The Chinese Electricity Market Infrastructure and Operation System: Current Status and Future Developments

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The Infrastructure of the Electricity Market – Introduction

- At the end of 2005 the installed generation capacity of 500 GW made China the second highest in electricity production in the world.
- 2006: 600 GW; 2010: 852 GW; 2015: 1120 GW; 2020: 1330 GW
- New electric energy infrastructure is required to transfer bulk electricity energy over a very long distance by the construction of the ultra high voltage power grid.
- The **ultra high voltage grid** would make the united national electricity market possible and facilitate the nationwide electricity market competition.
- The development of the national electric market should keep the pace with that of the development of the national grid.
- The unified national grid is separated into different layers and regions, which can operate under the same regulations and rules.
- The electric markets should adapt to the structure of the national grid.
The Infrastructure of the Electricity Market – Ultra High Voltage Grid

UHV Grid Capacity
>200 GW

Black: 1000kV AC
Red: 800kV DC
Pink: 750kV AC
Blue: 500kV AC
The Infrastructure of the Electricity Market – Electricity Market Structure

- Three-layer structure of the electricity markets: the national electricity market, the regional electricity markets and the provincial electricity markets

The future structure of the Chinese electricity market
The Infrastructure of the Electricity Market – Electricity Market Structure

• The ultra high voltage grid would make the united national electricity market possible and facilitate the nationwide electricity market competition.

• The unified national grid will facilitate electricity markets of different layers and regions, under the same regulations and rules.

• The electricity markets should adapt to the structure of the national grid.

• According to the structure of the national power grid, the structure of the electricity markets may be separated into three layers such as
  ➢ the national electricity market,
  ➢ the regional electricity markets
  ➢ the provincial electricity markets.
The Infrastructure of the Electricity Market – Electricity Market Structure

• The major function of the national electricity market:
  ➢ coordinating the electricity trading between different regions;
  ➢ ensuring the security and stability of the national power grid.

• The functions of regional electricity markets:
  ➢ open to the national electricity market;
  ➢ participating in the electricity market trading in the national electricity market;
  ➢ optimizing the utilization of energy sources within the region.

• The functions of provincial electricity markets:
  ➢ participating in both the regional and national electricity markets
  ➢ accepting the market scheduling from the national and regional electricity markets;
  ➢ optimizing the utilization of energy sources within the provincial area.
The Infrastructure of the Electricity Market –
The Level of the Competition

• The levels of competition:
  - The first level competition: the generation side competition with a centrally operated transmission system.
  - The next level of the competition: the wholesale competition that allows the large consumers to choose their own suppliers.
  - The final level: the retail competition: not only the larger industrial consumers but also smaller consumers can choose their own suppliers.

• The introduction of competition into a reformed power sector in China is a very complex process:
  - national energy strategies and policies,
  - economic developments
  - and national grid conditions.

• The present Chinese electricity market is the first level of competition
The Infrastructure of the Electricity Market
– The operation models of the electricity market

• An electricity market should include
  ➢ a real time energy market,
  ➢ a day-ahead energy market
  ➢ and a long-term energy market.

• The long-term energy trading can be conducted by means of contract and futures

• Types of contract
  ➢ physical contract
  ➢ financial contract

• Types of futures
  ➢ yearly futures,
  ➢ monthly futures,
  ➢ and weekly futures.

• Design of the electricity market model depends on
  ➢ economic rules of the market,
  ➢ technical characteristics of power systems.
The Infrastructure of the Electricity Market: Four operation models used in China

- **Real Time**
  - Day-Ahead
    - physical contract
  - Future
- **Real Time**
  - Day-Ahead
    - financial contract

**Partly Energy Bidding**

**Total Energy Bidding**
The Infrastructure of the Electricity Market: Four operation models used in Chinese

• The main difference between these four models is the type of long-term energy trading.

• Partly Energy Bidding: In Model 1 and Model 2, only 15%-20% of the total energy is traded through market bidding, and 80%-85% is traded by means of long-term contracts.

• Total Energy Bidding: In Model 3 and Model 4, all energy is traded through bidding.

• Model 1 and Model 2 were used in the first phase of deregulation in China.

• Model 3 and Model 4 are used in the current Chinese electricity markets and suitable for the wholesale competition and the retail competition.
The Infrastructure of the Electricity Market: A Notation in Three Dimensions

- The electricity market separated into different layers and areas, which includes the provincial, regional and national market;
- The operation models include operation model 1 to 4;
- The development level of the Chinese electricity market, includes generation, wholesale and retail competition.
Electricity Market Operation System in China

• The Electricity Market Operation System (EMOS): a control and management system for the operation of electricity market.

• The key issue for the design of the EMOS is that it should be suitable for the development of the three dimensional electricity markets.

• In the development of electricity markets, the key factor directly influencing the design of the electricity market operation system is the operation model.

• The basic idea of the electricity market operation system design is to adopt different layered components, such as core algorithms, application functions and subsystems, to build the electricity market operation system using suitable market models.

• The system designed is composed of some subsystems that meet different requirements without over-lapping each other. The subsystems can be loaded or unloaded according to the requirements of the market model.
Electricity Market Operation System in China

Attributes

- **Openness**: an open structure and functionally distributed system design.

- **Adaptability**: meeting the requirements of national, regional, provincial power markets.

- **Extendibility**: providing the development requirements of the electricity market and the smooth migration to a future competitive wholesale and retail market.

- **Real-time**: supporting real-time power trading and dispatching.

- **Security**: providing strict user management and ID verification, and firewall technology.
The Framework of the EMOS

Support Software

FTS
DATS
RTDS
MAF
SBS

Participants

SPD-NET

EMS
TMR
MIS

Interface

BPS
SIS
CMS
OMS
Support Software Platform
The Main Functions of the EMOS

- The Bidding Process System (BPS) receives and processes the bidding and re-bidding data from generating units, based on the latest bidding;
- The Day-Ahead Trade System (DATS) calculates the pre-dispatch schedules of generating units on the trading day per trading interval;
- The Same-time Information System (SIS) issues the latest information in the market;
- The Real Time Dispatch System (RTDS) calculates and issues real time dispatch command according to the latest bidding data of generating units;
- The Settlement and Billing System (SBS) settles all the income of the market participants by the market clearing price.
- Other subsystems: the Operation Management System (OMS), the Contract Management System (CMS), Market Analysis & Forecast System (MAF), and the Futures Trade System (FTS).
- EMOS is interfaced with EMS, TMR and MIS through interface software. The participants of the market bid or offer through SPD-Net.
Based on the above ideas, the Electricity Market Operation System only needs to install or uninstall the components of partial subsystems to adapt to the different market operational models.
It was decided that six pilot electricity markets were set up based on the competition of generation in 1998.

• In 1998, six provincial electricity corporations such as Shanghai, Zhejiang, Shandong, Liaoning, Jilin, and Heilongjiang were selected to establish provincial electricity markets based on generation side competition. In January 2000, these pilot electricity markets were put into business operations.

• Among the six pilot provincial electricity markets, the operation model of Zhejiang’s energy market using Model 3 consists of:
  - a real-time market,
  - a day-ahead market
  - and a long-term market

• The rest of the other five electricity markets using Model 1 only consist of:
  - a day-ahead market
  - and a long-term market.

• Features of Zhejiang Electricity Market:
  ➢ run by means of a spot market and financial contracts.
  ➢ The Market and System Operator (MSO) operated the spot market in which participants were governed by the rules and regulations for bidding, dispatching, market price and settlement.
  ➢ The model of “a Single Buyer and Contracts for Differences (CFD)” with all energy involved in bidding was applied in Zhejiang Electricity Market.

• The six pilot provincial electricity markets were all closed in 2003
In late 2002, in order to promote competition in the power industry and help integrate the fragmented provincial power market, the Chinese government broke up the State Power Corporation, the former electricity monopoly, into 11 generation, transmission and logistics corporations.
EMOS in Regional Electricity Market (2003-Present)

- In 2003, the SERC set a target for building two pilot regional electricity markets in Northeast China and East China.

- In 2004, the two regional electricity markets were put into pilot operation.

- In the two regional electricity markets, the competition is introduced in generation with a centrally operated transmission system.

- The models of the two pilot regional markets are using Model 2 and Model 3. These markets have only long-term trade in the first stage of the market development, and will gradually develop day-ahead trade and real time trade.
EMOS in Regional Electricity Market (2003-Present)
EMOS in Regional Electricity Market (2003-Present)

• The regional electricity market in East China is a common market.

• There were one regional market system operator and several provincial market system operators in the common market.

• 15%-20% of the total energy is traded through bidding in the regional electricity market.
  - A day-ahead market
  - A monthly futures market

• 80%-85% of the total energy is traded in the provincial electricity market by means of:
  - long term contracts
  - real-time balancing mechanisms
The EMOS in East China (2003-Present)

• The EMOS in East China includes:
  - the EMOS in regional MSO,
  - assistant EMOS in provincial MSO
  - and BIDDING terminal in IPPS
The EMOS in Northeast China Regional Electricity Market (2003-Present)

• The Unified Market in the regional electricity market in Northeast China
  
  ➢ Before July 2004, 20% of the total energy was traded through bidding in the regional electricity market, which consists of a real-time market, a day-ahead market and a monthly futures market, and 80% was traded by means of long-term contracts within provincial dispatch center.
  
  ➢ Under the supervision of the government, its operation model has been changed since 1st July 2004, 100% of the total energy is traded through bidding in the regional electricity market which consists of a real time market, a day-ahead market and a long-term market, 80% of the total energy is traded by means of yearly futures.
  
  ➢ The provincial dispatch centers receive the dispatch schedule of the generating units within its province and issue the dispatch commands to the generating units, ensuring the secure operation of the provincial power system.
Assistant EMOS in Provincial MSO

EMOS in Regional MSO

Real Time
Day-Ahead
Cont Fut
Model2

Northeast

Bidding Terminal in IPPS

EMOS in Regional MSO

Participants

EMS
TMR
MIS

SBS
FTS
CMS
Support Software
Platform

Participants

EMS
TMR
MIS

SBS
MAF
RTDS
DATS
FTS
OMS
CMS
SIS
BPS
Support Software
Platform
The EMOS in South China Electricity Market (2003-Present)

- The regional electricity market in South China has been building since 2005.
- The regional electricity market in South China is a common market.
- There are one regional market system operator and several provincial market system operators in the common market.
- At present, 15% of the total energy is traded through bidding in the regional electricity market, which consists of a monthly market and a yearly futures market, and 85% is traded by means of long-term contracts.
- Real time balancing mechanism is used in the provincial electricity market.
Future Development of Electricity Markets in China

• The Coordinated Operation of the Electricity Market in China

➢ The design objective of the national grid:
  ✓ fulfilling the requirements of power transmission from west to east and from north to south,
  ✓ removing the transmission bottle necks in economically developed areas,
  ✓ optimizing energy source distribution within larger areas,
  ✓ meeting the requirements of economic development, creating nationwide competitive energy markets.

➢ The national electricity market will optimize the utilization of energy sources within nationwide areas.

➢ The national ultra high voltage transmission grid will promote electricity trade between three different layers of the Chinese electricity markets, optimizing the utilization of energy sources within larger areas.
National Electricity Market

Regional EM A with lower price

Regional EM B with higher price

Price ($/MWh)

MW

MW

Pao

Pbo

buy

sale

buy

sale
National Electricity Market

Regional EM A with lower price

Regional EM B with higher price

Price ($/MWh)

MW

△Pab = Pbm - Pam

Pao

Pam

Price ($/MWh)

MW

Pbo

Pbm

buy

sale

buy

sale
Future Development of Electricity Markets in China

- **The Electricity Market for Tomorrow**
  - By 2010, the national ultra high voltage grid will be completed.
  - The structure of the electricity markets would be separated into three layers, such as national market, regional market and provincial market.
  - An even more competitive generating market will be fully established by 2010. The large consumers will be allowed to choose their own suppliers.
Future Development of Electricity Markets: Pilot three layer markets

National level

Regional level

Provincial level

National Market

Central China Market

East China Market

Hunan Provincial Market

Hubei Provincial Market

Put into operation by the end of this month
Conclusions

• The introduction of competition into a reformed power sector is a very complex process, depending on national energy strategies and policies, economic developments and national grid conditions, etc.

• This paper has discussed the structure, operation models and competition of the Chinese electricity markets.

• Electricity market models usually vary from country to country. Therefore, the operation models of the electricity market in China have been investigated.
Conclusions

• In line with the construction of an ultra high voltage transmission grid in China, the future structure of the electricity markets may be separated into three layers, such as national market, regional market and provincial market.

• In addition, the basic function and framework of the Electricity Market Operation System (EMOS) have been described. Furthermore, its applications in the first phase and second phase of deregulation in China have also been discussed.

• Finally, how the Chinese electricity market with three layers operates in different phases has been described. Then, the paper has summarized the development of the Chinese electricity market.
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