Proceedings of the 5th WSEAS/IASME Int. Conf. on SYSTEMS THEORY and SCIENTIFIC COMPUTATION, Malta, September 15-17, 2005 (pp79-84)

East China Power Market Development and Trial Operation

WEI XUEHAO, ZHU FENG, JIANG CHUANWEN, HOUZHIJIAN
School of Electronics, Information and Electrical Engineering
Shanghai Jiaotong University
No. 1954, Huanshan road, Shanghai
CHINA

Abstract: - The monthly market of East China Power Market (ECPM) started trial operation on May 18, 2004. This paper outlines the profile of the East China Power Grid and summarizes the development of ECPM. In particular, the paper describes the market structure that ECPM has selected, and analyzes the results of ECPM trial operation. The underlining rationale that determines the market behavior is explored, and recommendations for further improvement are provided.

Key-Words: - power market; monthly market; simulation; empirical analysis

1 Introduction

East China Power Grid covers the geographical areas of Shanghai Municipality, Jiangsu, Zhejiang, Anhui and Fujian Provinces. By the end of 2003, the total installed capacity in East China Power Grid had reached 81,300MW, with total annual electric energy consumption of 453TWh. There are 45 substations and power plants at 500KV level. The length of 500KV AC transmission lines had reached 7460 Km. 500KV DC transmission lines connect the East China Power Grid with Central China Power System where Three Gorge Power Station, the largest in the globe, is located. The large scale East China Power Grid offers an excellent platform for the trading of energy-related commodities.

The region East China Power Grid covers is one of the fastest economically growing and most prosperous regions in China, with a two digit annual GDP increases in recent years. The population accounts for 1/6 of China's, consuming 1/5 of electric energy in China, and having 1/3 of China's total economic production. The average per capital GDP in this region is over 1.7 times of domestic average level. The continuously fast economic growth has triggered two-digit increases in both energy consumption and peak load for some consecutive years. The fast economic growth, together with the dynamic market activities in other sectors and relatively advanced market management experience, provide a rather suitable external environment for the development of ECPM.

Before industry restructuring, East China Power Grid, the parental company of four provincial grid companies, had a long tradition of executing inter-provincial energy transactions. These transactions range from centrally planned proportional allotment, residual energy transactions, to bi-lateral contracts. In general, provincial grid companies participate in such transactions while individual generators do not. In particular, the bi-lateral trading among the provinces is booming in these years. The bi-lateral trading energy has reached 4.855 TWh in 2001, 11.836TWh in 2002 and 25.594 TWh in 2003, with an average increase rate 129.6%. From a historical viewpoint, these inter-provincial energy trading laid a solid foundation for the development of the East China Power Market.

During the period from 2000 to 2003, a number of provinces in east China region have opened free electricity markets in a provincial level. These markets were criticized because they offer competition only in provincial level. This motivated the idea of inter-provincial markets, which is of much the same flavor of Regional Transmission Organization (RTO) in USA.

Traditional wisdom suggests that the construction and development of the regional power market is a process of learning both international experiences and lessons that have been accumulated over times. It is also a process of reaching agreement and increasing awareness of the market initiatives. From June 2003, when the East China Power Grid was selected as one of the regional power market pilots, to May 18th, 2004 when trial market operation started, it took almost one year to complete the initial market preparation and construction. The major milestones can be listed below:

a) In March 2002, China government issued Power Industry Institutional Reform Plan (Policy No. 5), which outlines the direction of China's Power Industry reform. Generation business has been separated from transmission business and five major generation companies

have been formed. The establishment of the regional power market is given the top priority.

b) In June 2003, State Electricity Regulatory Commission (SERC) presided a meeting in Shanghai and clearly addressed the intention of establishing a pilot power market in East China.
c) According to the Policy No. 5, East China Grid Company Limited (ECG) was established on September 28, 2003, which bears leading responsibility for developing ECPM.
d) In November 2003, SERC issued the ECPM Pilot Plan, which is the blue print of the power market development.
e) In April 2004, SERC issued the ECPM Codes
f) On May 18th, 2004, ECPM trial operation was commenced. This is the largest regional power market pilot in China.

2 The Development of The Market

2.1 Guidelines

The Policy No. 5 guides the development of ECPM. The market development has to respect the unique characteristics of power industry, and international experiences are exploited. It starts with the separation of generation from transmission functions, which aims at optimal resources allocation by introducing competition into wholesale market. The market is expected to facilitate a sustainable and healthy development for power industry in East China Region to satisfy the requirement of regional economic growth as well as the needs of people's life. The objectives of ECPM Development include:

a) Introducing competition, breaking down market barriers and achieving optimal resource allocation in the East China region.
b) Encouraging power industry to improve management, efficiency and service standard etc.
c) Establishing a unified, open, competitive and stable regional power market under government regulation.

When including a subsection you must use, for its heading, small letters, 12pt, left justified, bold, Times New Roman as here.

2.2 The Principles of Market Design

The institutional structure of ECPM is judiciously chosen taking into account the characteristics of energy resources and consumption types within the region, technical requirements, the current institutional structure, and local economic conditions [1].

In the pre-restructuring model, the buyers and sellers are limited only to the provincial power companies serving as either single buyers or single sellers who trade for surplus or deficit of their own provinces. In the new market, all the market entities are competing on the same regional market platform. This design is expected to produce a better outcome in terms of resource allocation over a wider area.

In the preliminary stage of the ECPM, five buyers (four provincial power companies and Shanghai Municipal Power Companies), 171 sellers (conventional coal-fueled generators with capacity over 100MW) will participate in the centrally controlled regional power market.

A 500KV transmission network that connects the provinces and Shanghai Municipality has formed, which facilitates the inter-provincial energy trading. The separation of generation from transmission has largely been completed by 2004. Shanghai Municipality and Zhejiang Province who managed province-based power market pilots have accumulated some experiences for the development of the regional market.

2.3 The Stage Objectives

In accordance with the principles of integrated design and phase-in implementation, ECPM development shall be implemented in three stages.

a) Stage one objectives: Let most of the generation companies participate the competitive market, and a portion of the energy be centrally traded in the ECPM platform. Investigate to allow large customers to directly purchase from generation companies in a controlled fashion. Establish legal and regulatory framework for the operation of ECPM. Reform and improve pricing mechanisms for electricity. Establish an ECPM coordinated by the region and its provinces.
b) Stage two objectives: Let gradually more generation companies participate in the market, thus increase the level of competition; start bi-lateral trade between large customers, independent distributors and generation companies, set up ancillary services market and transmission rights market, increase trading products; Establish a well functioning market regulation framework and a market under unified operational control.
c) Stage three objectives: Introduce competition into retail segment of the industry, and allow all eligible customers directly participate in the market competition with more flexible trading

arrangements and products. Establish financial market for energy and form a unified, open, competitive and orderly ECPM under government regulation.

2.4 The Trading Arrangements

At initial stages of market development, market trading is a combination of contract trading and physical trading. Contract trading will be the major trading pattern, supplemented by physical trading. A small portion of the energy generated by generators is traded in monthly market and day-ahead market, the remaining energy is sold to network companies through annul contracts for difference (CfDs) and physical contract. Ancillary service is not included in this market at this stage. Non-market generators are expected to sign contracts with network companies under the guidance of SERC.

In the short term, ECPM trading includes annual contract, monthly contract, day-ahead market and real time balancing mechanism. With the development of the market, other forms of trading could be introduced such as quarterly competition and weekly competition. At initial stages of market development, approximately 85% of energy is determined by annual contract; the remaining 15% or so is traded in the market. Depending on the progress of market development, the portion of energy exposed to market competition can be increased.

2.5 The Bidding and Market Clearing Mechanism of the Monthly Market

The monthly market of ECPM, currently the only market that is under trial operation, is divided into two segments. One is for the peak hours trading with a price cap 482 RMB/MWh, the other is for the off-peak time with a price cap 321 RMB/MWh. Both market follow the familiar market clearing mechanism while transmission constraints are taking into consideration. Mathematically, the market clearing is represented as the following linear program in which the mathematical symbols are self-explanatory:

$$\text{Max} \sum_{p\in Prv}\sum_{i\in PrvBlock_p} PrvPrice_{p,i}\times PrvBid_{p,i} - \sum_{g\in Gen}\sum_{j\in GenBlock_g} GenPrice_{g,j}\times GenOffer_{g,j} \Big/ GLF_{g,j}$$

$$S.T. \sum_{p\in Prv}\sum_{i\in PrvBlock_p} PrvBid_{p,i} - \sum_{g\in Gen}\sum_{j\in GenBlock_g} GenOffer_{g,j} = 0 \quad (1)$$

$$0 \le PrvBid_{p,i} \le PrvBidMax_{p,i} \quad (2)$$

$$0 \le GenOffer_{g,i} \le GenOfferMax_{g,i} \quad (3)$$

$$\sum_{i\in PrvBlock_p} PrvBid_{p,i} - \sum_{\substack{j\in GenBlock_g \\ g\in GenPrv_p}} GenOffer_{g,j} < PrvInMax_p \quad (4)$$

$$\sum_{\substack{j\in GenBlock_g \\ g\in GenPrv_p}} GenOffer_{g,j} - \sum_{i\in PrvBlock_p} PrvBid_{p,i} < PrvOutMax_p \quad (5)$$

Implicit in the above formula is a zonal transmission model, each province (Prv) is considered as a transmission zone. The duals of the above linear program form the zonal marginal prices [2].

3 The Trial Operation of The Market

According to a SERC order, ECPM trial operation, which started on May 18th, 2004, only involves monthly competition. The monthly competition simulates the following processes: generator unit registration, bidding, price ranking and information publishing.

In this trial operation, both supplier and buyer should bid and offer for their intended energy. The price and volume that will be cleared in the monthly market is determined by the bidding and offering curve from both generators and provincial buyers respectively, although, it will not be settled during the trial operation period.

However, the provisions of the ECPM Code on market administration and network operation shall be strictly implemented even during the trial operation period in order for the safer operation during simulation stage. Market administration comprises market participant management, unit registration, market suspension, etc.

3.1 Simulation Results

3.1.1Results of June 2004

ECPM cleared at total electricity 4.503 TWh with an average price 369.5 RMB/MWh in June 2004. Respectively, in peak load time the cleared quantity is 3.326 TWh, accounting for 73.86%, the cleared price is 406.8 RMB/MWh; in off-peak load time the cleared quantity is 1.177 TWh, accounting for26.14%, and the cleared price is 273.1 RMB/MWh (see table 1 and table 2 below).

Table 1 The simulation results of peak load time in June 2004

Unit: RMB/MWh; MWh

Provinces	Clear Price	Supply	Demand	Export
Shanghai	406.8	538,020	143,220	394,800
Jiangsu	406.8	1,895,460	1,621,200	274,260
Zhejiang	406.8	248,220	1,275,960	-1,027,740
Anhui	389.0	568,680	0	568,680
Fujian	406.8	75,600	285,600	-210,000
Aggregation		3,325,980	3,325,980	0

Table 2 The simulation results of off-peak load time in June 2004

Unit: RMB/MWh; MWh

Provinces	Clear Price	Supply	Demand	Export
Shanghai	273.1	266,100	600	265,500
Jiangsu	273.1	292,200	0	292,200
Zhejiang	273.1	132,000	708,300	-576,300
Anhui	272.2	434,100	277,800	156,300
Fujian	273.1	52,800	190,500	-137,700
Aggregation		1,177,200	1,177,200	0

The market clearing of on-peak and off-peak hours are further illustrated in Fig.1 and Fig. 2.

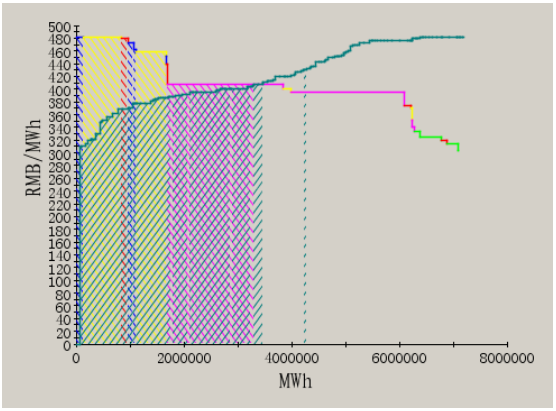

Fig. 1 The merit curve of peak load time in June 2004

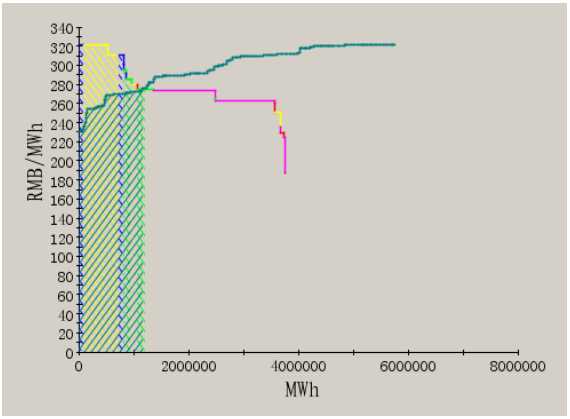

Fig. 2 The merit curve of off-peak load in June 2004

3.1.2 Results of July 2004

ECPM cleared at total electricity 6.820 TWh with an average price 405.4 RMB/MWh in July 2004. Respectively, in peak load time the cleared quantity is 4.849 TWh, accounting for 71.09%, the cleared price is 468 RMB/MWh; in off-peak load time the cleared quantity is 1.972 TWh, accounting for28.91%, and the cleared price is 289.3 RMB/MWh (see Table 3 and Table 4 below). The market clearing of on-peak and off-peak hours are further illustrated in Fig.3 and Fig.4.

Table 3 The simulation results of peak load time in July 2004

Unit: RMB/MWh; MWh

Provinces	Clear Price	Supply	Demand	Export
Shanghai	468.0	1,014,258	954,366	59,892
Jiangsu	449.9	2,139,620	2,070,180	69,440
Zhejiang	468.0	607,600	1,059,828	-452,228
Anhui	416.4	687,890	186,186	501,704
Fujian	468.0	399,280	578,088	-178,808
Aggregation		4,848,648	4,848,648	0

Table 4 The simulation results of off-peak load time in July 2004

Unit: RMB/MWh; MWh

Provinces	Clear Price	Supply	Demand	Export
Shanghai	289.3	865,520	0	865,520
Jiangsu	289.3	458,490	193,130	265,360
Zhejiang	289.3	244,280	1,399,030	-1,154,750
Anhui	289.3	288,610	199,950	88,660
Fujian	289.3	115,010	179,800	-64,790
Aggregation		1,971,910	1,971,910	0

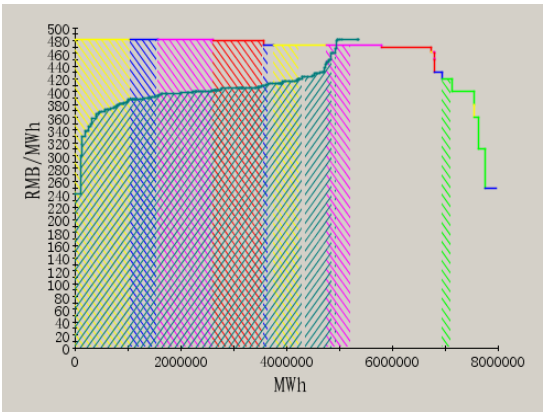

Fig.3 The merit curves of peak load time in July 2004

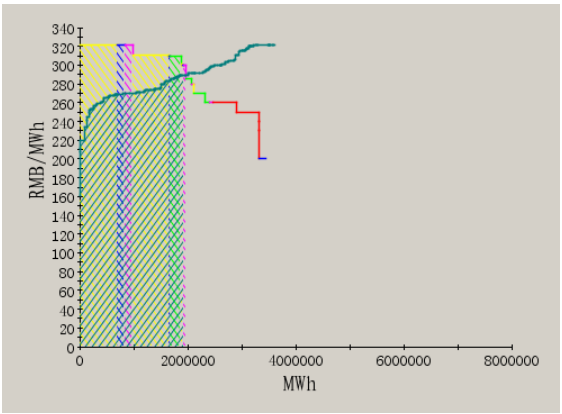

Fig. 4 The merit curves of off-peak load in July 2004

3.2 Results Analysis

The significance of the regional power market lies in optimizing resource allocation over a wider area, compared to the previous provincial power market. The problem is how to quantify the significance. In what follows we give a preliminary solution to this

question.

The significance can be represented by the market efficiency. According to the principle of economics [3], the market efficiency can be quantified by the total surplus, which is the sum of consumer's surplus and producer's surplus. In the regional power market, the Tie Line Flows among the provinces has a significant impact over the market efficiency. Assuming the transfer limits of the Tie Line Flows are zero, actual market flows and infinite respectively, the efficiency of the provincial market, actual regional market and ideal regional market can be calculated, the results are included in table 5.

Table 5 The regional market efficiency compared with the provinces

Unit: million RMB

	Provincial	Regional (actual)	Regional (ideal)
off-peak, June	23	52	52
peak, June	149	232	235
off-peak, July	44	93	93
peak, July	357	397	411
Aggregation	574	774	791

From table 5, it can be seen that the market efficiency of the actual regional market is 774 million RMB, while the province's is 574 million RMB. The regional power market proved to be maximizing the market efficiency. Fig.5 further illustrates the relationship between tie-line transfer capacities and market efficiency.

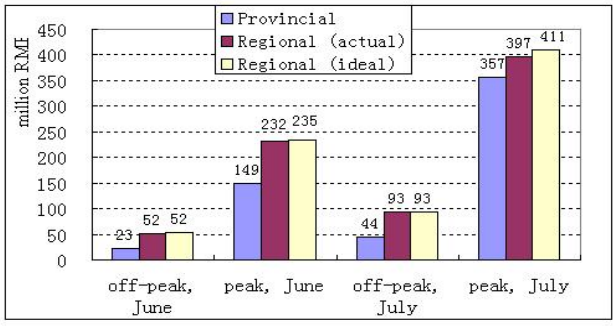

Fig. 5 Tie Line Flows affecting the market efficiency

Certainly, provincial markets with zero tie-line capacities are rather idealized markets. The transactions exist among provincial markets help to improve (provincial) market efficiency. However, the difference between an inter-provincial market and a group of provincial markets with transactions is fundamental.

Another issue that is receiving attention is the simulated deficit of network companies. As a result of the tight supply situation, the network companies' payment in the wholesale market has increased on a large scale. The analysis on trial operation revealed that the increased payment is 171 million RMB in June, and 334 million RMB in July respectively. The total increased payment, 505 million RMB, is far beyond the network companies' budget. This tendency has been one of the major concerns of the regional market.

We complete this section by summarizing the trial operation of the monthly market in Fig.6, where ISO means Independent System Operator.

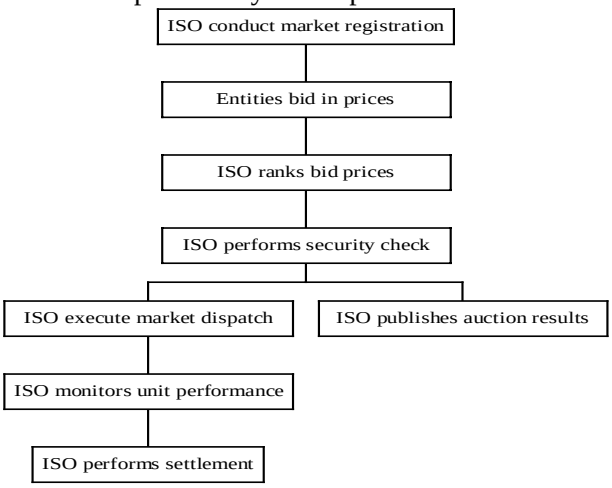

Fig.6. The monthly market operation

4 Concluding Remarks

As one of the pilots of regional power market, ECPM has renovated the provincial power markets to the regional platform with uniform codes, realized the inter-provincial competition under the multiple control area model, and optimized the resources allocation within a wider area. Despite of the institutional complexities, the monthly market competition, which adopts a two-way bidding mechanism, maximized the market efficiency and enhanced the social welfare.

The trial operation of the regional market has converted administrative relationships between the market participants into contractual relationships. The responsibilities and obligations of the market participants are declared by the market codes definitely. At the same time, the regional market clearing prices as signals indicate investments on the generation and transmission sectors. In addition, the ECPM model offered a good example for further restructuring of China power industry.

Although the ECPM faces a lot of difficulties and disadvantageous situations, it is believed that market reform will bring positive changes to social welfare and should be pursued down the road. To this end, international experiences such as those of Australia, North America are exploited. It is likely that the concept of pool-based market, widely accepted in the above countries, will be followed in the future market design. Although the suitability of Standard Market Design [4] remains skeptical, a day-ahead market with zonal marginal prices calculated centrally is envisioned.

Another question that ECPM faces is whether or not

it is feasible to centrally manage a market with rapidly increasing installed capacity. The total installed capacity of the market will exceed 100,000MW in 3 years! Fig.7 gives an illustration of sizes of some of the largest markets in the world. An extra-large scale market presents challenges to fundamental control center functions such as but not limited to security analysis, real-time dispatch, ancillary service provision, and AGC. This is in fact a question of common interest in the power community [5].

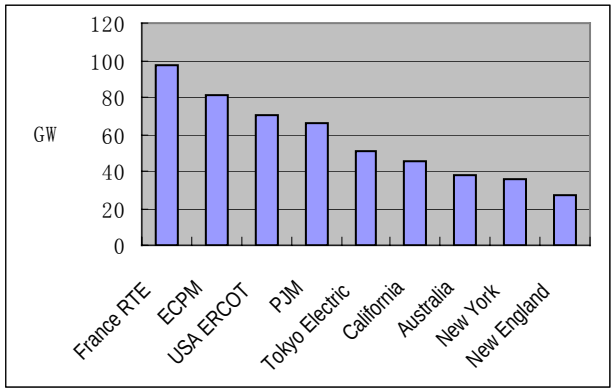

Fig. 7 Some of the largest power markets in the world

References:

[1] East China Power Market Steering Committee office, “East China Power Market Pilot Work Documents”, No. 18-19, 2004

[2] D. Gan, D. V. Bourcier, "Locational Market Power Screen and Congestion Management: Experience and Suggestions", *IEEE Transactions on Power Systems*, vol. 17, no. 1, February 2002, pp. 180-185

[3] A. Mas-Colell, M. D. Whinston, J. R. Green, *Microeconomic Theory*, Oxford University Press, Oxford, UK, 1995

[4] Federal Energy Regulation Council (FERC), “Working Paper on Standardized Transmission Service and Wholesale Electricity Market Design”, March 16, 2002. http:// www.ferc.fed.gov

[5] LECG, LLC, Kema Consulting, Inc, “Feasibility Study for a Combined Day-Ahead Electricity Market in the Northeast”, 2nd Draft Report, Albany April 26, 2001