The Power Market:
E-Commerce for *All* Electricity Products

By Edward G. Cazalet, Ph.D., and Ralph D. Samuelson, Ph.D.

Why not use the Web to buy and sell transmission rights at prices derived from bids and offers?

YOU MAKE AN OFFER, I ACCEPT. YOU DELIVER A product, I deliver money. This simple construct works well in just about any industry you can name**.** When a willing buyer and seller negotiate a contract, each achieves an outcome he considers best. Moreover, each is obliged to meet the needs of the other—reliably. No central authority sets the price or allocates supply. We depend on markets for reliable production and delivery of other essential goods; why not for electricity?

Now comes the Internet, with the promise of an electronic exchange for many commodities. Food, books, and wholesale commodities, such as steel, already trade over the Web. Electricity, so far an exception to this trend, is an ideal commodity for e-commerce. It is delivered by wire and controlled electronically. The technology of e-commerce is well suited to the real-time matching of supply and demand required by electric power markets. Why not use the Internet wires to trade electricity?

In fact, why not use the Internet to trade *all power prod*ucts, including (a) the *electricity commodity,* (b) the *transmission rights* needed for delivery, and (c) the *ancillary services* that support the grid?

In the United States, the Federal Energy Regulatory Commission has called for the development of regional transmission organizations (RTOs), to better coordinate markets and foster reliability. Yet buyers and sellers still find it difficult to negotiate and deal, even where electric markets have been "deregulated." That is why the FERC cannot afford to miss this historic opportunity to encourage truly competitive markets as it forges a new transmission sector.

No one disputes the FERC on the need for a central operator of the grid; such an operator is essential for reliability. Indeed, the grid operator is like the air traffic controller in the airline industry whose overriding focus is safety. However, just as the air traffic controller is not responsible for flying the aircraft, the power grid operator should not be distracted from assuring reliability by operating markets or performing economic optimizations. The problems that arise in grid management should not justify rules that can distort markets.

The FERC knows well that the physical flow of electricity over the transmission grid does not mirror the path implied by the contract. The reality of the grid differs from the transaction as described on paper. This contradiction is one reason why the commission encourages the formation of RTOs.

Some RTOs (the "pool-based" RTOs) see the contract path approach as a market failure that must be dealt with through centralized dispatch of generation over a very large area. Instead, the Internet and e-commerce technology now offer the capability of integrating markets for energy, transmission and ancillary services in a way that recognizes and rationalizes real-time power flows. The constraints that he within the transmission grid can be seen as "flowgates" over which energy flows on all paths must be scheduled. Markets will form that can find a more efficient solution than centralized dispatch. The answer lies in bilateral trading of energy, transmission and ancillary services through flow-based scheduling, facilitated by the Internet and the technology of e-commerce.

Let's face it. New transmission lines are difficult to construct. Yet local markets remain fractured for want of grid connections. Transmission must be used more efficiently. Why not use e-commerce to buy and sell transmission rights at prices derived from bids and offers?

In most of the United States, transmission is reserved and purchased on the Internet using the open access same time information system (OASIS), required by the FERC. However, further evolution of these systems is needed so that a transmission contract at market prices can be completed almost instantly. E-commerce allows for rapid bilateral trading at multiple locations, adjusting quickly to changing conditions. Faster trading cuts risk while increasing volume. It's more efficient. Instantaneous trading of both energy and transmission will drive the price difference between local markets toward the market price of transmission between the local markets.

Flow-based scheduling is less complicated than RTO-arranged schemes and will enhance markets.

FERC-imposed price caps on the sale and resale of transmission present a major impediment to U.S. markets. Instead, the FERC should permit and encourage transmission sales at prices determined in open trade. Wide-area access fees that reduce the pancaking of transmission rates will recover the basic revenue requirements of transmission owners without inhibiting trade. Revenues from transmission sales at market prices will offset these basic revenue requirements, keeping revenue-neutral the net effect on consumers.

Our focus here is on wholesale markets, but e-commerce should prove no less essential on the retail side. Furthermore, in addition to the United States, many other countries are restructuring their power industries. Because the Internet is global, all countries can move quickly and with little cost into a
new age of efficient, reliable markets for electricity.

Pool-Based RTOs: Costly and Inefficient

The PJM, New York and California Independent System Operators (ISOs) are pool-based RTOs. A pool RTO uses central dispatch, optimization and auctions to procure services and calculate after-the-fact, real-time hourly and daily prices. The proposed RTOs in Nevada and Texas resemble our idealized, market-enabling RTO, but no RTO to date encompasses our complete e-commerce vision.

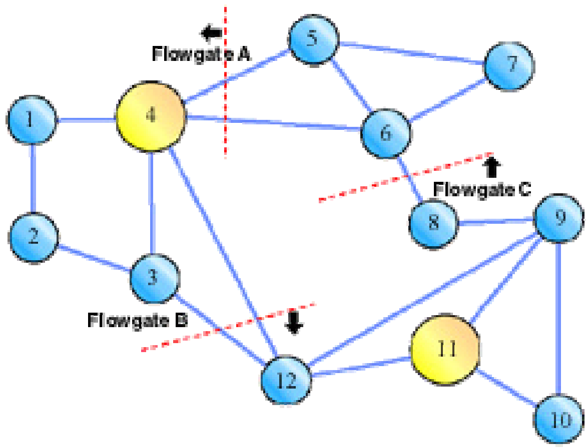
Pool RTOs that operate so called "markets" use central dispatch systems similar to those of a vertically integrated utility monopoly. Prices are computed in a series of periodic auctions and optimization procedures, run by the RTO. In California, a separate central organization, the

California Power Exchange, administers day-ahead and hour-ahead energy auctions, while the California ISO administers the ancillary service capacity auctions and real-time energy dispatch.

Flow-Based Scheduling: The Math is Easy

The total flow on each transmission flowgate is simply the sum of weighted flows from all transactions. The price of point-to-point transmission is simply the sum of weighted flowgate prices.

The simple network diagram below shows three flowgates defined in the directions indicated by the arrows:



Power can be injected in any node and removed at any node. The changes in flows on the flowgates are described by transfer distribution factors (TDFs). For example, the TDFs for a flow from Node 5 to Node 11 follow.

Flowgate A:	Flowgate B:	Flowgate C:
0.6	**0.6**	**-0.4**

Each megawatt flowing from Node 5 to Node 11 increases the flow across Flowgate A by 0.6 megawatts, increases the flow across Flowgate B by 0.6 MW, and decreases the flow across Flowgate C by 0.4 MW. Transactions between other pairs of nodes have different TDFs. The total flow on each flowgate is simply the sum of the TDF-weighted flowgate prices. Assume that the prices for each flowgate are as follows.

Flowgate A:	Flowgate B:	Flowgate C:
$5 per megawatt	**$10 per megawatt**	**$15 per megawatt**

To move 1 MW of power from Node 5 to Node 11, a participant must buy 0.6 MW of Flowgate A at $5 per megawatt, buy 0.6 MW of Flowgate B at $10 per megawatt, and can sell 0.4 MW of Flowgate C at $15 per megawatt. In total, the transmission price from Node 5 to Node 11 is 0.6 x $5 per megawatt + 0.6 X $10 per megawatt - 0.4 x $15 per megawatt = $3 per megawatt.

— E.G.C., R.D. S.

Unlike both e-commerce markets and current practice outside of pool RTOs, a pool RTO accepts energy schedules without requiring or allowing physical transmission reservations. A pool RTO will redispatch generation to bring transmission flows within flowgate limits. Participants are charged the incremental cost of this redispatch.

It appears convenient to allow energy schedules without transmission reservations. However, the pool RTO must have sufficient energy bids and offers to economically dispatch the generation needed to resolve congestion. That makes the pool RTO the dominant monopoly in energy markets. Such a monopoly distorts the market and requires extensive regulatory oversight. Transmission congestion prices and energy prices that are calculated through auction and dispatch by a pool RTO are highly volatile and arbitrary. In California, for example, an importer of electricity can be charged hundreds of dollars per megawatt-hour in congestion costs on a $30 per megawatt-hour energy sale and not know of the charge until after the deal is done.

In an attempt to protect participants from the risks of pool-calculated prices, pool RTOs have developed financial instruments called contracts-for-differences, which are settled against their after-the-fact auction prices. These contracts are complex. They can hedge risks only part way, because of differences in the products traded. By contrast, forward, physical markets that operate seamlessly via the Internet, from real-time to years ahead, will allow full hedging of risks.

Pool-based RTOs are expensive to implement and operate. A pool RTO usually combines, at great cost, several existing control areas to more easily apply central optimization methods. An RTO that relies on e-commerce markets to coordinate the existing multiple control areas and transmission operators should prove less expensive. Control areas can be combined when justified by operational savings, and an RTO based on e-commerce is easily interfaced with one or more independent transmission companies, or ITCs.

The facts demonstrate the high costs of pool RTOs. California has spent more than $700 million dollars to build and operate the California ISO and California Power Exchange over the last two years. This expense has added more than 5 percent to the cost of wholesale power. Only about one-third of the California ISO's costs are for control area operations that will be performed by an RTO based on e-commerce. (See The California ISO, "Analytical Support for California ISO Grid Management Charge," April 1999, p.6.) The remaining California ISO functions (scheduling, congestion management, market operations, and settlements, billing and metering), and all functions of the California PX, could be moved from the RTO to the market.

Flow-Based Scheduling: A Market-Friendly Dispatch

Where pool-based RTOs have not yet formed, electric transmission is arranged on a "contract path" basis, which maintains the fiction that electric power flows on a preselected path. Electric power actually flows according to the laws of physics over all possible paths. The power that is transmitted under a contract path reservation system may be limited by transmission constraints at interfaces called "flowgates" on other paths. *(See sidebar, "Flow-Based Scheduling. The Math is Easy.")* In the Western United States, a "cutplane" is similar to a flowgate.

The North American Electric Reliability Council (NERC) has developed transmission loading relief (TLR) procedures to curtail schedules on contract paths that contribute to violations of flowgate limits. Such systems were greatly stressed in the past two summers as reserve margins declined and the role of power trading increased.

Fortunately, a straightforward solution is to require market participants to buy and pay for capacity on the flowgates where their energy actually flows. Then curtailment of flows due to parallel path flows is unnecessary, except in emergencies. NERC has been working toward flow-based reservation systems for several years, and e-commerce systems enable an evolutionary, staged deployment of flow-based systems

Flow-based scheduling is less complicated than contract path scheduling. Given the source and sink of an energy transaction (or a set of energy sources and a set of energy sink, the use of each flowgate is calculated readily from published tables of distribution factors. The NERC Transaction Distribution Factors are an example of such tables. (See www.nerc.com/viewers.html.) The tables show the usage of each flowgate by a transaction between any source and sink in the network. This technology is rapidly improving, and already is used to determine which transactions are subject to curtailment during TLR events.

Typically, a given transaction will significantly impact only a few flowgates. The transaction distribution factors depend on the physical characteristics of the network, and are not significantly affected by the network flows. Only those flowgates that are "commercially significant" need be scheduled, and other constraints that have little impact on economic transactions can be managed by more traditional methods.

Flow-based scheduling is made easy by software that tracks a participant's flowgate holdings and needs. This software can execute buy and sell transactions for several flowgates with a few "mouse clicks"

Real-time changes in the capacity of each flowgate will occur, both because there are controllable elements in the network and because of line failures and other technical problems. Transmission owners can choose to sell flowgate capacity with a guarantee that unusable rights will be replaced or repurchased at a high price. The cost of buying back these rights would be paid through the higher prices that transmission owners likely would receive for a guaranteed flowgate product and adjustments in access fees.

Flowgate rights also are created by reverse transactions on a flowgate. Reverse flows on a flowgate effectively increase the capacity of the flowgate. The sale of flowgate rights created by reverse flows motivates participants to trade and redispatch generation to mitigate congestion on flowgates.

A single entity can be prevented by tariff from controlling more than a prescribed share of a single flowgate—say 20 percent. Such a limit will prevent abuse of market power by large players.

In a flow-based market, the price of flowgate capacity is determined by the bid and offer prices of participants. The price to move power from a location on the network to any other location easily is computed as a sum of the weighted gate prices. This calculation is illustrated in the sidebar on flowgate pricing.

The difference in electric energy prices at two locations, or nodes, will tend to equal the node-to-node transmission price computed as a sum of weighted flowgate prices. Trading will continue until traders find no way to profit from buying energy at one node and transmitting it to another node for sale.

When all flowgates are unconstrained, energy prices will be the same in all locations. When some flowgates are congested and trade at high prices, the market naturally will trade as a coupled set of locational markets with locational prices. Areas or zones with similar transaction distribution factors will have similar prices.

Ancillary Services: How to Phase Out Reserve Requirements

An e-commerce electric market can operate within intervals of 10 minutes or shorter during delivery. With enough participation in this real-time market, the need for RTO-arranged reserves is reduced or eliminated. The owner of a generator that suddenly fails immediately can obtain replacement energy and transmission from an exchange. Prices in the short-notice energy market under such events will rise to the levels necessary to provide others with an incentive to stand ready to provide this service.

The providers of short-notice energy ultimately will be loads rather than generators. Loads with real-time communication links and a willingness to shift usage in time are ideal sources of short-notice energy. Loads are likely to have faster response times and lower standby cost than generators. As e-commerce technology develops, consumers will buy smart appliances, such as air conditioners programmed to respond to the changing real-time and forward prices of electricity.

Until the e-commerce electricity market matures, the RTO will need to require participants to purchase ancillary service capacity reserves. The sellers of reserve capacity will be paid to maintain bids and offers in the real-time markets, which will not discourage voluntary bids and offers and voluntary balancing of supply and demand in real-time.

As the control area operator, the RTO will have a continuing role to curtail load and order increased generation in true emergency situations. Such situations should e rare in a mature e-commerce electricity market.

For loads and generators that are not balancing actual and scheduled generation in real-time, the RTO operator or a third-party agent, using grid level, real-time meter data, will buy and sell to balance load and generation in real-time. Those who cause real-time imbalances will be billed for the balancing costs.

The RTO operator and market participants will have a stack of short-notice energy bids and offers from both loads and generators. They will include ancillary service and voluntary bids and offers. The RTO operator will use these real-time bids to buy or sell to bring the system into balance. Generators and loads will respond because they will have offered a price that is profitable. This incentive to respond promotes the reliability of the system.

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The Ideal RTO Has No Trading Exchange
Stand back and let e-markets develop for the energy commodity.

In the new world order, a regional transmission organization (RTO) ought to confine its job to operating the control area and assuring reliability. Leave energy markets to the independent exchanges and electrical bilateral trading over the Internet. E-commerce trading can proceed independently and competitively, just as electronic stock trading now competes with the major public exchanges.

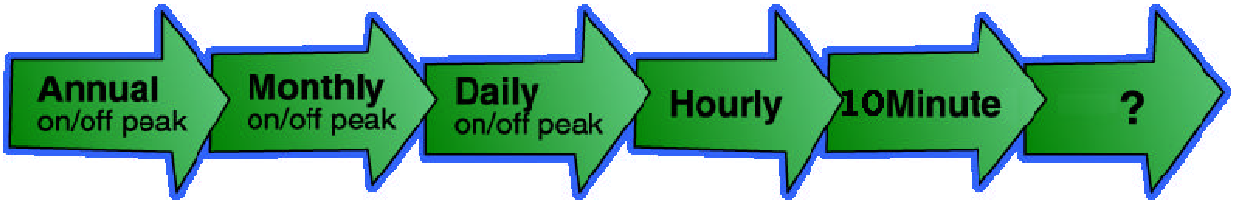
DECENTRALIZED DECISIONS. With e-commerce markets, decision-making becomes decentralized. Market participants gain forward price information. They can use that information to make better decisions regarding investment, maintenance, generation commitment and plant operations.

PORTFOLIO FRIENDLY. Moreover, if the intent of deregulation includes reducing the social cost of electricity, then forward price information should spur environmental improvements in generation, transmission and energy-use technology. E-commerce also can aid development of specialized exchange markets for green or renewable energy. Forward markets may help generators site plants to reduce dependence on long-haul transmission.

THE BILATERAL EXCHANGE. An e-commerce electricity exchange is simply an automated way to form bilateral contracts. The exchange accepts buy orders at bid prices or sell orders at offer prices. All exchange participants see these orders instantly and anonymously, and can quickly accept or improve on the orders. Internet markets can function quickly enough that only a few electricity products need be traded: energy, transmission and ancillary service capacity. As a fundamental commodity, transmission can be purchased over the interval of time. Ancillary services include reserve capacity, which will have a declining value as a distinct commodity as automated markets gain maturity and function in real time.

Trading in e-commerce markets takes place in a series of forward markets, as illustrated in the figure below. Annual electric energy and transmission products are traded years ahead of delivery. Such annual contracts provide for delivery across all peak or off-peak hours for an entire year.

Sequence of Forward Markets for Electric Power Commodities



Annual products are broken into monthly contracts and further divided into daily and hourly contracts. The length of the interval traded is increasingly short as the time to delivery draws closer. That allows market participants to shape supply based on changing and uncertain demand. Energy, transmission and ancillary service capacity all are traded in this manner.

Just before delivery, five- or 10-minute interval markets open for automated trading to provide real-time balancing and load following. Until confidence in this new approach is developed, an e-commerce system also can use existing control area real-time dispatch systems within each five- 10-minute interval.

— E.G.C., R.D.S