The Inspiration of the Expansion History of the European Integrated Market for Electricity for China

Qiuyang Ma[1a] , Jing Liu[2b] ,Zhongyang Chen[2c],Bin Han[3d], Zhi Cai[3e]

[a]qiuyangma22@sina.com,[b]443956240@qq.com,[c]1246477100@qq.com,[d]hanbin2010@epri.sgcc.com.cn, [e]caizhi2010@epri.sgcc.com.cn

[1]Corporate and Strategy Research Centre, State Grid Energy Research Institute, Beijing, China,
[2]Urban Energy Internet Research Center, State Grid Shanghai Electric Power Research Institute, Shanghai, China
[3]Laboratory of Power Dispatching Automation Technology China Electric Power Research Institute, Beijing, China

Abstract. The construction and expansion history of the European integrated energy market is similar to the situation faced by China's electricity market establishment. This paper summarized the experience from the European market as well as the special practices in the market operation, to provide insight and opinions for China. There are three main inspirations: 1) China should establish the unified national electricity market from simple to complex; 2) the unified electricity market should be more inclusive, to allow local markets still retain the special characteristics of their own market transactions; 3) The Chinese power market should further enrich the multi-time scale trading varieties, establish a more flexible medium- and long-term market, and expand the coverage of the spot market.

Keywords: Market design, European Internal Market, Chinese national unified electricity market

1. Introduction

Since the implementation of the "Opinions on Further Deepening the Reform of Electricity System" (No. 9 of 2015), the construction of China's electricity market has steadily advanced, and the two-tier operation market framework has been basically established, and the market mechanisms have been improved in practice.

At present, a new round of electricity market reform in China has been launched, which aims to emphasis the commodity attributes of electricity by establishing a competitive market. In order to better implement the various reform tasks, the Chinese power market not only needs to learn from foreign energy market designs, but also needs to consider China's current conditions[1,2]. There are three main characteristics. The first is the reversal distribution of China's energy supply and demand. The second is the need for a wide range of renewable energy absorption due to the increase of renewable energy. The third feature is the urgent energy transition targets and the achievement of the "carbon peak, carbon neutral" goal.

MSEA 2023, May 26-28, Nanjing, People's Republic of China

DOI 10.4108/eai.26-5-2023.2334235

1.1 The process of the extension of SDAC

SDAC is an initiative between the Transmission System Operators (TSOs) and the Nominated Electricity Market Operators (NEMOs). Through the SDAC market, the cross-border trading across Europe via implicit auctions can be implemented and the power could be delivered for the next following day[3].

Due to the early implementation initiatives and pilot projects, the SDAC initiative has achieved significant progress in extension. The Multi Regional Coupling (MRC) and the 4M Market Coupling (4M MC) are the two parallel coupling markets which rely on the Price Coupling of Regions (PCR) (PCR) solution.

From the prototype of a five Nordic countries cross-border trading market in 1990 to an integrated market coupling with 28 European countries in 2021, the development and expansion of SDAC market can be divided into three main phases, just as Table 1 shown below[4].

Table 1: The big issues during the development of EU unified integrated energy market

Phases	Year	Big issues	Related Countries
Phase I: Initial Pilot	2000	Nord Pool,the world's first cross-border power market has been established	Five Nordic countries (Denmark, Finland, Norway, Iceland and Sweden)
Phase 2: Extensive interconnection	2006	The SDAC market of electricity was launched	France, Belgium and the Netherlands
	2010	the coupling of the day-ahead market in Central and Western Europe was completed	Mainly including Germany, France and the Benelux region.
Phase 3: Formal launch of the EU unified integrated energy market	2014	the EU launched the road map of the construction of the unified integrated energy market	

In 2014, the EU launched the road map of the construction of the unified integrated energy market. The construction and expansion process of the SDAC market has been illustrated in Figure 1.

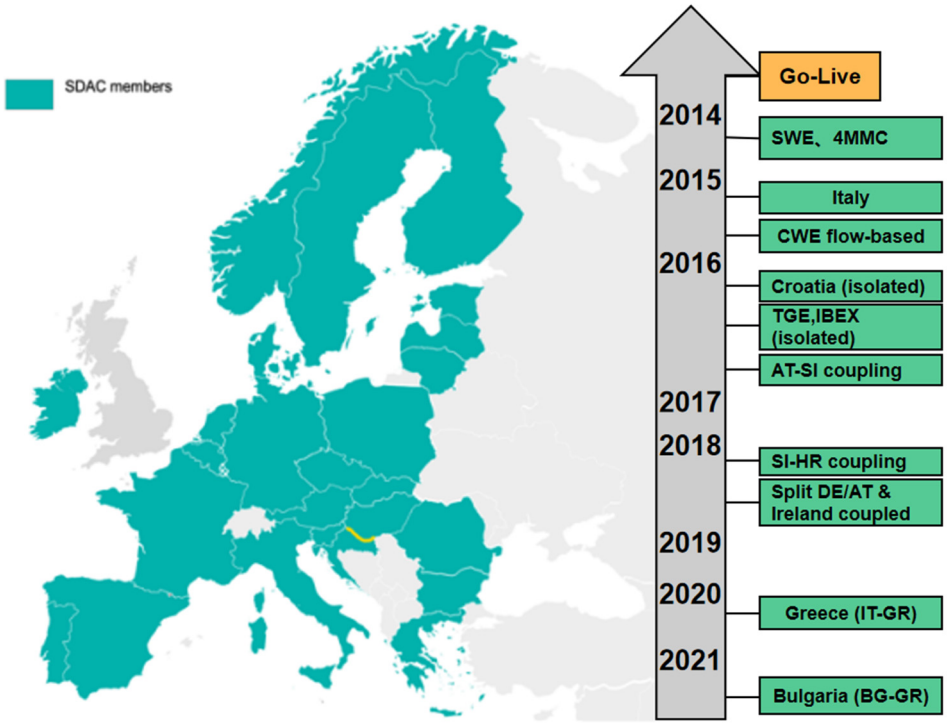

Fig. 1. The construction and expansion process of the SDAC market

1.2 Single Day-ahead Coupling (SDAC) function

The European integrated market is coupled through the implementation of PCR. Each market member bidding to its own exchange center, and the clearing price of each price zone is formed through the centralized coupling market in each region, thus breaking the geographical limitation of power trading, and the energy generators and users in different regions can be matched without barriers, thus realizing the optimal allocation of resources in a larger market[4].

At the same time, SDAC calculates the optimal energy allocation of all available power resources within the coupling range by considering constraints such as system power balance, transmission capacity limits of transmission lines with the goal of maximizing social welfare through Euphemia algorithm to maximize the overall welfare.

Ultimately, market players make decentralized decisions and execute them based on the trading results according to their own conditions, independently determine the on/off mode, daily generation curve, power consumption curve, etc., and assume Ultimately, market players make decentralized decisions and execute them based on the trading results according to their own conditions, independently determine the on/off mode, daily generation curve, power consumption curve, etc., and assume corresponding self-balancing responsibilities, making SDAC's electricity and energy trading more market liquid and flexible.

1.3 Transaction Organization Process in SDAC

The basic principle of the SDAC market can be summarized as follows: each market member submits its own offer, and the Available Transmission Capacity (ATC) of the cross-border transmission line is used as a constraint for market clearing optimization to calculate the traded electricity and price of each market member [5]. The coupling steps of the SDAC market include the following four steps.

1.3.1 Market bidding phase: SDAC started bidding in the morning of the day before operation (D-1), and TSOs of each country calculated the ATC for each price zone and submitted to the market coupling system [6,7]. Since the market was conducted based on medium- and long-term contracts, TSOs need to consider the results of the auction of physical transmission rights displayed in the medium- and long-term market as well as the limitation of each transmission line. All the biddings are submitted to the exchange center in each country, then all the bidding will be uploaded to the market coupling mechanism by the exchange center.

1.3.2 The first market clearing: The SDAC rotating power trading agency is responsible for SDAC market clearing based on the ATC situation. In this way, the transactions and its clearing prices, the capacity allocation for every transmission line contacted in each price zone can be figured out. However, since the price limit requirements are different among countries, the market will be opened again for 10 minutes after the first release of the clearing results, to allow market participants who exceed the price threshold to adjust the biding information.

1.3.3 The second market clearing: After each market player adjusts their biding information according to the primary clearing result, SDAC releases the second clearing result at around 12:55. Then, the platform forwards the clearing results to all power exchange centers of each country to confirm with TSO.

1.3.4 Market clearing result execution: Eventually, each market player needs to make decentralized decisions based on the final clearing result and arrange to make their own cross-border trading plans and submit them to the relevant TSO.

2 The Development Process of the SIDC Market

As the share of installed intermittent renewable energy sources increases, it becomes increasingly difficult to secure the energy system balance through the day-ahead market alone. The incremental demand for intra-day market transactions continues to grow.

The SIDC market aims to create a single EU intra-day electricity market that enables market participants to trade continuous intra-day electricity across Europe.

The SIDC program started on June, 2018, with 15 countries coupled together and more than 25 million transactions were completed in the relevant countries during the following 16 months. Then, from November 2019 to September 2021, additional 8 countries has join the SIDC market coupling. Nowadays, there are total 24 countries in Europe are coupled and clearing together in the intra-day energy spot market [8].

Figure 2 illustrates the geographical expansions of the 1st, 2nd and 3ed SIDC Go-Live as well as the fourth Go-live countries that will enter the intra-day coupling market by the end of 2022. The coupling scope will be further expanded in the next step.

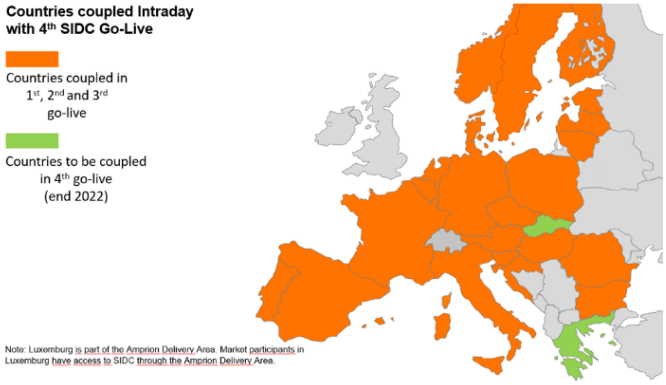

Fig. 2. The expansions for SIDC market

3 State-Quo and Challenges of Chinese Power Market

3.1 Development Path of China Power Market

As we see from Figure 3, the reform started in the 1980s, China firstly introduced investment into the power generation sector, then established the State Power Corporation of China by separating the power-related business from the government. In 2002, the corporation re-structured into 2 power companies, which are SGCC and the China Southern Power Grid Company, 5 main generators and 4 complementing industry companies.

The new round of power sector reform in China began in 2015, marked by the publication of the "Several Opinions of the CPC (Communist Party of China) Central Committee and the State Council on Further Deepening the Reform of the Electric Power System" (No. 9 Document). This main document focused on establishing and improving the power market mechanisms, building a fair-open and competitive market, which can allocate energy resources in the most efficient way.

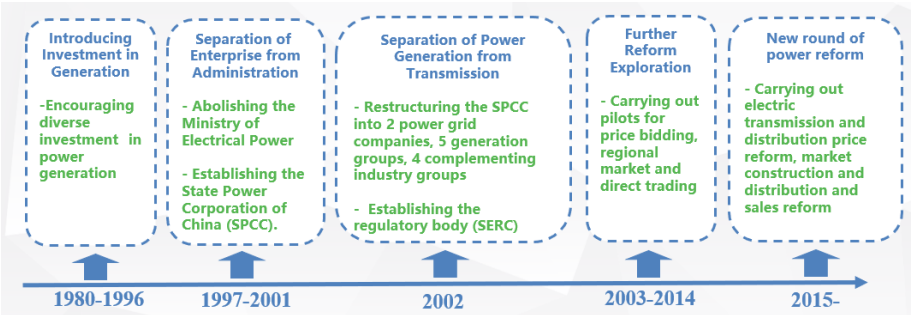

Fig. 3. The development process of Chinese electricity market reform.

3.2 Construction Conditions of Chinese Power Market

To gain a better understanding of Chinese power market, this sector will introduce some basic conditions of China.

3.2.1 The reverse distribution of resources and demand: The first characteristic of the Chinese power market is the reverse distribution of the energy resources and the main demand. The wind and solar resources are mostly located in the Northwest, Northeast and North China areas, far away from load centers in Central and East China, which determines that energy resources should be optimally distributed within the entire country. The reverse distribution of energy resources and loads drives the demand for allocating resources in a wide range.

Also for this reason, China puts lots of effort into the establishment of the Ultra High Voltage (UHV) power grid. The robust grid structure has largely supported the transmission from the provincial local balancing to the whole grid balancing which on a larger land scale.

3.2.2 The differences between provinces become larger: In traditional way, due to the economic development structure with provinces as the basic unit in China, the power system balance is mainly based on the intra-provincial balance. However, with the increasing growth of renewable energy, the power installation structure in many provinces has changed. By analyzing the performance of the grid in the 2021 year, Sichuan, Xinjiang and Shanxi provinces are the main exporting provinces. The highest exported power accounted for 191.9% of their provincial demand. On the contrary, Beijing, Shanghai and Tianjin are the typical importing grids. The highest import power accounted for 87.3% of their demand. In this way, the basic condition of the local energy system in each province becomes different. With the fact as above mentioned, it is much more difficult to remain the system balancing within a province. The need for larger scale balancing has become more prominent.

3.2.3 With high penetration of renewable energy, but thermal power still be the main generation: By the end of 2021, the installed power generation capacity in China was 2.38 billion KW with an increasing rate of 7.9% over the same period last year. Just as the Fig.4 demonstrated, the installed capacity of renewable energy generation is 0.63 billion KW, accounting for 26.5% of the total installed capacity, which increase18.7 % than the previous year. In terms of classification, 1.11billion KW of thermal power, 0.39 billion KW of hydro-power, 0.33 billion KW of wind power,0.31 billion KW of photovoltaic power, 50 million KW of nuclear power and 0.19 billion KW of other generation sources. However, the thermal power still the main generation of China, which accounts for nearly 50% of the total capacity.

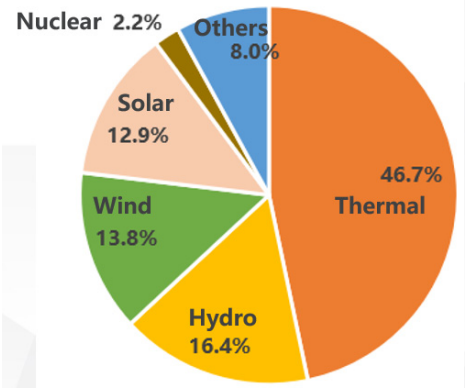

Fig. 4. The installed capacity of different energy resources in 2021.

3.3 State quo of China power market

The structure of China's two-tier electricity market system has been formed.

The upper tier is the inter-provincial market, whose objective is to promote resource allocation and the consumption of renewable energy in a wide range according to national energy strategy. Including cross-regional spot trading of renewable energy, direct trading of electricity, contract trading, pre-listing trading and ancillary services.

The second tier is each provincial market. Its goal is balancing electricity supply and demand and guaranteeing the safe and reliable operation of the power system. Including medium and long term trading, direct power trading, power generation right trading, spot trading and ancillary services.

3.4 Challenges of China power market

Achieving the “Carbon Peak and Carbon Neutrality” has become China’s national strategy, which will guide China’s energy transition for a long period. However, there are only 30 years for China to reduce emissions from the peak level to carbon neutralization, making it a really tough task.

The emission of the power sector is the highest one in China which accounts for about 41% of the total emission caused by fossil combustion. In the future, with more and more industries turning to using electricity instead of fossil energy, the emissions in the power sector will be increasing. Therefore, the dual-carbon target will promote fossil energy substitution and speed up the development of renewable energy, but meanwhile, introduce significant challenges in the power industry.

4 The Inspiration of the EU’s integrated Market to China’s Electricity Market

The uneven distribution of energy resources and the urgent need for energy system cleaning transition are the two similarities between the EU and China’s power market. Therefore, the

development of EU unified integrated electricity market is valuable to investigate. The experience of EU market construction has enormous significance and inspiration for China.

4.1 Build an inclusive market to meet the requirements for different provincial situations

Second, the EU unified electricity market is more inclusive, and individual countries still retain the special characteristics of their own market transactions when integrating into the cross-country coupling market. For example, in the SDAC market, each country is allowed to retain its own market price limitation and give market players the second opportunity to adjust the bidding information through the secondary market clearing mechanism. In the intra-day coupling market, a 60-minute intra-day coupling auction was set up for Switzerland and Italy, and a 15-minute auction was set up for Germany to promote the consumption of new energy.

China's province-based economic structure is difficult to change. In order to better build a national unified electricity market, some special mechanisms can be introduced in the unified market in order to meet the requirements for different provincial actual situations [9]. Therefore, this paper proposed a two-tier trading framework that follows the principle "Provincial control and national cooperation", just as Figure 5 shown below. In this way, the volumes matched in the national market needs to be firm and should be seen as the constraints for the local dispatch. And each province will still have the right to dispatch in its own province and the different provincial market structures are allowed.

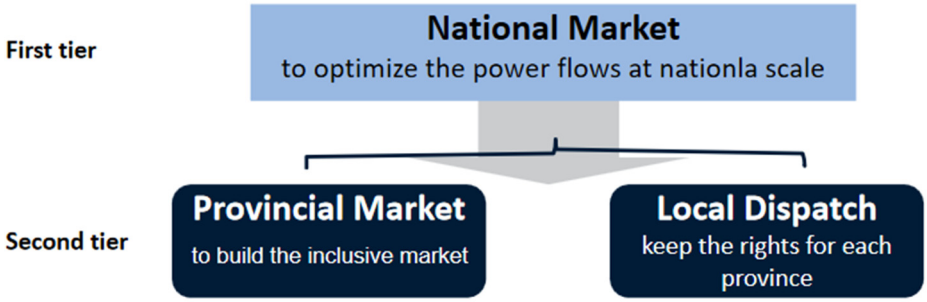

Fig. 5. The trading framework of the two-tier market.

The first tier is the national market and the second tier presents the local provincial market. The responsibility for the first tier is to optimal power flows on a national-scale, for both cross-border power flow and internally power flows in provinces.

4.2 China should establish the unified national electricity market step by step

The first inspiration is that: China should establish a unified national electricity market from simple to complex. By considering the market operation difficulties will increase due to the shortening of the transaction time period, the EU did not start the construction of both day-ahead and intra-day coupling market at the early stage, but adopted a step-by-step approach to improve the market system: 1) Firstly, EU carried out the medium-and-long term trading between regions; 2) Secondly, the coupled day-ahead market clearing was carried out; 3) Then, the coupled intra-day market was launched in 2018. China's national unified electricity market

establishment can also refer to the step-by-step model. Following the top-level road map, promoting the integration of inter-provincial and intra-provincial markets gradually.

To achieve the optimal resource allocation, integrate the renewable generation and reduce the entire cost of electricity supply, the national energy market of China needs to be established. However, the Chinese energy market, at state-quo, is a multi-level system with different time frames [10]. Therefore, as a starting point, the day-ahead auction market is proposed to be the main national market which conducts the short-term resource allocation and utilization of transmission capacity and to ensure the optimal electricity flow from low to high price areas based on the national merit order.

Then, the intra-day auction market could be the next step to be expended national-wide, just like the development of the EU unified electricity market. There are two main reasons. The first one is that the intra-day market shares a similar mechanism as for the day-ahead market; the second reason is the auction structure of the intra-day market is based on the merit order which avoids the risk of opportunistic at the early stage of the market construction. In addition, the long-term market sill constitute a tool to manage the risk in the long-term perspective. Both the national and local provincial contracts can be traded in the long-term market.

Since the results from the national market are the constraints to the local province market, the balance responsibility needs to be implemented based on the volumes marched in the national market. Furthermore, an imbalance settlement mechanism needs to be established to compensate for potential imbalances in scheduled flows. The overall flowchart of the two-tier model is demonstrated in Figure 6.

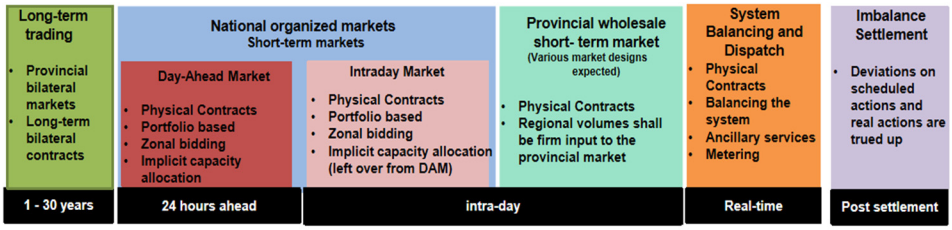

Fig. 6. Flowchart of the two-tier energy market model

4.3 Enriching the multi-time scale trading varieties to integrated with the short-term market

The third inspiration is to further enrich the multi-time scale trading varieties, establish a more flexible medium- and long-term market, and expand the coverage of the spot market. Traditionally, the agreements on power trade have been trading of capacity (whose unit is MW), not the energy (MWh). On the basis of annual and monthly regular market openings for medium- and long-term trading, there should further enrich the number of multi-time scale trading varieties, such as weekly and multi-day, to increase the frequency of trading and enhance the flexibility of the medium- and long-term market. Actually, in China, many provinces have already changed to trade by energy gradually. In this way, the medium-and long-term market could realize the integration with the energy spot market.

5 Conclusions

This paper has two main contributions. The first one is that summarized the experience from the European market as well as the special practices in the market operation, to provide insight and opinions for China. Since the construction and expansion history of the European integrated energy market is similar to the situation faced by China's electricity market establishment, there are three main inspirations from the EU integrated market to China: 1) China should establish the unified national electricity market from simple to complex; 2) the unified electricity market should be more inclusive, to allow local markets still retain the special characteristics of their own market transactions; 3) The Chinese power market should further enrich the multi-time scale trading varieties, establish a more flexible medium- and long-term market, and expand the coverage of the spot market.

The second contribution to this paper is to propose a two-tier energy trading framework for China. This framework is inclusive by allowing the local market to retain the rights in each local area. Meanwhile, the notional market should begin with the short-term day-ahead market, then extend to the intra-day market. To avoid the risk of opportunistic, the framework recommends the intra-day auction market instead of the continuous market.

Acknowledgment

This work is supported by the Science and Technology Project of State Grid Corporation of China "Research on Key Technologies of collaborative operation of trans-provincial spot market Learned from European market coupling mechanism" (5209402000G).

References

[1] CAO Yijia, LI Qiang, TAN Yi, et al. A comprehensive review of Energy Internet: basic concept, operation and planning methods, and research prospects[J]. Journal of Modern Power Systems and Clean Energy, 2018, 6(3): 399-411.

[2] Senlin Zhang, Zhi Lu, Reflections on the framework system of the national unified electricity marke[J].Journal of China Power Enterprise Management ,2021(01):49-52.

[3] Leonardo Meeus. The Evolution of Electricity Markets in Europe[M].Edward Elgar Publishing:2020-11-17.

[4] ENTSO-E, information on SDAC[EB/OL]. [16-06-2021] https://www.entsoe.eu/network_codes/cacm/implementation/sdac/.

[5] OMIE, Electricity markets[EB/OL]. [26-06-2021] https://www.omie.es/en/mercado-de electricidad.

[6] Belpex, ApX, Powernext, Trilateral coupling of the Belgian, Dutch and French electricity markets [R], 2007

[7] Mathilde Laure. Electricity markets: Balancing mechanisms and congestion management[D]. Dupuy Institute, 2008.

[8] ENTSO-E, information on SIDC,[EB/OL]. [16-06-2021] https://www.entsoe.eu/network_codes/cacm/implementation/sidc/.

[9] Jiannan Zhang, Yi Shen, et al. Research on key issues in the top-level design of the electricity market[J]. Journal of Technology Innovation and Application,2021(10):85-88.
[10] Li Ma, Menghua Fan, et al. China's electricity market construction path and key issues in market operation[J]. Journal of Electricity Power,2020,53(12):1-9.