As the US' premier regional transmission organisation, PJM Interconnection's pricing and transmission congestion models must be foolproof. *Sandy Fielden* describes how they work and the associated risk management mechanisms available to participants

Congestion charges

★ PJM Interconnection (PJM) is a regional transmission organisation (RTO) that coordinates the movement of wholesale electricity in a market that serves nearly 20% of the US economy. The organisation serves approximately 51 million customers and has a generating capacity of 164,000 megawatts.

PJM members wishing to buy or sell wholesale electricity have four choices. First, they can 'self supply', which means that they generate their own electricity at whatever price it costs them. This is an approach a small utility company with its own generation capacity might pursue, because this tactic isolates it from any adverse transmission or price risk it may encounter if its operation is more integrated with the grid. The second choice is a bilateral deal between a consumer and a producer of electricity at an agreed-upon price. Bilateral deals don't have to be for long periods of time, but they typically cover firm requirements for energy over the medium term. Thirdly, participants may trade electricity in the RTO organised day-ahead energy market; and lastly, they may trade in the real-time energy market.

The day-ahead and real-time energy markets are the mechanisms that PJM uses to balance the supply of generation to the demand for electricity. The day-ahead market allows participants to make firm commitments to buy or sell power for delivery during the following day. The real-time market acts as a balancing mechanism during the delivery day, providing incremental electricity to meet unanticipated demand at a price determined in real time.

The day-ahead energy market requires buyers and sellers to submit bids and offers for electricity by 12.00pm of the day before delivery. Participants in the day-ahead market submit firm bids and offers to generate or consume electricity. A computer model is then run to determine the economic dispatch of generation to meet the load requirements during each hour of the day ahead. Model results are posted at 4.00pm on the day before the electricity flows. The basic function of the model is to determine the lowest priced generation bid into the system that will meet the expected load. The market price will 'clear' at the intersection of supply and demand bids. The market clearing price will increase as higher demand requires more expensive generation capacity to be brought on line.

The day-ahead market computer model produces a single, market-wide clearing price for each hour of the day across PJM. In theory, all transactions would then be carried out at the system cleared price. However, the model is also required to take into consideration the impact of congestion.

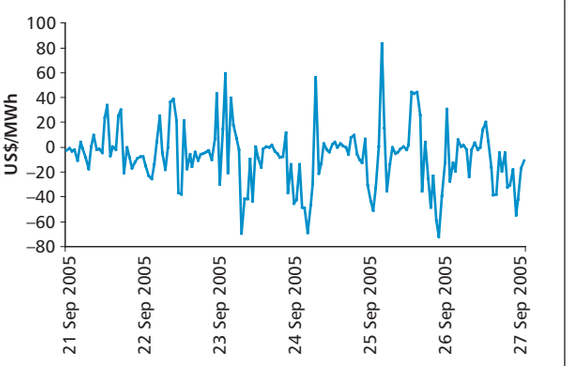
Transmission congestion

Transmission system congestion occurs when available low-cost supply cannot be delivered to the demand location due to transmission limitations. As market participants compete to use the scarce transmission resource, the RTO needs an efficient, non-discriminatory mechanism to deal with the congestion problem. Higher-cost generation closer to the load must be used to meet demand. The costs associated with more expensive generation are translated into transmission congestion costs in the pricing model.

In the PJM RTO price model, each location at which a generator injects electricity into the grid (known as a 'source')

F1. Real-time vs day-ahead LMP prices for PJM RTO, September 21-27, 2005

Source: www.pjm.com



Hourly prices in the real-time market are generated as a response to real-time fluctuations in generation and demand. Day-ahead prices are the generated based on firm commitments the day before the electricity flows. If participants end up consuming more power than they asked for in the day-ahead market or generate less power than they commited in the day-ahead market, they pay PJM the difference between real-time and day-ahead hourly prices.

and each location from which a buyer withdraws electricity from the grid (known as a 'sink') is designated a node ID. Each node in the model ends up with a slightly different price, which reflects the system-wide price plus or minus the impact of congestion. This mechanism is known as location marginal pricing (LMP). There are more than 8,000 individual nodes in the PJM system, each of which potentially has a different price every hour.

As an example, a market participant using the transmission system will source electricity at one LMP node and sink electricity at another LMP node. If the LMP price that PJM sells electricity for at the sink is higher than the LMP price PJM pays for electricity at the source, then the participant will have incurred a congestion charge for using a scarce transmission line. Conversely, if the LMP at the sink is lower than the LMP at the source, the participant will be rewarded with a congestion credit for flowing power in the opposite direction to the congestion (see table 1).

Participants are guaranteed that PJM will buy the electricity they offer and sell them the electricity they bid for, as long as their requirements are cleared in the day-ahead market. If they end up requiring more electricity during the day than they have bid for, or if they are not able to generate the electricity that they have offered, they must pay to the RTO the difference between the day-ahead market price at the designated LMP node and the real-time price prevailing when the electricity flows.

Because PJM has to balance the immediate needs of the network, real-time price models are generated every five minutes. When there is a shortage of generation, higher real-time prices attract electricity onto the grid. When there is a surplus of generation, lower real-time prices deter generators from entering the real-time market. Every hour, the LMP model produces an aggregated set of five-minute prices that become the clearing price for the real-time market (see figure 1).

The day-ahead LMP market is an efficient way to ensure that buyers and sellers with known requirements can perform their transactions ahead of time with a guarantee of price and delivery. To this extent, the day-ahead market is a hedging instrument against unexpected spikes that often occur in electricity markets. Day-ahead participants avoid real-time price hikes unless they exceed their committed requirements. However, for any participant seeking to move electricity across the grid – for example, to meet the needs of customers outside their immediate territory – there are still risks associated with transmission congestion charges.

Source: www.pjm.com

Node A				Node B
LMP				LMP
$15				$20
Source	→	Congestion charge $15	→	Sink
Sink	←	Congestion credit $5	←	Source

A transmission congestion charge occurs if the LMP at the point of generation (source) is lower than the LMP at the point of consumption (sink). A transmission credit occurs if the LMP at the point of generation (source) is higher than the LMP at the point of consumption (sink).

T1. Power and congestion revenue flows

FTR market

In order to offset congestion charge risks, the PJM RTO provides participants with hedging instruments that offset exactly the transmission congestion charges between two nodes. These instruments are called financial transmission rights (FTRs).

FTRs are purely financial instruments designed to allocate the congestion charges that the RTO collects through LMP pricing to those participants who pay the fixed cost of the transmission system.

An FTR protects the holder against congestion charges in the day-ahead market for a minimum of one megawatt between a given source and sink on the transmission network for a defined period of time. If the specified transmission incurs a congestion charge, the FTR pays out an equal amount of compensation. If there is a congestion credit because the transmission is in the opposite direction to the congestion, the FTR holder must pay the surplus back to PJM.

In PJM, FTRs have been available to 'firm' point-to-point and network service customers since the inception of LMP pricing in April 1998. Firm transmission effectively means guaranteed delivery. In the beginning, firm transmission customers were allocated FTRs as stakeholders in the transmission system. Since June 2003, the annual system of FTR allocation by the RTO has been replaced by a series of FTR auctions throughout the year.

Auction market

FTR auctions generate revenues that are re-distributed to firm transmission customers as auction revenue rights (ARRs). These ARRs can either be used like an FTR to offset congestion charges or can be spent at auction to buy additional or complimentary FTRs. The auction mechanism introduces a strategic trading element into the process of congestion risk management through an open market that any PJM member firm may participate in.

FTR auctions are held annually beginning in March with four successive monthly auction rounds, each for 25% of the designated transmission capacity. Any residual FTRs available after the annual rounds are auctioned on a monthly basis. Any market participant holding FTRs can sell them at the monthly auctions. After the auctions, there is an electronic bulletin board market for FTRs known as eFTR, conducted via the PJM website. Participants may also buy and sell FTRs in the bilateral (over the counter) market between themselves.

PJM auctions two types of FTR. The first is the standard obligation, which is revenue-neutral. Holders of obligation FTRs receive compensation for congestion costs arising from a given sink and source combination, but pay back any congestion credit for the same transaction. The second type of FTR is an option, which is the right to collect positive congestion revenue but with no obligation to pay back congestion credits. The obligation FTR provides a participant with a perfect financial hedge against congestion charges. The option FTR provides a

Source: www.pjm.com

	Source node	Sink node
	Panda 13kv	Hagerstown aggregate AP
Average* day-ahead LMP:	$115.67/MWh	$136.75/MWh
FTR credit (sink–source): $136.75 – $115.67 = $21.08/MWh		
August 2005 on-peak hours=23 days, 16 hours a day = 368 hours		
FTR credit total = $7,757.44 per MW		
FTR auction clearing price (cost) = $ 3,048.32 per MW		
FTR option net credit = $4,70912 per MW		

The on-peak option shown here from the August PJM FTR auction results, was the most profitable example that month. Calculating the most profitable FTR requires figuring the average on-peak LMP from the hourly data for 8000 LMP's and then ranking all the possible node combinations to identify the widest LMP price difference. Since options are not auctioned for all paths, it is then necessary to match the list of possible combinations to the list of eligible combinations to identify the 'winner'. In this case the FTR option holder realized gains of $4,709.12 per megawatt for the month.

**Average = calculated average of hourly LMP valuesfor each 'on-peak' hour in the month*

T2. August 2005 PJM FTR auction result example: on-peak options

hedge against negative congestion charges only.

Option and obligation FTRs are auctioned for peak and off-peak hours or for 24-hour blocks. The period of coverage for the FTR is either annual or one month, depending on the auction. The charges or revenue accruing from an FTR are settled every day with PJM.

The FTR auction market provides firm transmission users with an ability to completely hedge their congestion costs. A utility company, serving its load customers across the network will not be liable for congestion charges if they convert their ARRs to FTRs. Large unexpected transmission users will be vulnerable to congestion charges unless they purchase protection in the FTR market. In addition, the auction sales open up the market to non-traditional players.

Because FTRs are financial instruments, they can be bought and sold by participants who don't necessarily use the equivalent transmission. These participants might simply speculate on the auction value of an FTR that can be bought and sold like other traded instruments. Since FTRs effectively neutralise congestion costs by providing a complimentary cashflow, they are not materially different to financial swaps. Financial institutions are therefore attracted to the FTR markets as a natural extension to their risk services.

The sale of FTR options as well as the risk-neutral obligations offers a further speculative element to the auctions. FTR options are only auctioned for a limited subset of node paths. This is because options are not revenue-neutral, and the goal of the auctions is to balance revenue with transmission costs. FTR options do represent an intriguing market for speculative players, although understanding the market requires complex analysis (see table 2).

The LMP model used by PJM provides comprehensive price information at every point on the grid. Congestion cost risks are managed through financial transmission rights. FTR auctions open up risk management in the PJM electricity market to outside financial players, some of whom may have a speculative agenda. In the end, FTR markets are so complex that just managing the data can be a headache. That's where information management companies such as Logical Information Machines can play a role. ER

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