

Problems and prospects of transformation and upgrading of China's power industry under the goal of carbon neutralization and carbon peak

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Abstract

"Carbon neutralization and carbon peak" is an important driving force to promote the transformation and upgrading of China power industry. China is a large power consumer. Under the dual carbon goal, the whole society is facing great challenges. In order to truly realize the dual carbon goal, we need the guidance of correct theories and methods and scientific deployment. Therefore, based on the current situation and transformation development situation of China power industry, this paper analyzes the essence of the double carbon goal, points out the way out for the power industry to achieve the double carbon goal, and analyzes the zero carbon energy power generation load index and the transformation and upgrading trend of traditional power under the double carbon goal from the comparison between traditional thermal power generation and new energy power generation in the power industry and combined with foreign experience.

Keywords

Carbon neutralization; Carbon peak; Development trend; Power industry.

1. Overview

At the climate summit, China made a commitment to "reach the peak of carbon" by 2030 and "carbon neutrality" by 2060; It is estimated that by 2030, the total installed capacity of wind power and solar power generation in China will reach more than 1.2 billion kw, and the consumption of non fossil energy will account for about 25%. In recent years, driven by relevant technologies and national policies, the power industry is gradually transforming and expanding. Internationally, all countries that realize a high proportion of wind power generation have established a modern power market system with the power spot market mechanism as the core. Therefore, the establishment of a national carbon emission trading market is an important path to achieve the goal of carbon peak and carbon neutralization. At the same time, in order to ensure the orderly operation of the carbon emission market, we need to establish and improve the policy and regulation system to regulate the carbon emission trading activities of relevant subjects. At present, the first performance cycle of the power generation industry in the national carbon market has been officially launched, and 2225 power generation enterprises will be allocated carbon emission quotas. The annual emissions of these enterprises have reached 26000 tons of carbon dioxide equivalent. From the perspective of trading mode, the carbon trading market is dominated by quota trading, supplemented by certified voluntary emission reduction trading.[1] Therefore, according to the requirements of carbon peak and carbon neutralization, improve the quota allocation scheme of the national carbon market,

scientifically calculate the total quota and benchmark value of the power generation industry in the national carbon market, reasonably coordinate the quota allocation of various regions, and carefully verify the "correction coefficient of regional power supply quota" set by various provinces, so as to make better use of the market mechanism to ensure the supply of coal power and flexibly regulate the power supply.

2. Problems of China power system under carbon emission

2.1. Transformation dilemma of thermal power industry

In recent years, with the transformation of China national economic development from simply pursuing high-speed economic growth to pursuing green development, the economic development concept of "green water and green mountains are golden mountains and silver mountains" has gradually become China policy development concept, which has attracted great attention of the public. Fossil energy is widely used in China power industry. Due to technology, energy structure and other reasons, the cumulative thermal power generation capacity will reach 4709.59 billion kwh in 1-11 months of 2020, accounting for more than 70% of the total power generation in China. [2] thermal power generation is still one of the important sources of power in China, even exceeding the total power generation capacity of all types in the United States.

At present, China economic situation is in the throes of economic reform and structural adjustment. Economic growth slows down, downward pressure increases, and the growth of power demand slows down, but the new driving force still maintains rapid growth. From 2013 to 2016, China electricity consumption increased by 3.61% annually, the installed capacity of full-scale power generation increased by 9.69% annually, and the average annual growth of coal-fired thermal power units was 6.23%, but the utilization efficiency of thermal power was not high. For example, the utilization hours of power generation equipment continued to decline from 2013 to 2016. In 2016, the utilization hours of thermal power decreased by 199 hours year-on-year, the lowest level since 1964. Until 2019, China power industry is still in a state of excess electricity. Among the 31 provinces and cities in China in 2019, 14 have thermal power utilization hours higher than 4293 hours and only 2 have thermal power utilization hours higher than 5000 hours. [3] Although strict investment control has become a conscious action of some enterprises, the power industry is large and difficult to turn around. Even if the state makes efforts to reduce thermal power investment and some projects are suspended or delayed, the situation of power overcapacity is difficult to fundamentally change in a short time. With the continuous advancement of China power transmission projects and the continuous improvement of cross regional resource allocation, clean energy outside the region continues to occupy the space of traditional thermal power generation, which intensifies the situation of power overcapacity and brings a huge impact on the operation environment of traditional thermal power.

2.2. Main problems in the development of new energy power

In 2019, China energy consumption reached 4.87 billion tons of standard coal, an increase of 3.2% over the previous year. In terms of structure, coal consumption shows a downward trend, falling to less than 60% in 2018 and further down to 57.7% in 2019, but coal is still the main energy base of China power in the short term. Meanwhile, the proportion of clean energy such as natural gas, hydropower, nuclear power and wind power increased from 13% in 2011 to 23.4% in 2019, almost doubling. However, in China energy composition, coal is still in the dominant position. At the same time, oil and natural gas are highly dependent on foreign countries, which has cast a shadow on the development of some clean energy. In the past decade, the global renewable energy power generation accounted for 52% of the increment of power

consumption, while in the early stage of the 13th five year plan, China accounted for only 38% (hydropower accounted for 12% and new energy accounted for 26%) [4]. China needs to speed up the green transformation of power production. During the 14th Five Year Plan period, it is necessary to further improve the position of renewable energy in China energy system.

Due to the dynamic characteristics of new energy power generation, it has the characteristics of fluctuation and intermittence. The change trend of power load fluctuates significantly, and the power regulation is difficult. It is difficult to carry out flexible energy regulation. At the same time, the utilization rate of many trans regional transmission channels is not high due to factors such as coal power capacity regulation and power grid security constraints.

The peaking characteristics of China power load curve are obvious, and the duration of 5% peak load is no more than 48 hours. Under the influence of the above series of factors, the difficulty of real-time power balance increases. With the large-scale development of new energy, the power system may show the "double high" characteristics of high proportion of renewable energy and high proportion of electronic equipment in the future. From the perspective of electrical characteristics, the anti disturbance ability of power system will be greatly weakened. From the perspective of fault characteristics, the fault is easy to form a chain reaction impact from local to global. From the perspective of stability characteristics, the system stability form is becoming more and more complex, prone to problems such as insufficient reactive power, voltage instability and frequency out of limit, which will make the power regulation more complex after new energy power generation.

For example, the power outage in Northeast China shows that by 2020, due to the abundant wind power resources in Northeast China, the installed capacity of wind power in the three provinces in Northeast China has reached 22.44 million KW, accounting for 17%. From September 23 to 25, 2021, due to the randomness and volatility of wind power, the power generation decreased sharply, and the power supply gap was further exacerbated. Weather conditions are the main factors affecting wind power. At the peak of summer in 2021, the total installed output of 35 million kW wind power in Northeast China was only 34000 kW at one time. [5] although it is an instantaneous small probability event, the power supply should ensure the stable supply at any time throughout the year. Once this happens for a long time, it may be similar to the power outage in Northeast China, resulting in the collapse of the power grid. Considering the volatility, intermittence and randomness of new energy, the market forms of extreme abundance and extreme scarcity will appear alternately. In the past, the power system and power market established on the stable primary energy system will be a great challenge if we want to establish a stable power system and stable power market under the current unstable power generation capacity.

3. Measures to solve the problem of carbon emission in China power industry

3.1. Overview of measures

With the progress of science and technology and the upgrading of technology, the development speed of power system will accelerate in the future, the changes of power industry will change with each passing day, and the uncertainty will gradually increase. The value chain of power industry is undergoing a transformation from "taking physical asset management as the core" to "taking the integration of physical assets and informatization as the core" to "taking digital empowerment as the core. By 2050, the pattern of the whole energy industry will undergo earth shaking changes, fundamentally changing the way of human life.

3.2. Transformation and development strategy adjustment of energy group dominated by thermal power - SWOT analysis based on Huadian Group

(1) Advantage

As the world largest producer and consumer of electric energy, China has a huge power market and good development potential. As one of the five national wholly state-owned power generation enterprise groups established during the reform of China national power system, Huadian Group has good technical foundation, perfect operation system, strong scientific research ability and high market competitiveness.

(2) Disadvantages

Under the new normal of changing economic growth mode and increasing pressure on resources and environment, it is imperative to promote the sustainable and healthy development of power energy industry. China Huadian Group Co., Ltd., which has always focused on the thermal power industry, has a large scale, mature system, certain institutional inertia and great difficulty in reform.

(3) Opportunity

China has a long history of thermal power development. With the reform and development of modernization, a large number of traditional thermal power enterprises came into being. Most of these thermal power enterprises have a single structure, and most of them are small capacity thermal power units with high energy consumption and high emission, which have serious equipment aging problems. Deeply influenced by the planned economy, there are some problems, such as weak awareness of market competition, lack of experience in market-oriented management, and imperfect market-oriented marketing system and mechanism. Therefore, if Huadian Group can seize the opportunity of reform, based on its own advantages and accelerate the reform process, it will take the lead in winning the market opportunity.[6]

(4) Risk

As a large power group in China, Huadian Group has great competitive pressure, reform pressure and high opportunity cost. If it cannot carry out effective reform and innovation, the survival and development of the enterprise may be greatly impacted and the future development will be difficult.

3.3. How to promote the rapid development of new energy in China through PEST model

(1) Politically, remove institutional obstacles. The current power grid supervision system is not conducive to the development of new energy. In terms of industry supervision, the design of supervision authority of power grid supervision system is relatively decentralized, lacking social and public supervision. In terms of Ownership Supervision, SASAC focuses on maintaining and increasing the value of state-owned enterprises, and lacks the assessment of the performance of public responsibilities. The planning coordination mechanism does not pay enough attention to new energy, and the examination and approval management mechanism has the problem of overlapping functions. The operation and management mode of financial subsidy mechanism needs to be further improved. The scope of fiscal and tax policies for new energy support objects is relatively limited, the incentive measures and financial subsidies for the power grid are insufficient, and the compensation for the provision of standby capacity units is insufficient. By strengthening the construction of basic research and application platform, establish a mechanism for the market to determine the electricity price, and improve the prediction accuracy of new energy output. Enrich the varieties of power market, decompose medium and long-term and spot transactions according to the length of time, and realize continuous market transactions. Establish a competitive and orderly auxiliary service market, improve the price and trading mechanism, and provide a basis for large-scale participation of

energy storage in system operation and supervision. We will accelerate the construction of the national market, expand the scope of market transactions, realize cross provincial and cross regional direct transactions between large users and power generation enterprises, and break down inter provincial barriers. Establish a market-oriented trading platform for green certificates and carbon emission rights, combine voluntary subscription with compulsory trading, and use the price mechanism to reflect the green and low-carbon attribute of new energy.[7]

(2) Economically, optimize the layout and promote large-scale development. During the 14th Five Year Plan period, new energy power generation will form a balanced development trend of large-scale centralized utilization and distributed local production and consumption. China "Three North" areas are rich in scenic resources, which can be developed on a large scale. Through the implementation of unified planning, unified construction and unified operation, give play to the scale effect and share the development, construction and operation costs, so as to reduce the electricity price cost.

During the "14th five year plan" period, we can make full use of the transmission efficiency of the built UHV transmission channel, further promote the construction of regional scenery bases in Inner Mongolia, Gansu, Qinghai and Xinjiang, and improve the capacity and proportion of new energy electricity. The central and eastern regions can fully consider resource endowment, land reserve, load characteristics and other factors to develop new energy projects with distributed access and local consumption. Innovatively adopt the development mode of "wind power +" and "photovoltaic +" and carry out construction by using idle land space resources such as subsidence areas, barren mountains and hills, building roofs, highway and railway slopes. Increase the participation of village and town communities through land equity, promote the complementary development modes of agricultural light and fishing light, and integrate the development with information industries such as telecom base stations and big data centers. Southwest China can rely on the hydropower regulation capacity of Jinsha River, Lancang River, Dadu River and other rivers, fully tap the transmission capacity of existing export channels, carry out the exploration of surrounding scenery resources and the mapping of construction conditions, timely start the development and construction of water scenery comprehensive base, orderly arrange the development sequence of drainage power and new energy, and clarify the new energy consumption market. During the 13th Five Year Plan period, the cost of offshore wind power gradually decreased, but affected by factors such as the difficulty of equipment manufacturing and construction, the cost of power generation is still very high. It is estimated that there will be an opportunity to realize parity Internet access at the end of the 14th five year plan period. During the "14th five year plan" period, the development of offshore wind power still needs subsidy support. According to the project wind energy resources and construction conditions, combined with the economic development level of coastal provinces, the development scale, subsidy mode and intensity are reasonably determined. Offshore wind power mainly focuses on the development of large-scale offshore projects, gradually promote the construction of offshore long-distance projects, explore the transmission mode of long-distance flexible DC transmission, and study the key technologies of deep-sea and high-sea integrated floating wind power.

(3) From the perspective of social support, actively integrate into the market operation mechanism. Under the current development trend, the business orientation and business model of traditional thermal power enterprises have undergone fundamental changes. It is urgent to take the market as the guidance, change the marketing concept and reshape the marketing system. The core content of the new round of power system reform is to open the distribution business to social capital. For power generation enterprises, it mainly involves two aspects: one is to increase the investment and construction of distribution network, and the other is to establish the main body of power sales. However, in terms of investment in

incremental distribution network business, since the national energy administration is still promoting the pilot stage, it has not made substantive progress. Therefore, enterprises should focus on extending the distribution industry chain. As a result, the operation direction and mode of traditional thermal power enterprises have undergone fundamental changes. There is an urgent need to be market-oriented, change the marketing concept and reshape the marketing system, so as to better integrate into the tide of the times and realize transformation and upgrading and enterprise value.

(4) Technically, develop energy storage and promote high proportion consumption. By the end of 2020, the installed capacity of pumped storage in China has reached 32.1 million KW, and the installed capacity of new energy storage has reached 2.9 million KW.[8] With the increase of the proportion of non-aqueous renewable energy, the demand of power system for energy storage will further increase. For pumped storage, due to the impact of site conditions and load distance, China pumped storage site resources are limited. For the new energy storage, the battery system has low energy density, high cost and great potential safety hazards, which affects the rapid development of the industry. In order to achieve the goal of high proportion consumption of new energy, we must vigorously improve the regulation scale of energy storage. For electrochemical and other new energy storage, actively promote the implementation, vigorously promote the construction of energy storage on the power side, power grid side and user side, and reasonably arrange the construction layout. Carry out the research and development of key energy storage technologies, improve the battery manufacturing level, and achieve the goals of large battery capacity, high density, low cost, high safety and long service life. In order to boost the development of energy storage, we must strengthen innovation and R & D in the field of new energy and increase funding for basic science and key equipment technology research in the field of new energy. Improve the existing R & D evaluation system, learn from the advanced and excellent experience of the United States, Denmark and Germany, and establish China renewable energy laboratory to integrate innovative R & D resources and carry out basic research and cutting-edge technology R & D. Following the principle of "application generation, R & D generation and reserve generation", widely solicit the opinions of the industry, formulate medium and long-term technology development roadmap and industrial application objectives, implement major national new energy science and technology projects, and mobilize industry university research innovation units to jointly participate in the technological innovation of the whole industrial chain.[9] We will strengthen the legal system for intellectual property protection, establish a sound implementation system for intellectual property protection, and enhance the enthusiasm of enterprises for innovation and R & D. Encourage and support projects with high conversion efficiency. By building new energy projects with advanced technology, increase guarantee time or give priority to Internet access, promote the application of products with high conversion efficiency and promote industrial upgrading.

3.4. Analysis of investment in power industry through Porter five forces

In order to reduce risks and carry out diversified development, the power market will continue to change in power generation, transmission and distribution, consumption and other aspects. The complex interaction of low-carbon path, technological progress, changes in consumer preferences, changes in the balance of oil and gas industry and government policies is leading to the subversion of the traditional power industry, [10] increasing the uncertainty of investment. The following will analyze the investment direction of the power industry through Porter five forces analysis

1.Competition from existing competitors

Due to the competitive characteristics of the power industry, there are mainly five power groups in China power industry. The levels of these five groups are different, and the scale is

not different. The competitiveness of the five groups is relatively balanced and have some relative competitive advantages, but no group has an overwhelming advantage. Although the number of competitors is small due to the high entry threshold due to the characteristics of the industry, due to the current supply side structural reform and the development of new energy industry, the competition scale and competitiveness among the five major enterprises are intensifying. In addition, with the release of power generation and consumption plan and the development of power marketization, the scale of power market has been expanding. In order to obtain local advantages, major power generation groups have fought a "price war" to a certain extent, and the competition among them is more intense.

2.Competition for substitutes

With the rising share of renewable energy in China power generation, the competition between renewable energy enterprises and China traditional power enterprises is gradually intensifying. Projects such as UHV AC / DC lines have enhanced China ability to transmit power from inland provinces rich in energy resources to coastal populations and industrial and commercial centers. On the other hand, at present, electric energy plays an absolutely dominant role in the form and structure of domestic energy consumption. At the same time, the state has also advocated "electric energy substitution" in recent years, which shows that electric energy is still the cleanest and most efficient secondary energy for user terminals such as industrial, agricultural, commercial and ordinary residents. Chinese power generation enterprises still have a better living space.

3.Bargaining power of the buyer

After the power reform, the emergence of direct electricity trading has turned the buyer of power commodities from a power grid company into a whole society user who can participate in direct trading, and the on grid price is no longer a single benchmark, but an upper limit, which is used as a basis for negotiation or bidding. This has turned into a single "buyer market" under the current situation of relatively excess power capacity, The bargaining power of the buyer is unprecedentedly strong, but with the vigorous development of emerging power terminals represented by new energy vehicles, it has increased the demand of the retail end. With the implementation of marketization, the direct transaction price will become rational, and the bargaining power of the buyer will be moderately reduced.

4.Bargaining Power of suppliers

Considering the current actual situation, the supplier of coal, the raw material with the highest proportion of power generation cost, is taken as an example.

With the growth of thermal power installed capacity since 2002, the demand for coal has also increased simultaneously, which has led to the rise of coal prices all the way. The bargaining power of upstream industries such as coal is strong, while thermal power enterprises stabilize coal prices through the government on the basis of power protection. With the basic realization of the balance between supply and demand, coal prices began to enter a downward channel for several years, and the bargaining power of suppliers decreased. However, with the implementation of the coal de capacity reform, the supply and demand began to tilt to the coal market, the coal price market began to rise again, and the bargaining power of coal suppliers increased significantly again. In the face of the current instability of new energy power generation, I afraid the coal price will continue to operate at a high level for some time. However, in the long run, with the reduction of the cost of new energy power generation, new coal-fired power plants gradually become unprofitable. Investment in fossil fuel power plants will drop sharply. Under such a prospect, coal prices will fall back to a stable range again.

5.Threats from new entrants

External industry participants are also beginning to lay out the power market. For example, technology Internet enterprises have participated in the integration of energy revolution and

digital revolution, such as smart home, smart grid, electric vehicle, battery and energy storage technology. Traditional Chinese power enterprises are transforming into comprehensive energy service companies, which have advantages in financing ability, commodity trading and so on. Many companies are beginning to lay out new businesses through investment and acquisition, such as electric vehicle charging facilities, networks, technologies, etc., and invest in new and alternative energy around the world through venture capital subsidiaries. Faced with the threat of new entrants and considering the relationship between electric energy and China energy security, under the above efforts and China tax and profit protection, China power enterprises will still make continuous progress and development, but they will also be affected to some extent.

4. The fourth chapter looks at the road of China power reform from the perspective of American power system

4.1. Summary

As one of the first countries to use electricity in the second industrial revolution, the United States has rich experience in power management and perfect power consumption system and system, and the United States also has an important reference for China domestic power market reform in the reform and adjustment of power system. At the same time, as the most developed capitalist economy in the world, the United States has many differences from China in terms of power system, which can also provide new countermeasures for China.

4.2. Comparison between the operation mechanism of American power market and China

The American power market has two different characteristics from many other countries. The first is the diversification of participants in the power supply market, including power generation, transmission and distribution, and the relative lack of supervision of the federal government on the power market. The long-term market-oriented reform and various participants have created a highly privatized power generation market in the United States. In the United States, 84% of electricity is supplied by enterprises owned by private investors, only 4% is supplied by companies managed by the federal government, and the other 12% is supplied by state enterprises and cooperative enterprises. At the transmission and distribution end, marketization presents the same diversity and segmentation trend. A total of 3200 companies transmit and distribute power to consumers, of which 2200 are government-owned companies. Due to such diverse market players and different regulatory structures and means among States, the U.S. federal government has been lack of power market policies at the national level.

In the energy structure of the United States, the first energy is oil, accounting for 37.1% of the power energy structure of the United States, the second energy is natural gas, accounting for 23.8% of the energy structure, and the third energy is coal, accounting for 22.5% of the energy structure. The remaining new energy and nuclear power together account for 15.8% of the energy structure. Compared with China energy consumption, coal accounts for 64%, oil for 18%, natural gas for 6% and renewable energy for about 12%.The proportion of non fossil energy consumption was 13.3%, an increase of 1.3 percentage points, and the proportion of fossil energy consumption was 86.7%.It can be seen that there is a big gap in China energy structure compared with the United States. China energy consumption is relatively single and relies too much on fossil energy such as coal. However, with the development of clean energy such as wind power, photovoltaic power generation and hydropower in China and the breakthrough of nuclear power technology in recent years, the proportion of clean energy sources in China energy structure will further rise. At the same time, the opening of the west to East Gas

Transmission and Russia natural gas pipeline will further increase the use of natural gas in China.[11]

4.3. The Enlightenment of American power system to China and its future development direction under the goal of carbon neutrality

Although China has made proud achievements in the field of power, it still has a long way to go. The market-oriented reform methods of American states are worthy of China reference. Its active, diverse and highly privatized generation side market players are considered to improve the efficiency and stability of the system.

Correspondingly, China power market has a long way to go on the road of breaking the vertical power grid enterprises, encouraging various subjects to participate and releasing the vitality of the market. Similarly, how to achieve the goal of renewable power and power system informatization at the same time of reform is also noteworthy.

5. Conclusion

At present, China is facing the new situation of power industry transformation and development, which is to promote the integration, intelligence and marketization of comprehensive power management. In the future, under the new requirements of "double carbon", the power industry will follow the road of adhering to the construction of power resource database, the improvement of power trading market mechanism, infrastructure construction and key technology research, and systematically promote the advancement and reform of comprehensive power management. In order to ensure the smooth development of the power industry, as long as China can improve the policy mechanism from the aspects of top-level design, standards and norms, price and subsidy mechanism and market-oriented transaction mechanism, with the help of the east wind of new digital infrastructure, the digital construction of power system and the enabling of massive data on the operation level of new power system, and the low-carbon power industry ecology linked by data. It will certainly promote the vigorous development of the power industry and add strong impetus to the realization of the "double carbon" goal.

References

- [1] Zhao Yuehao, Li Zhiyi, Ju Ping, Wang Chong Elasticity of integrated energy power system under low-carbon Transformation: summary and prospect [J]Power automation equipment, 2021,41 (09): 13-23 + 47
- [2] Cai Shaokuan Challenge of double carbon target and Prospect of power structure adjustment [J]Southern energy construction, 2021,8 (03): 8-17
- [3] Sun Xiujun Transformation and development of traditional thermal power enterprises in the new era [J]China electric power enterprise management, 2018 (11): 56-59
- [4] Yang Fan, Xia Rongli, Yang Wei Development trend of new energy under the background of carbon peak and carbon neutralization [J]China engineering consulting, 2021 (09): 22-26
- [5] Ma Chenchen, Wu Simin Thermal power is short of coal, and the huge power gap of wind power in Northeast China needs to be filled [n]China business daily, September 19, 2021
- [6] Liu Jingyi, di Zhaoqiang Applying Porter five forces model to analyze the competition status of power design industry [J]China collective economy, 2011 (12): 96 + 105
- [7] Mei fang, Li Xiaochen 2030 China Power scenario outlook [Z]KPMG China, 2020
- [8] Duan Qin Research on marketing management of Chongqing l hydropower company under power market reform [M]Chongqing Normal University, 2021
- [9] Wu Guoqiang, Lin Wei, Kang Yong Competing for excellence: industry impact outlook of the 14th five year plan [Z]KPMG China, 2021
- [10] Forward looking Industry Research Institute. Analysis on the development status of China power industry in 2020 [J]Electrical industry, 2020, (10): 48-50

- [11] Yang Jinsen Analysis on the history and development of China power industry [J]Science Forum, 2010 (9): 53-54 + 41