier, broker or wholesale customer should have access to the grid and be allowed to buy and sell power in the spot market. The operation and control of the grid should be limited to the technical but not the commercial operation of the market.

As with other industries, an efficient spot market in electricity must combine with long-term contract arrangements for both energy and transmission. These contracts should define rights and responsibilities and share price and other financial risks as the parties agree. Energy contracts between wholesale customers and generators can insure generator cash flow and provide the required support for financing new projects. Such long-term energy contracts would provide an option for customers seeking greater price stability. Of course, buyers and sellers would have the option of relying on the spot-market. This creates the possibility of facing highly volatile prices. However, buyers and sellers would also have the option of agreeing on separate bilateral financial payments that hedge against any changes in prices in the spot market. Furthermore, in the presence of the spot market, the long-term energy contracts are limited to financial hedges and do not constrain the operation of central economic dispatch by requiring operation of specific generating plants for specific customers. Actual purchase and sale of power is provided through the efficient spot market, with payments under the contract returning agreed compensation for fluctuations in the spot price.

Although long-term energy contracts can arise naturally through bilateral negotiations built around the operation of the spot market, corresponding contracts defining transmission rights and payments must work through the monopoly grid operator. Because of these operational requirements of the power grid, long-run transmission capacity rights cannot be granted solely in terms of specific performance. In the presence of system congestion and changing load patterns, it will not be possible to meet load, guarantee reliability, minimize costs, and simultaneously generate power at the locations consistent with long-term transmission rights. The technical conditions of electric power transmission require that the grid operator recognize and

incorporate the interactions of different users of the system. In the short run these interactions lead to efficient transmission usage prices. In the long run, the grid can operate a market in transmission capacity rights. Just as with long-term energy contracts, these transmission rights are limited to financial hedges and do not constrain the technical operation of central dispatch. Hence the transmission capacity rights are really transmission capacity "rental" rights, not rights to control use of the grid.

The financial payments for transmission rights provide the natural compensation for the fluctuations in spot prices. However, unlike the long-term contracts with generators, the definition of rights and the computation of the associated financial payments for transmission requires the participation of the grid. Fortunately, the necessary payments can be determined automatically in the calculation of the short-run marginal costs associated with the optimal economic dispatch for the spot market. Hence the grid can provide the technical operation of the spot market and act as a clearinghouse for payments under long-term capacity rights.

The definition of the capacity right reduces to a selection of two points in the network and the associated capacity assigned for transmission compensation between these two points. In normal operations of the power system, users will sell or purchase power, or arrange for equivalent transmission. For each accounting period, the transmission usage price includes a congestion component. The actual grid users pay the grid the associated usage prices for real and reactive power. In turn, the grid will pay the transmission capacity-right holders the congestion rental for the allocated capacity.

The principal requirement in maintaining the viability of the transmission capacity-right allocations is to ensure that the combination of all allocated rights is feasible within the operating

constraints of the grid. Because of the network interactions, this implies that the capacity cannot be determined by examining particular paths of individual transactions in the system. Transmission in one part of the grid may increase or decrease capacity for transmission in other parts of the grid. However, as long as the aggregate transmission would be feasible under the loads and power conditions envisioned with the capacity rights, then the implicit usage payments under economic dispatch will fund payments in the settlement system needed to compensate the capacity-right holders.

Creation and use of the financial transmission capacity rights would provide the normal mechanism for capturing the benefits of the transmission grid. By distributing the revenues obtained from short-run transmission usage back to the holders of transmission capacity rights, we leave the costs of the transmission system to be collected from a set of fixed charges under long-term contracts. Combined with short-run marginal cost prices, the fixed charges are economically efficient as the other half of a two-part tariff structure and fall naturally to the recipients of the transmission rights. Customers who wish to reduce the costs of congestion implicit in payments in the electricity spot market have an incentive to invest in transmission expansion and reinforcement. Such investment creates new transmission capacity. The right to the financial benefit of that new capacity can be assigned to the customer who agrees to pay the investment cost. Those who invest in long-term transmission capacity rights will not face the possibility of later paying congestion costs induced by other users of the system. This provides the complementary long-term financial assurances found in the companion long-term energy contracts.

The overall structure of the market would reduce to a transparent system that preserves

the necessary central control over technical operation of the system, provides essential ingredients for a more competitive electricity market, and simplifies governance of the system. The connection is through recognition of the equivalence of optimal economic dispatch and the results of equilibrium in a competitive market. The dispatch process produces the information needed to determine short-run marginal costs. These marginal costs provide the transparent basis for efficient spot-market prices. Everyone has non-discriminatory access to the spot market to buy or sell energy at these efficient prices. Long term financial arrangements can operate through contracts to hedge generators and customers against fluctuations in spot prices. With the assistance of the central grid as a clearinghouse, similar long-term contracts can operate to provide financial transmission capacity rights that hedge against the costs of congestion in the system. These long term contracts provide the necessary analogy to property rights to promote economically efficient incentives for long-term investment in both generation and transmission. The combined system conforms to the "user-pays" principle. In the short-run the user pays the efficient spot prices. In the long-run the user captures the benefits of new economic capacity and pays the investment cost needed to create that capacity.

GENERIC TRANSMISSION RIGHTS PROVIDE A NATURAL INNOVATION

The basic idea for transmission capacity rights builds from three simple principles for redefining the terms of the transmission debate. First, *promise only what you can deliver*. It is clear that under optimal dispatch with changing loads on the system, even firm transmission rights cannot guarantee specific performance. It will not always be possible both to meet load and to take power from one place and deliver it to another. Hence the definition of a firm

transmission right needs to include a method for payment to compensate for the higher costs incurred when transmission is blocked. In essence, this would extend to transmission the evolving British practice for new generation contracts, where the contract terms for the producers often hedge against the changing level of the grid buying price.

Second, *respect the facts of the transmission network*. The contract network proposal would redefine a long-term transmission capacity right as a license either to deliver power from one point on the grid to another point, or to receive a payment that compensates for the higher cost of generation if the transmission system is congested. The rights would be defined not on a "contract path" but within a "contract network." The compensation scheme would follow from the specification of the contract network. The essential detail is in the determination of contract network transmission prices that reflect the true marginal costs in the electric network.

For a given dispatch within any transmission network, the recognized method for calculating the necessary marginal costs at each bus or location also determines the implicit transmission costs.[11] And for the optimal power dispatch, these marginal costs will equal the market-clearing prices. The theory was developed originally with an eye toward improving efficiency in the choice of loads and generation, and this pricing method could drive future improvements in the dispatch process.

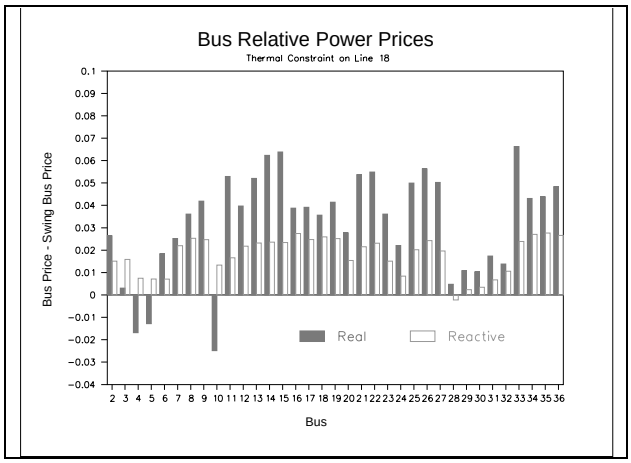
Happily for the present, however, this same theory provides the framework for determining the appropriate compensation for a long-term transmission right, without necessarily

[11] F.C. Schweppe, M.C. Caramanis, R.D. Tabors, and R.E. Bohn, Spot Pricing of Electricity, Kluwer Academic Publishers, Norwell, MA, 1988.

tampering with the dispatch process.[12] This leads to the third motivating principle of the contract network. Namely, *fix only what is clearly broken*. If the dispatch process is working well and would be difficult to change, accept the dispatch as given. Then it is possible after-the-fact to calculate transmission prices that both reflect the appropriate short-run incentives and provide the required long-run compensation.

The details are not obvious, but they have been worked out with readily available examples. For instance, Figure 1 shows the real and reactive power prices at each bus in an example with a thermal constraint on one line that induces a five per cent increase in cost at a particular bus.[13] The prices include the marginal cost of losses and the marginal cost of congestion at each location. By definition, the transmission price for any given transaction is the difference between the prices at the starting and ending locations. These transmission prices would both pay for losses and fund payments in a settlement system that guarantees the long-run transmission economics of the firm transmission capacity rights. Transmission users would pay the calculated price for transmission. Transmission capacity-right holders would be paid the corresponding cost of congestion. In effect, the day-to-day users of the transmission system would rent capacity from the owners of transmission capacity rights.

Figure 1



[12] W. Hogan, "Contract Networks for Electric Power Transmission," Energy and Environmental Policy Center, Harvard University, Discussion Paper E-90-17, September 1990.

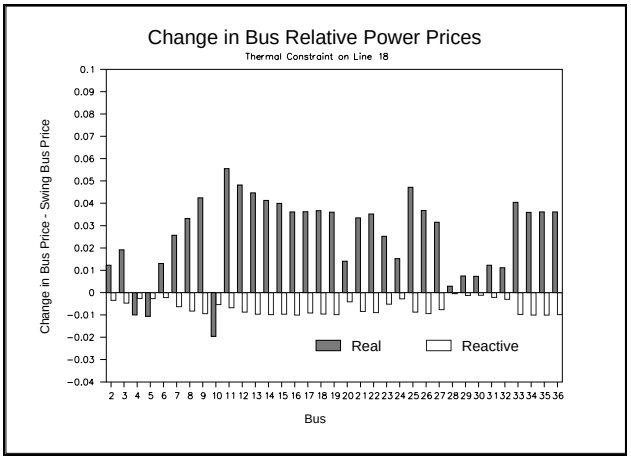
[13] The prices are reported relative to the cost of real power generation.

The contract network model would calculate the market-clearing capacity rental prices implicit in the power dispatch. These required rental payments are easy to compute after the fact. Hence it is possible to implement a compensation scheme which could provide a perfect hedge against the risks of system congestion. Within a contract network framework, these could be bankable long-term transmission capacity rights.

Since the contract network respects the facts of the transmission system, it avoids the problems of the contract path. All users pay the full opportunity cost of their use of the system. If loop flow creates congestion that affects the holders of transmission rights, the settlement system provides the appropriate compensation. The capacity rights of the network can be well defined, and honored, even though the actual transfer capability may change later with altered load patterns. Furthermore, the transmission prices incorporate the costs of constraints that arise from voltage or contingency limits, as well as thermal limits on individual lines. And once the network is specified, the information requirements are not much different from the data already used routinely to implement the common "split savings" calculations in many power pools.

Although the contract network framework is only a proposal, representative tests reinforce the promise of the method. These same tests illustrate a range of problems now ignored in transmission pricing, such as the great potential variation in transmission costs. For instance, Figure 2 summarizes the errors in the bus prices that

Figure 2



follow from ignoring the thermal limit in the example and pricing only according to losses. Apparently the impacts of even modest congestion can spread throughout the network. Furthermore, voltage limits and reactive power deficiencies can have significant effects on real power prices.

Congestion and even small associated changes in delivered prices can produce dramatic impacts on transmission prices elsewhere in the network. But the congestion payments in the contract network always provide the compensation needed to preserve the economics of the long-term transmission rights. With the contract network transmission capacity right in hand, **Cooperative Company, Weak Wheeler, Big Buyer** and all those clamoring to join the transmission club could turn their attention to the other problems that afflict transmission reform.

A contract network framework would not be a panacea. It cannot eliminate the problem of market power, but the creation of a viable long-term transmission capacity right can facilitate entry and mitigate market power without requiring the "no fault" assumption of unlimited transmission capacity. The contract network definition leaves open determination of the access charges needed to cover total costs, but it provides a consistent and efficient definition of usage prices. The discussion here neglects the questions of initial allocation and valuation of the rights or the transition problems in moving from the current system, although many options are available. In addition, the contract network will not guarantee optimal expansion of the transmission network, although the prices will provide information about the need for new capacity. Finally, the contract network will not eliminate the need for regulation of the transmission grid. However, the mix of regulation and market forces will change as new entrants can make viable long-term transmission arrangements.

CONCLUSION

The transmission debate requires new generic models to frame the choices of appropriate terms of transmission access and pricing. Transmission reform proposals should confront the problems of congestion in complex networks. The contract network proposal provides one example of a workable framework that respects the facts of transmission grids and yet allows the power market to evolve. A contract network accommodates good wheeling, and by imposing order and eliminating "free wheeling," it could reduce the pressure for bad wheeling. Given the broad experience with closely related practices such as after-the-fact estimation of split savings, use of settlement systems, and reliance on contracts to hedge performance risks, the contract network offers an option for transmission reform built on a reasonable adaptation of proven institutions. The contract network proposal merits further discussion, development, and prudent experimentation.

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