Comparison and Enlightenment of Foreign Electricity Market Operation Modes

Bowei Wu

The University of Hong Kong, Hong Kong 999077, China.

Abstract: The separation of the power grid and power plants, as well as bidding for the power grid, was the first wave of market-oriented reform in the power industry, which began in the late 1980s in Britain. The US, Europe, and other developed countries then developed various types of the electrical market in turn. Since the 1990s, China has been reforming the electricity market to choose the most appropriate operation mode. This paper makes some proposals for the existing operation modes of China's electricity market based on an analysis of the key operation modes of overseas markets.

Keywords: Electricity Market; Operation Mode; Transaction; Deregulation.

Introduction

For a long time, most countries have used vertical integration to operate monopolies in the power business. In today's globe, breaking monopolies, introducing competition and creating an open and competitive energy market have become an unavoidable tendency in the power industry's evolution. Power market operation mode is the basis of power market system construction and the main factor determining the success or failure of reform. It is related to the safe and stable operation of power grid, the development of national economy and social stability.

As a result, the focus of this paper will be on the structure and operation mode of the electricity market in the USA, UK and Northern Europe, as well as an exploration of China's power reform and development, to provide a useful reference for China's electricity market construction.

1. Basic operation mode of the electricity market

The operation modes of the electricity market are split into four types based on the degrees of competition and choice, including monopoly mode, purchasing agent mode (single buyer mode), wholesale competition mode, and retail competition mode.

1.1 Monopoly mode

Figure 2-1 depicts the first mode, which corresponds to the conventional monopoly of public utilities. The integration of power generation, transmission, and distribution is represented by sub-mode (a). Utility companies monopolize power generation and transmission and sell electricity to regional monopoly distribution companies in sub-mode (b). Bilateral energy transactions between utilities in different regions only occur at the wholesale level. Public utilities are vertically integrated into sub-mode (a), and the distribution business is run by one or more separate enterprises in sub-mode (b) [1].

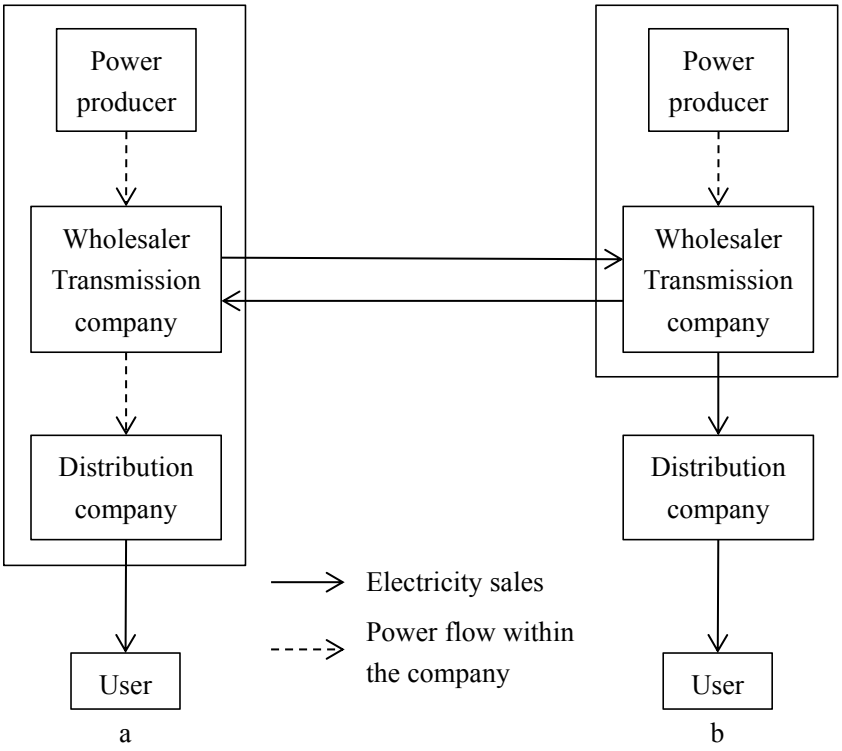

Figure 2-1 Monopoly mode

This monopoly form encourages the construction of major power plants and power grids, as well as the development of the power industry. However, as the power industry's scale economy becomes saturated, exposing the shortcomings of this monopoly mode, such as low investment efficiency, low economic efficiency, and low operating efficiency.

1.2 Purchasing agent mode (Single buyer mode)

The first development direction of introducing competition into the power business is seen in Figure 2-2 (a). Integrated utilities no longer have a monopoly on the system's whole generation capacity. As purchasing agents, independent power producers can connect directly to the power grid and sell electricity to utilities. Figure 2-2 (b) shows the evolution direction of this mode, that is, utilities no longer have any power generation, and all electric energy must be purchased from independent power producers. To meet the power consumption needs of their own users, distribution companies need to purchase electric energy from the purchase agent entity.

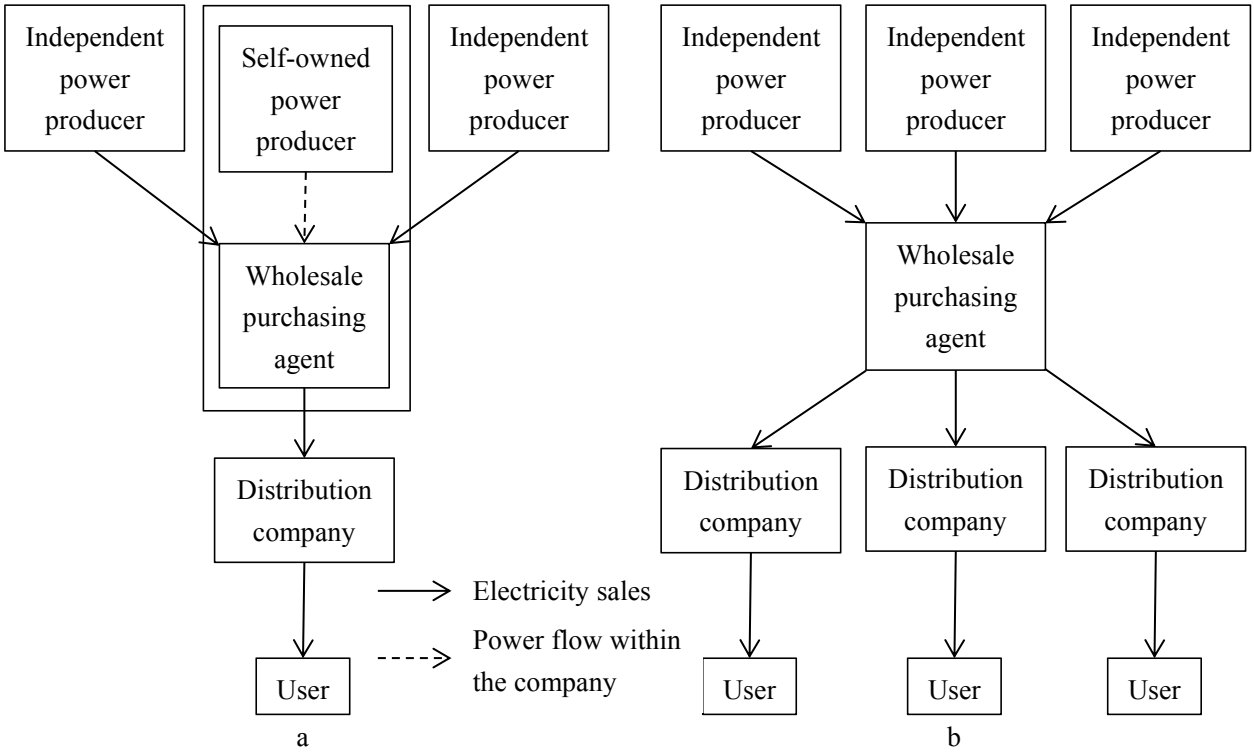

Figure 2-2 Purchasing agent mode

(a) Integrated form; (b) Decentralized form

In this mode, the market mechanism is initially introduced into the field of power generation, creating an equal competition environment for power generation. The power transmission, distribution, and sales systems, however, remain monopolized in this mode. The single buyer is the power grid corporation with the transmission and distribution system, which is the only power buyer and seller in the market.

1.3 Wholesale competition mode

There is no centralized body responsible for electricity supply under the wholesale competition mode, as indicated in Figure 2-3. To meet consumer demand for electricity, distribution companies purchase electricity directly from generators. The wholesale electricity market is where this type of electricity trading is most common. Large-scale users, in addition to distribution corporations, are permitted to purchase power directly on the wholesale market. There are two ways for distribution companies (or large users) and generators to participate in power market competition: power pool or bilateral transaction.

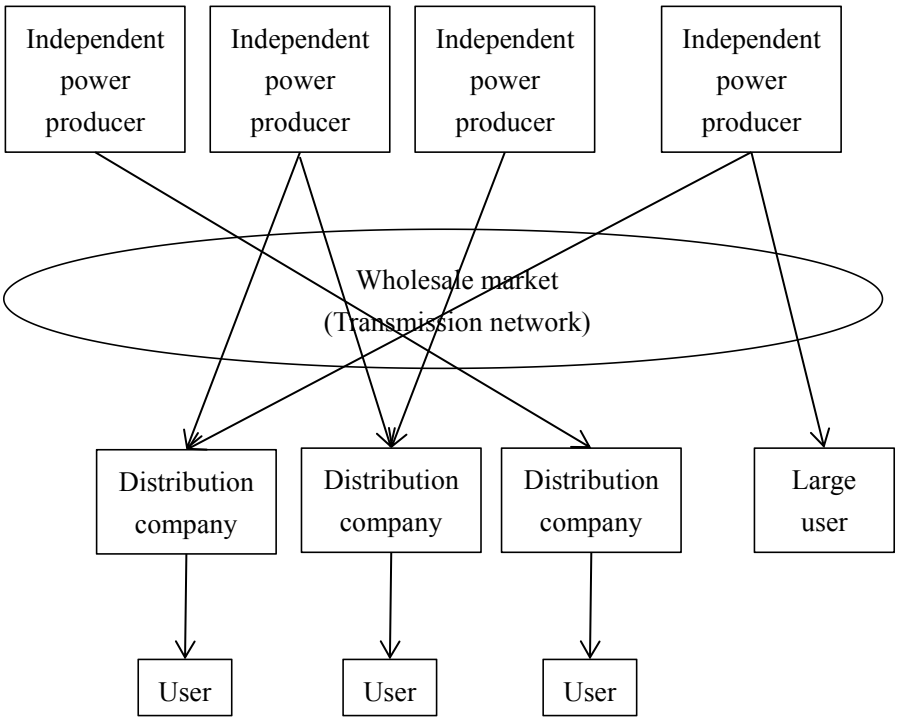

Figure 2-3 Wholesale competition mode

Compared with single buyer mode, transmission and distribution companies do not have to carry the price risk of the power generation market alone. Secondly, Power generation companies can compete based on their production capacity and cost, while distribution companies (or large users) can compete based on their demands. Then, electricity prices can accurately represent the cost of power generation as well as market supply and demand imbalances. This mode is more suited to the electrical market's stable operation and development [2].

1.4 Retail competition mode

Figure 2-4 shows the final form of a competitive electricity market, in which all users can choose their suppliers. Only large-scale users will choose to buy electricity directly in the wholesale market, while most small and medium-sized users will buy electricity from retailers, who will then buy electricity on their behalf in the wholesale market. The supply and operation of transmission and distribution network services are currently the only monopoly business in the energy market.

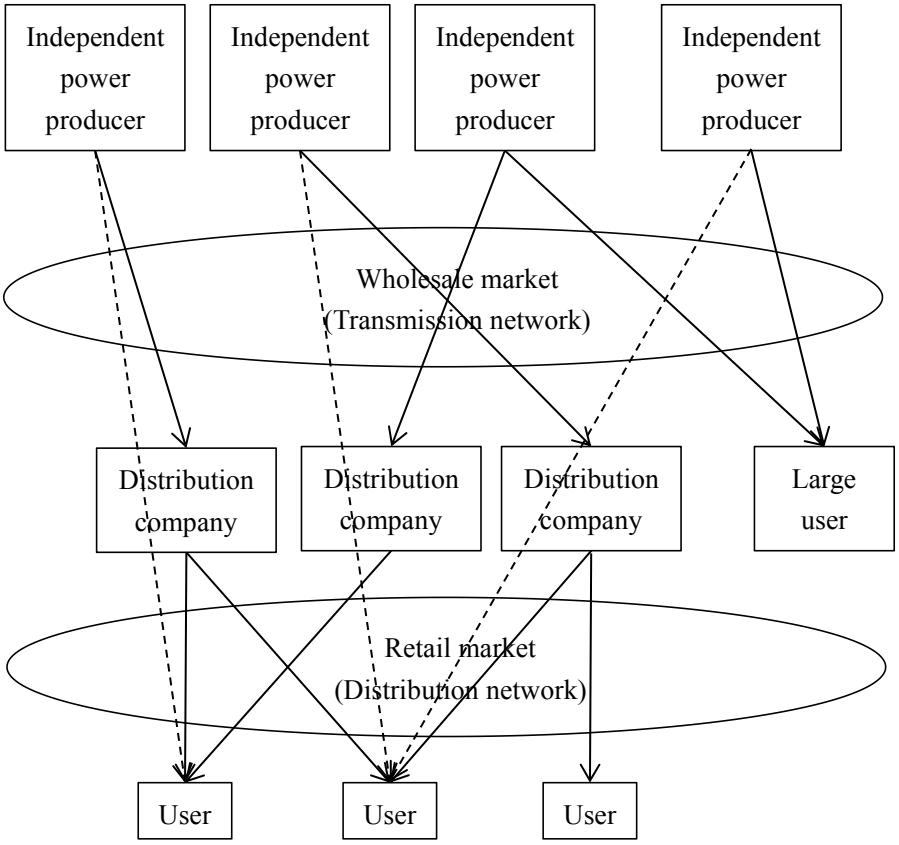

Figure 2-4 Retail competition mode

All types of users and power providers have a lot of options in the retail competitive electricity market. Participating in market competition as a group can raise the level of competition and resource optimization more efficiently. Secondly, Users have more options, the market rivalry is fiercer, and decision-making is more decentralized. Then, the power supply and demand balance are shared by both the supply and demand sides of the market transaction. It minimizes the difficulties of power grid operation and dispatching when compared to traditional, monopolistic, and other electricity market types [3].

2. Analysis on operation mode of foreign electricity market

2.1 California electricity market

California is one of the first states in the US to create a retail competitive energy market. The retail price of energy in the United States was high in 1995, prompting the California Utility Commission to create retail options. Also, investor-owned utilities (IOUs) were encouraged to sell a portion of their power-producing assets.

2.1.1 Electricity market structure

The California power market was formally launched on March 31, 1998. The goal was to create severe competition in the power supply, provide users the right to choose, develop a California independent system operator (ISO) and power exchange (PX), and provide power trade via the real-time market, bilateral trade, and contract for difference. Figure 3-1 depicts the specific structure.

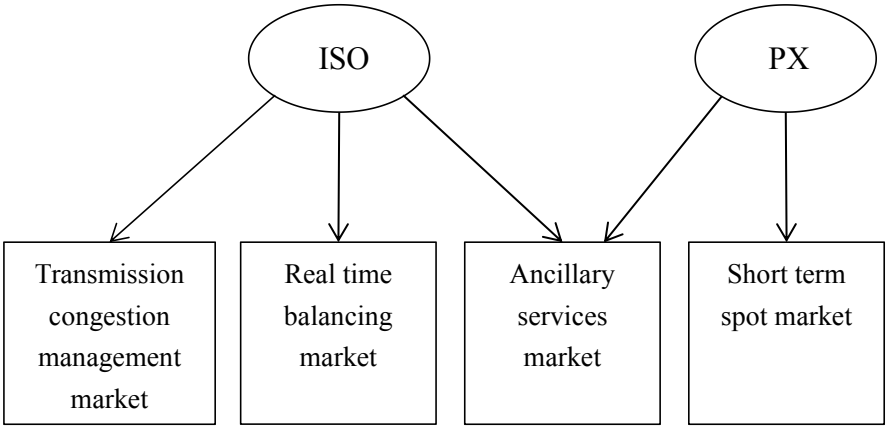

Figure 3-1 Simple structure of California electricity market

Plants, Power Exchanges (PXs), Scheduling Coordinators (SCs), Independent System Operators (ISOs), distribution corporations, merchants, and consumers are among the participants. ISO is in charge of dispatching, power grid operation, transmission services, and congestion management, as well as procuring and offering auxiliary services and balancing the power grid's real-time supply and demand through a real-time market. It is responsible for three major markets: competitive auxiliary services procurement, real-time energy, and bulk futures. PX is a non-profit organization that offers energy trading venues, primarily the market for the next 24 hours and one hour, as well as bilateral and cross-market trade. PX is a type of SC that must also submit the final confirmed transaction to ISO for approval. To avoid network congestion, ISO can change these transactions as needed. PX creates and submits a trading strategy to ISO, which serves as the foundation for ISO's power grid coordination [4].

Figure 3-2 depicts the present power market structure in California. The power trading center allows all market participants to trade electricity futures, including power producers, retailers, and middlemen. Contracts between scheduling coordination companies can also be signed on a bilateral basis. Through the power trading center or its planning and coordination business, all market players must submit their energy plans and quotations to California ISO. California ISO executes inter-regional congestion management by dispatching and revising energy bids days and hours ago, according to all submitted energy plans and quotations. Before the day and hour, ISO must also purchase a set quantity of various auxiliary services to ensure the system's safe and stable operation. In real-time operation, ISO balances the system's energy supply and demand by deploying supplemental energy bidding and the energy of auxiliary service units [5].

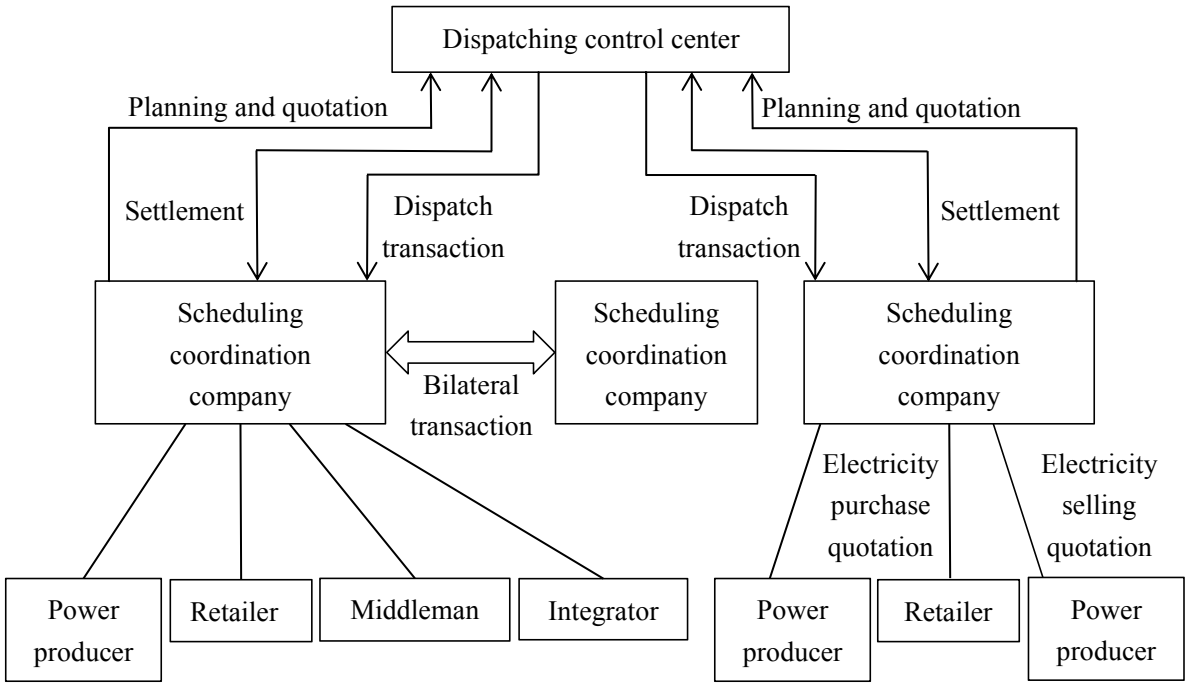

Figure 3-2 California electricity market structure

2.1.2 California power crisis

The electricity crisis in California drew worldwide attention from 2000 to 2001. The main manifestation of California's power crisis is the sharp rise in wholesale on grid electricity prices. In 2000, the total cost of wholesale electricity to meet the load increased by nearly four times, so the wholesale on grid electricity price also soared. California's electrical companies were severely in debt by the end of the summer of 2000. Furthermore, the reliability of electric power was deteriorating. In 2001, there were 36 level III emergencies in the independent system operation organization, resulting in many consecutive power outages to ensure the balance between supply and demand [6].

There are many reasons for the power crisis in California. The superficial reason is the serious power shortage, and the deep reason is the mistakes of California's power reform planning and rules. The mistakes of market planning are as follows:

(1) The misalignment between wholesale price liberalization and retail price control.

(2) Electricity trading laws were not designed to account for variations in electricity supply and demand, making it difficult to deal with rapid increases in electricity consumption.

(3) Because long-term power purchase contracts were prohibited by energy legislation and market rules, distribution businesses were forced to rely on the volatile real-time market when power was scarce, limiting their ability to withstand risks.

(4) Demand was inelastic because of the fixed price.

2.1.3 Brief review

The California power crisis is inevitable, manifested in the irrationality of its market model design, specifically manifested in the serious imbalance of the competition mechanism and risk distribution mechanism, the one-sided pursuit of the completeness of competition in the market model and the exquisite and complex structure of the market model, ignoring the basic risks Distribution mechanism.

Most countries start with the restricted competition generation side centralized trading mode in the power market operation mode, which necessitates the construction of both a competition and a risk distribution mechanism at the same time. Simultaneously, we should strengthen the massive user involvement and demand-side response mechanisms, as well as steadily increase the proportion of users who participate. Furthermore, we should gradually integrate decentralized bilateral

or multilateral transactions outside of the centralized market, so that the power market can develop into a target mode with both centralized optimization and free choice benefits.

2.2 UK electricity market

The British electric power industry began to restructure in the early 1990s. Its distinguishing trait was that market-oriented reform and privatization reform are carried out simultaneously.

2.2.1 Reform process of the power industry

2.2.1.1 Stage Ⅰ: privatization and deregulation

On March 31, 1990, England and Wales formed a national power supply company composed of three power generation companies, 12 regional distribution companies and one high-voltage transmission company, while Scotland formed two vertically integrated companies of power generation, transmission and distribution and one Scottish nuclear power company. In addition, 12 state-owned distribution enterprises were transferred to the private sector to modernize market access regulation.

The reform of the power grid is through the listing and sale of the state-owned equity of the power grid company. National Grid Company (NGC) was placed on the stock exchange in 1991, and 60% of the state-owned shares were sold. NGC's remaining state-owned shares were sold in 1995. Although the transmission network retained its monopoly status, the introduction of private capital improved management. Particularly, the grid company did not own a power plant, allowing each power generation company to compete fairly and freely (as shown in Figure 3-3).

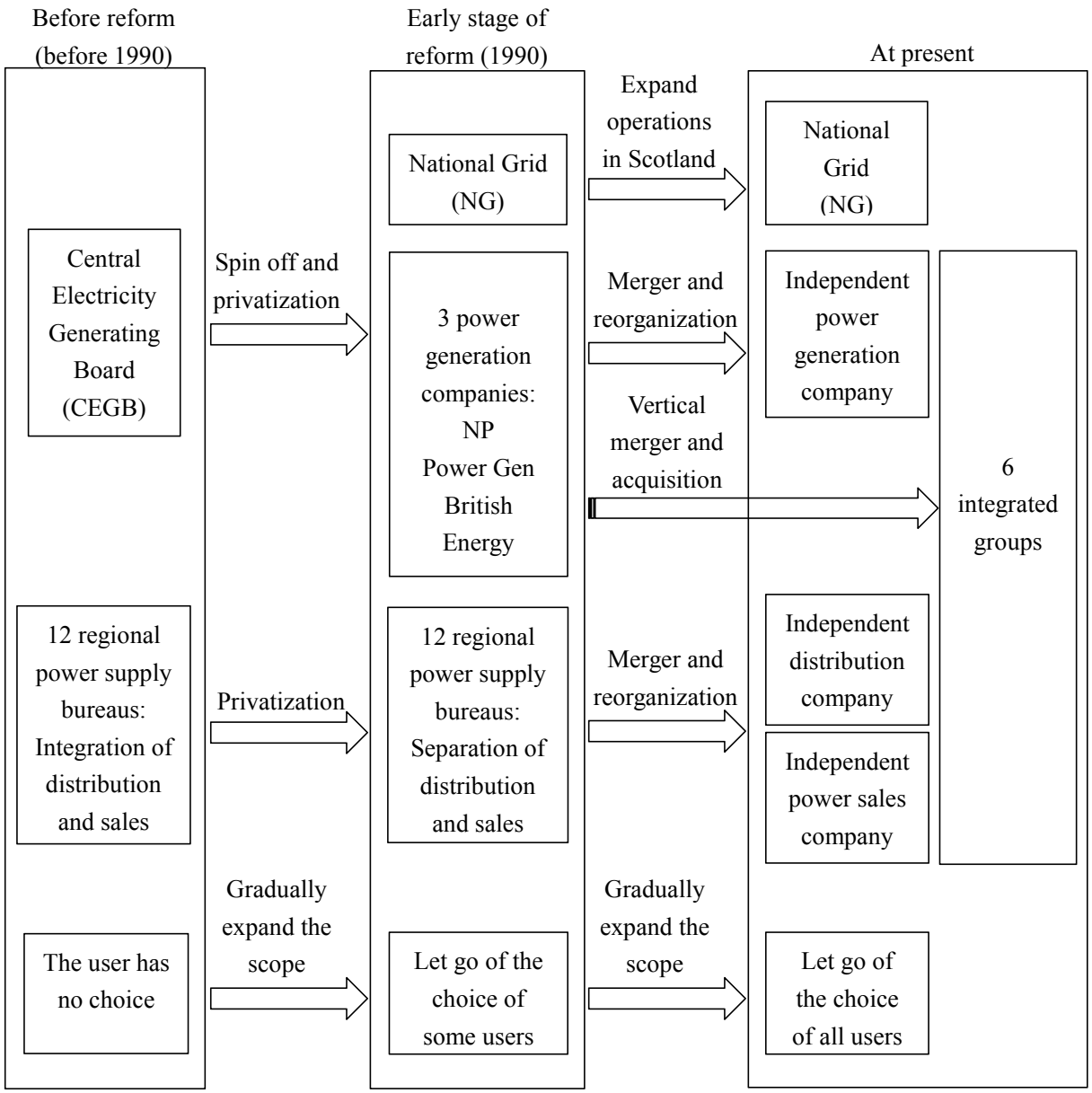

Figure 3-3 Organizational structure of the UK electricity industry

2.2.1.2 Stage Ⅱ: price regulation relaxation and three types of operation modes

Deregulation of the electric power business was accomplished in two ways. The first step was to recognize the user's right to select the generator. The second step was to create a power trading market operation mode. Three separate market operation modes, POOL, NETA, and BETTA, have gradually emerged as a result of the reform process.

2.2.2 Electricity market operation mode

The British electricity market mechanism was established in two stages: POOL from 1990 to 2001 and NETA from 2001 to the present. Scotland was mostly integrated into the British electricity market when BETTA was implemented in April

2005.

2.2.2.1 POOL mode

POOL mode is the first time a free power trading wholesale market has been established. Power producers sell electricity to the power pool, power suppliers buy electricity from the power pool. Power grid companies are responsible for the daily management of the power pool. The power output and operation time of each unit will be determined based on each power generation company's quotation.

Power pool, as the spot market for electric power, serves as a central hub for all-electric power transactions. Licensed generating units sell electricity to the power pool via competitive bidding, and all power supply firms buy electricity from the power pool at the system's unified price. NGC is in charge of power generation quotations, market power generation plans, and real-time dispatching. NGC is also in charge of market settlement and capital turnover. Figure 3-4 depicts the power pool architecture. Contract for difference market, a day-ahead market, dispatch market, power pool settlement, and contract for difference settlement are all part of it.

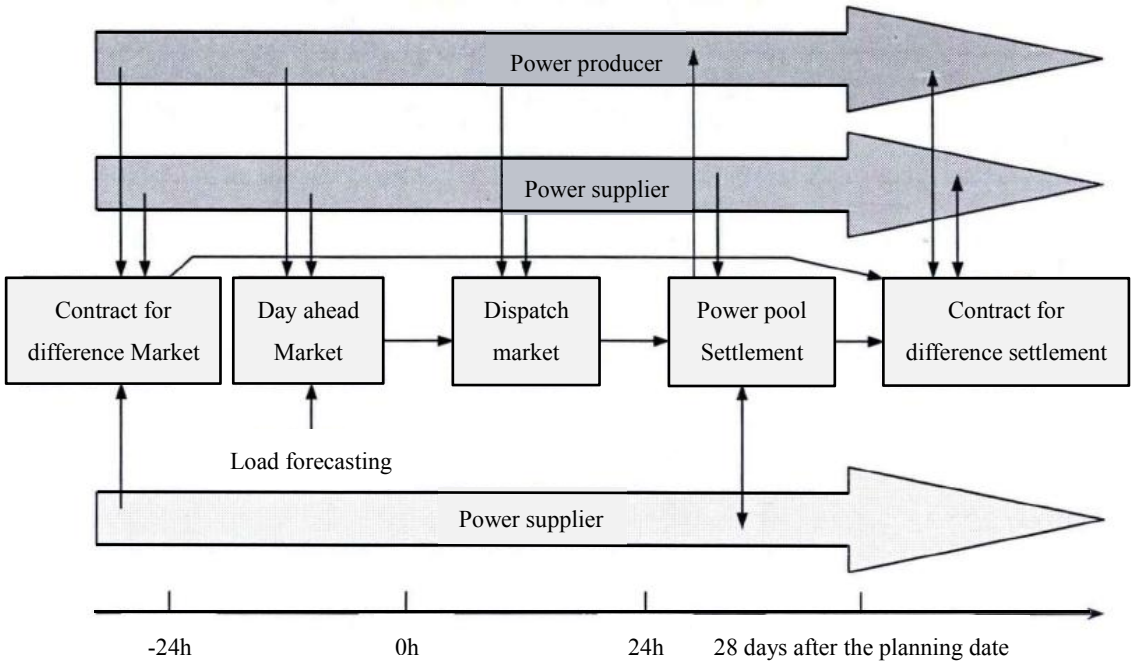

Figure 3-4 POOL mode of UK electricity market

The Contract for Difference (CFD) is a commercial contract signed privately by the power generation and power supply companies outside the power joint venture. The day ahead market operates on the day before operation. The generator makes a quotation to NGC in the day ahead market. NGC determines the system marginal price and the purchase or sale price of the joint venture according to the quotation. Data gathering, preliminary settlement, inquiry, final settlement, and bank transfer are all part of the power pool settlement process, which is usually completed within 28 days of market operation [7].

2.2.2.2 NETA mode

On March 27, 2001, the first phase of the NETA went into effect. The basis of NETA is a bilateral trade market in which electricity producers, suppliers, middlemen, and users all participate voluntarily. It is mostly made up of the following elements: forward contract market, related derivatives markets, short-term two-sided market, and balanced market.

In contrast to POOL mode, bilateral transactions can be conducted face to face or at any Power Exchange Center (PX). The transaction's number, manner, timing, and location are all versatile and convenient. Market participants have more

autonomy, a simpler quotation form, a more transparent energy price, and closer proximity to real-time electricity trading, resulting in more stable power grid operation. This method of power market transaction is more efficient and that the price mechanism can be more effective. However, the power regulatory authorities always require the power sector to reduce costs, and the safety problem has been ignored.

2.2.2.3 BETTA mode

Scotland's electricity reform process was very slow. Scottish Electricity Company, Scottish and Southern Energy Company, and British Energy Company continued to monopolize the majority of the power generation market. Therefore, OFGEM published a study in December 2001 recommending a fresh reform idea. It would extend NETA from England and Wales to the entire British region by changing the energy market in Scotland, resulting in a unified British Electricity Trading and Transmission Arrangement (BETTA) [8].

BETTA increases competition in the whole British wholesale electricity market, particularly in Scotland. A market participant can enter into a commercial contract to purchase and sell electricity with another market participant anywhere in the UK. Scottish energy suppliers may be able to purchase electricity on behalf of their consumers in a larger, more liquid, and competitive wholesale electricity market.

2.2.3 Brief review

POOL mode, which was first adopted in the British electricity market, took the lead in introducing competition into the power industry system. The operation, however, has several flaws: First, the mandated power pool membership scheme stifles internal reform and innovation. Second, the stages of power pool quotation and price setting are overly complicated, making it difficult for power producers to develop effective competition. Third, the demand side's participation is limited by the power pool, and pricing is a result of a lack of competition.

NETA and BETTA modes are better than POOL mode: First, the market is more open, and competition has spread beyond power producers to all elements of power generation. Second, the market structure is straightforward, and the transaction is more adaptable. The quotation form is simpler than the pool, and the price transparency is higher. Third, market players' autonomy and choice have been enhanced, and the two parties willingly consummate the transaction in the form of a contract at the agreed-upon price. Fourth, the market allows demand-side participants to fully participate.

2.3 Nordic electricity market

The Nordic electrical market concept is slowly gaining traction. Nord Pool was founded in May 1992 and began trading in 1993. In January 1996, Sweden was the first to join, and the two countries formed the Norway Sweden United Power Exchange. Finland joined in June 1998, and the EL-EX exchange was jointly owned by the State Grid Corporation of Sweden and the State Grid Corporation of Finland. Western Denmark became a member in July 1999, followed by Eastern Denmark in October 2000.

The Nordic Power Trading Center is the world's first transnational power trading center, providing a trading platform for participants in the Nordic power market. The Nordic electricity trading center conducts organized electricity trading and settles on-site and off-site electricity trading using standard commodities. It also preserves neutrality and treats all market players equally, ensures transaction transparency, and publishes the transaction price and quantity of electricity.

Nordic power market organizers include Nordic power exchange and grid companies of Norway, Sweden, Denmark and Finland. Futures and spot electricity trading are not conducted by power grid providers in many nations. Power corporations, as market participants, do not isolate power plants from power grids. They can have power transmission and distribution networks as well as power plants operating at the same time and supplying electricity to users. Users have complete control over which power companies they use. Power contracts are available for purchase on the open market [9].

The Nordic electricity market also has cross regional energy transactions with Russia, Poland and Germany. This transaction mode has certain reference significance for the establishment of regional power market in China.

3. Enlightenment of foreign electricity market operation modes to China

3.1 Marketization process of China's power system

In 2002, the State Council produced Document No. 5, proposing the separation of power plants and power grids, and the reorganization of state-owned power assets. In 2015, the CPC Central Committee and the State Council produced Document No. 9, signaling the start of a new era of power reform in China. The new power reform has carried out work in terms of transmission and distribution price reform, electricity market construction, establishment and standardized operation of power trading institutions, orderly development of power consumption plan, and electricity sale side reforestation. In 2017, the National Energy Administration selected the Guangdong, Mengxi, Zhejiang and other places as the first batch of pilot projects for the construction of power spot market, and began the exploration of spot market [10].

3.2 Structure and operation mode of China’s electricity market

China has six regional grids and one independent grid. The current market structure suitable for China's national conditions should be: the regional and electricity markets should be established first, within the framework of hierarchical division, to realize the planning, operation, and resource allocation of the cross-regional power grid. The provincial electricity market should next be built and improved. Finally, the unified power wholesale market and local retail market have progressively formed a shared development pattern.

The optimal mode is to construct the following four operating entities: Independent Power Producers (IPPs), Grid Company (GC), System Operator (SO), and Power Exchange (PX). The establishment of independent power producer IPPs is to meet the needs of power generation link and power generation side bidding, break monopoly in production link, introduce competition and become an open mode of power generation side. The integration of SO and GC is based on the formation of the power generation market, breaking the monopoly in the transmission link, and introducing competition. Finally, PX is established on this basis to break the monopoly in the sales link and introduce competition to form an open mode of distribution network.

The regional energy market's operation center will be the hub for regional power system planning, grid dispatching, and market transaction settlement, including cross-provincial interconnection lines and ultra-high voltage trunk lines in the region. This market mode is simple in level and distinct in structure, by the grid's operation law, has a large-scale electricity market pattern, and the provincial electricity market has a good material foundation and organizational structure, all of which contribute to the market's stability and security. As a result, establishing numerous regional electricity markets based on China's original six regional power grids is appropriate.

3.4 Enlightenment for the construction of China's electricity market

Although China has made significant progress in recent years in terms of energy supply policy and power system reform, there are still certain flaws. The following suggestions are made to improve the operating mechanism of China's electricity market, based on the construction and operation experience of foreign energy markets:

(1) Pay attention to the planning of trans provincial transportation channels. Due to transmission channel capacity limitations, the EU regional linked tariff mechanism is not fully realized, while some transmission channel projects in China will not be able to reach the specified transmission capacity after completion. Long-term dynamic optimization should be carried out in the transmission project planning under the premise of safety, taking into account the future impact of supply and demand relationships and capacity structure.

(2) Remove trade obstacles between provinces. Compared with foreign successful regional power markets, such as Nordic power market, the differences in delivery mode, transaction frequency and openness of markets among Chinese provinces, as well as the intervention of local governments in the market, all increase the difficulty of regional market coordination and optimization.

(3) Enhance the ability to estimate total energy output, improve new energy prediction accuracy in the medium and

long term. Accurate production forecasts are beneficial not only to the power grid's scientific operation plan and accurate price prediction, but also to power generation companies' ability to exploit the cost advantages of new energy, compensate for the uncertainty of new energy through technology, and increase new energy's market competitiveness.

(4) Improve the market information disclosure method. The US, UK, and other nations have websites that allow users to query the electricity market's real-time price, and their trading centers and regulatory authorities also issue market analysis reports to the public every quarter and year. Information transparency aids in reducing information disparities between the participants, improving market efficiency and fairness, and providing a database for power market research.

(5) Continue to explore the real power market. Users in the UK, the US and other countries can freely choose the power consumption schemes provided by different electricity sellers. In China, due to the complex power grid system structure, the weak market awareness of participants and other factors, there are still many obstacles in the process of promoting marketization. Deepening reform requires a multi-pronged approach to encourage compatible market mechanism design, clear division of functions and powerful regulatory institutions, release both development and sales sides, and give market subjects more choices and freedoms [11].

4. Summary

Different countries and regions have chosen different reform processes and market models during the building of electricity markets in diverse countries, with both successful and unpleasant lessons learned. Based on the experience of the United States, Europe, and other developed countries or regions, the choice of market mode should be integrated with the country's or region's political economy, resource endowment, network architecture, and other basic national conditions, and market construction ideas should be dynamically adjusted.

China is a developing market economy, which means that the market mechanism isn't perfect, the degree of economic development in different regions is exceedingly uneven, and the formation of China's electrical market is more complicated. The construction of China's power market needs to fully respect China's development stage and actual national conditions, and gradually explore the construction of a unified, open, competitive and orderly China's power market system.

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