Power Markets Across the Globe and Indian Power Market

R. K. Mediratta, Vishal Pandya, and S. A. Khaparde

***Abstract*—The restructuring of power systems across the globe started with the redesigning of its power markets. The power market design determines the level of efficiency, transparency, and flexibility offered to the market players. This paper discuss the operational aspects of some of the important power markets in North America, Europe, and Australia. The power sector reforms in the Indian electricity market are also discussed along with the power exchange operations of Indian Energy Exchange (IEX) which is the first online electricity trading platform of India.**

***Index Terms*—market design, power exchange, power pool**

I. Introduction

ELECTRICITY reforms brought about during the last few years in various power markets around the world have revolutionized the way in which the markets have typically viewed the electricity. Electricity sector reforms have enabled a transition from a vertically integrated private or public monopoly market structure to one of competitive wholesale and retail mechanism with marketplaces like power pools and power exchanges. The sole purpose of these reforms is to promote competition among market players and to make the electricity market more efficient, liquid and complete. Electricity reforms have brought about mobility in the electricity market, increased the number of private players, created very dynamic marketplaces, and changed the electricity pricing pattern.

The instantaneous and perishable nature of electricity, and the ephemeral and sporadic demand-supply mismatch at geographical level, calls for a marketplace where surpluses can be disposed off efficiently on a real-time basis. Also, to mitigate the financial consequences of uncertain electricity market, appropriate arrangements for long-term contracts are required. These requirements of electricity market calls for a transparent, equitable, and efficient platform which also provides necessary means to fulfill short-term and long-term requirements of an electricity market. Power pools and power exchanges provide an organized marketplace which offers standardized products for the short-term and long-term electricity market. The design of the marketplace plays a crucial role in the overall system operations and the growth of the market.

Various market models have been adopted by different electricity markets. Australia (NEMMCO) and USA (PJM) are the mandatory power markets whereas NZEM (New Zealand), Nordpool, BETTA (UK), and IEX (India) are some of the examples of voluntary marketplaces. Power market models differ mainly in the following aspects:

Timing sequence: It is defined in terms of scheduling and time units. Nordpool offers day-ahead scheduling and ex-ante price settlement with a separate market for real-time balancing whereas NEMMCO (Australia) offers real-time trade and ex-post settlement.

Timing: Marketplaces like Nordpool, PJM (USA), PowerNext (France), OMEL (Spain), EEX (Germany) operate on hourly contracts. NEMMCO (Australia) offers half-hourly contracts whose prices are determined by a time-weighted average of six 5 minute intervals for clearing the market.

Pricing rules: Marketplaces like PJM, NZEM (New Zealand) use nodal pricing approach in which the price at each individual node is calculated separately whereas NEMMCO, Nordpool use zonal pricing approach where a set price is used for every zone without inner congestion.

Auction rules: A variety of auctions can be exercised in an electric power market. One discriminating factor among the different auctions is the number of bidding sides. If price bids from only one market side - normally the sellers - are accepted, the auction is called one-sided. In contrast, a double-sided auction uses bids from both sellers and buyers of the traded commodity. Auctions also differ in the way bids are handled, i.e. whether they are disclosed to all participants or not (sealed vs. open auctions). Nordpool exercises a vertical option in which the day is divided into 24 one hour vertical blocks whereas marketplaces like Borsen (Slovenia), EEX (Germany) divide the day into standard time blocks for base load, peak load and off-peak load.

Market clearing: There are two general variants in this. First, uniform pricing provides the same price for every accepted bid e.g., as in Nordpool. The price is set according to the price limit of the last accepted bid. Second, transactions can be priced in a discriminatory manner (pay-as-bid pricing) e.g., BETTA (UK), with the price being the limit of the accepted bid in question. OMEL (Spain) uses a different kind of pricing mechanism in which the buyer of the highest bid gets the electricity at the second highest bid price (Vickery auction) [1].

The following sections discuss design aspects of some important power markets in Europe (Nordpool), North America (PJM), Australia (NEMMCO), and India(IEX).

II. Market Design in European Countries

In Europe, trading arrangements are mainly bilateral. Most wholesale trade is in so-called over the counter (OTC)

R. K. Mediratta is Vice President (Business Development) at Indian Energy Exchange. Vishal Pandya and Prof. S. A. Khaparde are with the Department of Electrical Engineering, Indian Institute of Technology Bombay, Mumbai.(email: rajesh.mediratta@iexindia.com, vishal.pandya@iitb.ac.in, sak@ee.iitb.ac.in)

markets, often supplemented with day-ahead auction trade [2]. Exchanges operate the trading activity with maintaining anonymity and taking the counter party risk. The market operates on a decentralized way where exchanges operate independent of the system operator and participation in exchanges is voluntary. The day-ahead auctions in the European market do not determine the generation schedule for the next day and are weakly linked with the actual deliveries.

To facilitate cross-border trading and provide non-discriminatory access, separate markets for transfer capacity have been developed which link the wholesale electricity markets of different countries with each other. This is referred as coupling of electricity markets. The market coupling is usually facilitated by exchanges with the day-ahead auction market. As the day-ahead market closes at the day-ahead stage, intra-day and realtime markets are not accessible by the market player across the border. More recently, APX (Nether Land), Belpex (Belgium), and PowerNext (France) are the first exchanges to jointly allocate the day-ahead capacities on their internal borders [2]. The internal network constraints are not taken into account in the wholesale pricing and zonal pricing approach is used to clear the market. Market is divided into different zones when the network gets congested.

Nordic market is one of the most developed market in the Europe and the first international power exchange to offer multinational contracts. The following section gives the brief overview of the Nordic power market operations.

A. Nord Pool

Nord pool is jointly operated by two transmission system operators (TSO) - Statnett in Norway and Svenska Kraftnat in Sweden. Nord pool also operates a spot market called Nord Pool Spot. The Exchange Act prohibits Nord Pool from operating its clearinghouse activities in the same company that operates exchange activities. Thus, Nord Pool has transferred all clearing and settlement operations to a wholly-owned clearing company, Nordic Electricity Clearing House ASA [3].

The day-ahead spot market in Nordpool is organised by *Elspot* which offers contracts for the next day delivery. The Elspot exchange price is taken as reference price for the financial contracts offered by other financial power markets. The Elspot pricing is done using area pricing approach in which market is split in different price areas when congestion occurs. The market following the Elspot market is the Elbas. *Elbas* facilitates the intra-day and hour-ahead trading and covers every individual hour of the day. The Elbas enables power plant producers, distributors, industries, and brokers to fine tune their portfolio of their physical delivery contracts.

Apart from offering physical electricity delivery contracts, Nord pool also offers varied products for the financial market. *Nordpool ASA* is a financial market which provides contracts for price hedging and risk management. Nordpool offers contracts of up to six years' duration, with contracts for days, weeks, months, quarters and years. Nordpool also offers European union allowances (EUA) and certified emission reduction units (CERs). Nordpool clearing house (Clearing ASA) provides clearing service in which Clearing ASA enters into the financial contracts as a contractual counter-party. This means that Nordpool assumes liability for covering the future clearing of financial contracts in order to reduce the risk of the contracts for buyers and sellers. Nord Pool Clearing provides clearing for financial, standardised electricity contracts traded on and off the exchange [4]. Fig.1 provides the graphical representation of the Nordpool operations.

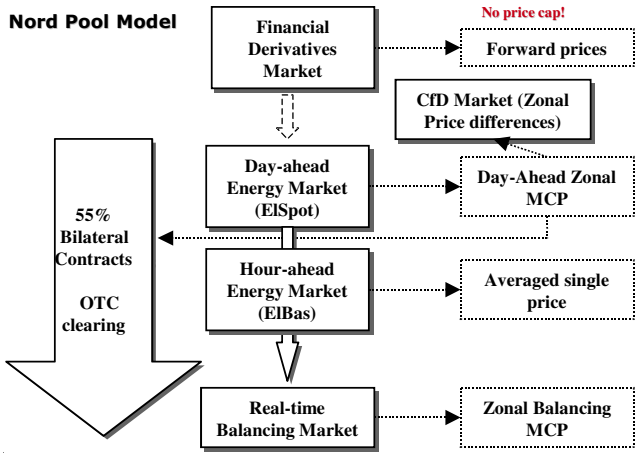

Fig. 1. The market structure in Nordpool

III. Market Design in North American Continent

The North American wholesale market design is based on a mandatory auction that runs one day ahead of delivery. Typically, all network constraints are already taken into account at the day-ahead stage by the so-called power pools. These day-ahead auctions largely determine the generation schedule for the next day. Intra-day and real time trading arrangements make deviations from this schedule possible, but there is a strong link between the day-ahead commitment and the actual delivery. All the internal network constraints are considered in day-ahead contracts itself unlike in European market. Hence, if all the constraints are binding, every node of a system can have a different price i.e., nodal price [2].

The common market for Pennsylvania, New Jersey, and Maryland (PJM) was the first wholesale electricity market designed in North America. PJM now is considered as the most successful market in North America. The Federal Energy Regulatory Commission (FERC) now advocates PJM market design as the standard market design. Table I shows the market activity of PJM market. The following section discusses the PJM market structure in more detail.

A. PJM

PJM operates a day-ahead energy market, a real-time energy market, a daily capacity market, monthly and multi-monthly capacity markets, a regulation market, and the monthly Financial Transmission Rights (FTRs) auction market. Day-ahead market and real-time balancing market are the part of the two-settlement system of PJM market. In two-settlement system *day-ahead market* acts as a financial market and provides a hedge against price fluctuations in the real-time market. Day-ahead market calculates market clearing prices and volumes

TABLE I
MARKET DATA OF PJM [5]

Sr. No	Description	Amount
1.	Member Companies	500+
2.	Millions of people served	51
3.	Peak load in MW	144,644
4.	Generation capacity in MW	164,905
5.	Miles of transmission lines	49,970
6.	Gigawatt-hours of annual energy	729,000
7.	Number of generation sources	1,271
8.	Area served	14 states

for each hour of the day taking into account all the generation offers, load bids, bilateral transactions, incremental and decremental bids, and virtual bids. Virtual bids are the bids from the load side with no physical loads. The purpose of virtual bids is to increase the generation availability in the real-time and reduce the system prices.

The *real-time balancing market* clearing is determined by the real-time system operations. The balancing market is the real-time energy market in which hourly clearing prices are determined by the actual bid-based, least-cost, security constrained unit commitment dispatch. Load serving entities (LSE) pays balancing prices (real-time LMP) for any demand that exceeds their day-ahead scheduled amounts but will receive revenue (real-time LMP) for demand deviations below their day-ahead scheduled amounts.Transmission customers pays congestion charges (or may receive congestion credits) for bilateral transaction quantity deviations from day-ahead schedules.

An LSE has the obligation to own or acquire capacity resources greater than or equal to the peak load that it serves plus a reserve margin of about 18% [5]. LSEs have the flexibility to acquire capacity in a variety of ways. Capacity can be obtained by building units, by entering into bilateral arrangements, or by participating in the capacity credit markets operated by PJM. Collectively, these arrangements are known as the *Installed Capacity Market*, or ICAP. The PJM capacity credit markets are intended to provide the mechanism to balance the supply of and demand for capacity not met via the bilateral market or via self-supply. Monthly and multi-monthly capacity credit markets provide a mechanism that matches longer-term capacity obligations with available Capacity Resources.

PJM introduced *Financial Transmission Rights* (FTRs) in its initial market design in order to provide a hedge against congestion for firm transmission service customers, who pay the costs of the transmission system. PJM introduced the monthly FTR auction market to provide increased access to FTRs and thus increased price certainty for transactions not otherwise hedged by allocated FTRs. In PJM, firm point-to-point (PTP) and network transmission service customers may request FTRs as a hedge against the congestion costs that can result from locational marginal pricing. An FTR is a financial instrument that entitles the holder to receive revenues (or charges) based on transmission congestion measured as the hourly energy locational marginal price differences in the day-ahead market across a specific path. Transmission customers are hedged against real-time congestion by matching real-time energy schedules with day-ahead energy schedules. FTRs can also provide a hedge for market participants against the basis risk associated with delivering energy from one bus or aggregate to another. An FTR holder does not need to deliver energy in order to receive congestion credits. FTRs can be purchased with no intent to deliver power on a path.

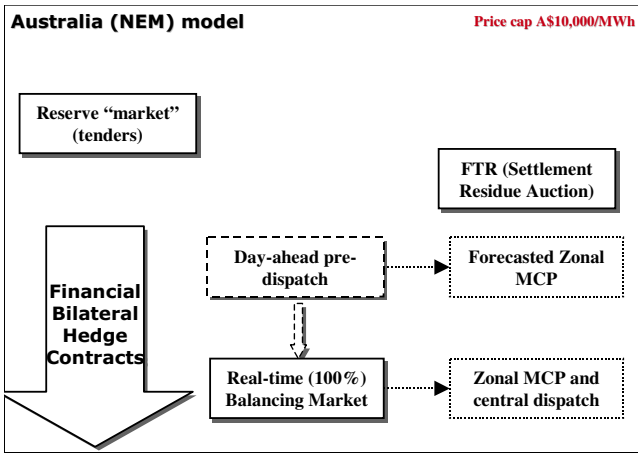

Fig. 2. The market structure in NEMMCO

IV. POWER MARKET DESIGN IN AUSTRALIA [6]

The National Electricity Market Management Company Limited (NEMMCO) was established in 1996 to administer and manage the National Electric Market (NEM), develop the market and continually and improve its efficiency. The governments of Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Tasmania are members of NEMMCO. Each of these governments nominates a director to the NEMMCO board.

The National Electricity Market of Australia is completely competitive, with any participant able to purchase from any other. Participants in the National Electricity Market can choose to take part in any combination of two levels of trading:

- Spot trading with energy traded through a commodities-type pool and a spot price set every half hour by the last (most expensive) generator selected to run. All wholesale electricity is accounted for through the pool (this is called a gross pool or energy-only pool)
- Short term forward market trading in which purchasers lock in energy prices through hedging contracts (contracts for differences)

Under a standard hedging contract, the purchaser (typically an electricity retailer) agrees to purchase a specified quantity of energy from the spot market at a set price (strike price). If the actual price paid in the spot market by the purchaser is higher than the strike price, the counter party to the contract (typically an electricity generator) pays the purchaser the difference in cost. Conversely, if the price paid is lower than the strike price, the purchaser pays the counter party the difference. Hedging contracts are financial instruments and can be traded in a market similar to other financial markets. There are numerous

TABLE II
A CONSOLIDATED OVERVIEW OF NORDPOOL, PJM, NEMMCO, AND IEX

	Nord Pool	PJM	NEMMCO	IEX
Participation	Voluntary for day-ahead and adjustment market	Compulsory for day-ahead market	Compulsory for day-ahead spot	Voluntary
Market Offerings	Day-ahead spot, hour ahead, Forwards, Futures, Options	Day-ahead spot, real-time balancing, capacity credits market	Day-ahead spot and short-term forwards	Day-ahead spot
Bidding Type	Double sided	Double sided	Double sided	Double sided
Adjustment Market	Elbas: intra-day auction market	Bid-quantity can be changed till gate closure	-	Not available
Real-time / Balancing market	Counter-trade for real-time, Participants are given MCP	Deviations are traded in real-time	Through purchase of Ancillary services, reserve capacity buying	Deviations are subjected to UI charges
Pricing rule	Zonal pricing	Nodal pricing	Zonal pricing	Zonal pricing
Pricing type	Ex-ante	Ex-post	Ex-post	Ex-ante
Risk Management	Forwards, Futures, Options	FTRs-ARRs, Bilateral OTC, Multi-settlement market, virtual bidding, Financial trading @ NYMEX	Bilateral OTC, Derivatives on Sydney futures exchange	Bilateral OTC
Congestion Management	Area splitting	Security constrained economic dispatch	Locational signals for transmission tariff	Area splitting
Transmission Losses	Included in zonal price	Included in LMP	To be purchased by generators	To be purchased by participants
Time blocks	Hourly blocks	Hourly blocks	Half-hourly blocks	Hourly blocks

variations on the standard hedging contact available in the market, often containing complicated financial arrangements.

From the bids submitted, NEMMCOs systems determine which generators are required to satisfy demand, at what time, and their production levels in a process called scheduling. Offers to generate are stacked in order of rising price, and are then scheduled and dispatched into production. The use of the rising-price stack means that more expensive generators are scheduled into production as total demand for electricity increases.

At times, the technical capacity of the transmission network may determine which generators are scheduled to meet demand. In such a situation, generators may be scheduled out of price order so that demand in a particular area supplied through the network may be satisfied.

V. INDIAN POWER MARKET

In India, electricity reforms started with the reevaluation of Electricity Supply Act, 1948 and the Indian Electricity Act, 1910 which led to The Electricity Act, 2003. The Electricity Act, 2003 has been brought about to facilitate private sector participation and to help cash strapped SEBs to meet electricity demand. The Electricity Act, 2003 envisages competition in electricity market, protection of consumer's interests and provision of power for all. The Act recommends the provision for National Electricity Policy, rural electrification, open access in transmission, phased open access in distribution, mandatory SERCs, license free generation and distribution, power trading, mandatory metering, and stringent penalties for theft of electricity. One more welcome step the Indian electricity market has seen is the implementation of Availability Based Tariff (ABT) which brought about the effective day-ahead scheduling and frequency sensitive charges for the deviation from the schedule for efficient real-time balancing [7].

The fixed and variable costs of electricity production are treated separately in the ABT. Fixed cost, known as *capacity charge*, is associated with the availability of the plant and its capacity to deliver MWs on day-to-day basis. Generating plant is paid the capacity charge according to its average availability over a year. Variable charge, know as *energy charge*, is the charge associated with the variable cost of energy production and the total amount paid to the generators is based on their scheduled energy production rather than actual production. The third component of ABT is called *unscheduled interchange* which is the payment for deviation from the schedule, and the rate is decided according to the system frequency as shown in fig.3. Deviations are allowed as long as they do not endanger the system security. Beneficiaries are paid for the underdrawal or charged for the overdrawal according to the system frequency. Thus the UI mechanism acts as a balancing market in which real-time price of the electricity is determined by the system frequency.

To promote power trading in a free power market, CERC (Central Electricity Regulatory Commission) approved the setting up of Indian Energy Exchange (IEX) which is the first power exchange in India. IEX has been modeled based on the experience of one of the most successful international power exchanges, Nordpool. The exchange has been developed

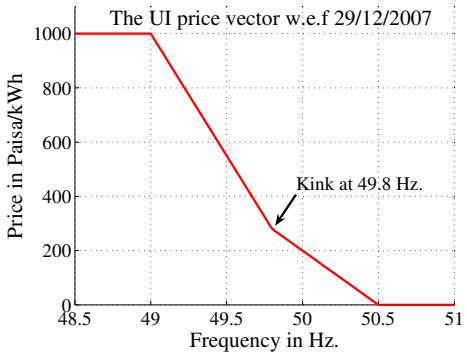

Fig. 3. Revised UI rates w.e.f 29.12.2007 [7].

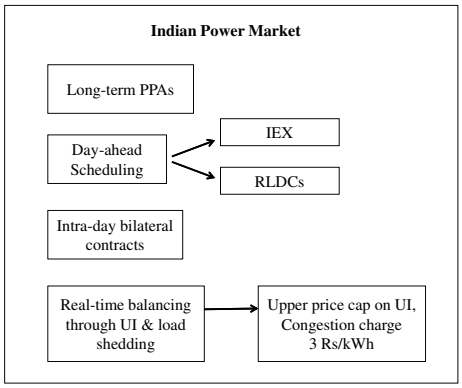

Fig. 4. Indian power market structure.

as market based institution for providing price discovery and price risk management to the electricity generators, distribution licensees, electricity traders, consumers and other stakeholders. The participation in the exchange operations is voluntary. At present, IEX offers day-ahead contracts whose time line is set in accordance with the operations of regional load dispatch centers. IEX coordinates with the National Load Dispatch Centers/RLDCs and SLDCs for scheduling of traded contracts' to get up-to-date network conditions.

The day-ahead market of IEX offers double sided auction and discovers the price incorporating the supply and demand side bidding. Network constraints are considered in deriving the price and market splitting approach is used to clear the market with congested lines. All the buyers and sellers are expected to bear transmission charges and losses in their regional transmission system till the periphery of transmission system. They are also required to bear operating charges (a charge to cover costs of System Operators) and transaction fee of the exchange which is nominal at 1 paisa/kWh. The exchange, as of now, offers only day-ahead contracts of an hourly time blocks. However, the exchange has plans for future to offer the adjustments contracts and long-term contracts like forwards and futures to hedge the risk against the uncertainty in electricity market. IEX has started operations on 27th June, 2008 and traded more than 300 Million kWh (MUs) on the platform in two months (by 31st Aug,08). Maximum trade on a single day has touched record of 18.6 MUs [8]. Putting together ABT mechanism, IEX and other market stakeholders, the Indian power market operations can be described as shown in fig.4.

VI. Conclusion

Table II summarizes various aspects of market design of Nordpool, PJM, NEMMCO, and IEX. Nordpool and IEX are the voluntary marketplaces who do not have direct control over the actual physical delivery of electricity. Whereas, in PJM and NEMMCO, participation in day-ahead contracts is mandatory which makes the day-ahead schedule for the next day the generation schedule for the same day. In terms of product offering, Nordpool offers wide range of contracts for adjustment market, real-time balancing, and long-term financial contracts to mitigate the risk. Zonal pricing approach used in Nordpool, NEMMCO, and India is comparatively easy for a market to adopt but, nodal pricing and the security constrained economic dispatch used in PJM is considered the most efficient approach. However, PJM market model requires high level of system integration, complex algorithms, and efficient computational techniques to operate the market. Also, the security constrained dispatch requires centralization of all the markets and therefore, participation through power exchanges or auction markets for spot transactions becomes compulsory for the market participants. This reduces the flexibility to the participants.

European electricity market design is simpler and pro-market which makes it easier to introduce products. The voluntary nature of market, as available in European markets, requires low level of system integration and simplified transmission pricing rules. This makes the European market model, an "easy to adopt" market model for the developing markets. Like European market, Power market in India is also following the decentralized market model. The Indian power market has now achieved all its segments of (i) Bilateral markets constituting long-term, medium term and short-term markets; (ii) Multilateral market i.e., power exchange (IEX) presently covering day-ahead segment and (iii) real-time multilateral balancing market i.e., Unscheduled Interchange(UI).

References

[1] Optimisation of Cogeneration Systems in a Competitive Market Environment. [Online]. Available: http://www.oscogen.ethz.ch/reports/oscogen_d5_1b_010702.pdf (accessed on Aug. 2008).
[2] M. Leonardo and R. Belmans, "Is the prevailing wholesale market design in Europe and North America comparable?" *IEEE Power Engineering Society General Meeting*, pp. 24–28, Jun. 2007.
[3] N. Flatabo, G. Doorman, O. Grande, H. Randen, and I. Wangensteen, "Experience with Nord Pool design and implementation," *IEEE transactions on Power Systems*, vol. 18, no. 2, pp. 541–547, May. 2003.
[4] Nord Pool Website. [Online]. Available: http://www.nordpool.com (accessed on Aug. 2008).
[5] PJM Website. [Online]. Available: http://www.pjm.com/index.jsp (accessed on Aug. 2008).
[6] NEMMCO Website. [Online]. Available: www.nemmco.com.au (accessed on Aug. 2008).
[7] Central Electricity Regulatory Commission. [Online]. Available: http://www.cercind.gov.in (accessed on Aug. 2008).
[8] Indian Energy Exchange Website. [Online]. Available: www.iexindia.com (accessed on Aug. 2008).