Study on China’s electricity market mechanism of renewable Energy

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Abstract. This paper first introduces the current situation and background of China’s renewable energy power generation, and analyzes the difficulties of renewable energy consumption in detail. The next section mainly introduces how China’s electricity market mechanism adapted to renewable energy of high penetration. China’s electricity market mechanism is further designed based on the existing market mechanism. These market mechanisms are divided into two stages. The first stage is that the spot market has not yet been established, and the second stage is the establishment of the spot market. In both stages, the design of a market mechanism to promote renewable energy accommodation is based on the national market.

1. The current situation and problem of China's renewable energy development

In recent years, China's renewable energy generation has increased rapidly and entered an important stage of comprehensive, rapid and large-scale development. Wind power and solar power have become the third and fourth largest power generation in China. At present, the installed capacity of wind power and solar power is the first in the world. In 2015, the cumulative installed capacity of new energy power generation (referring to wind power and solar power generation, the same below) reached 170 GW, accounting for more than one-fourth of the installed capacity of new energy power generation in the world. During the "12th Five-Year Plan" period, the annual installation of wind power increased by 36% and the annual installation of solar energy increased by 172% in the operation area of the State Grid. The accumulative installed capacity of wind power and solar power generation is 116.64GW and 39.73GW, which makes China the one that has the largest power grid connected to new energy in the world.

The problem of China's renewable energy consumption is closely related to the country's energy resource and characteristics of energy mix. At the same time, this problem is aggravated by the large scale of centralized development and excessive local growth in the renewable energy-enriched areas. In addition, in recent years, the increasing rate of China's demand for electricity is slowing down, and the construction of power grid and the policy support to renewable energy are lagging behind. Therefore, if we do not pay enough attention to it and solve it as soon as possible, then problems in renewable energy consumption will be more prominent. [1] The reasons for the above problems are as follows:

First, the renewable energy generation is focused on large-scale development, and is usually remote from load centers. Therefore, the capacity of local consumption is limited. The distribution of wind and solar energy resources in China is concentrated while the distribution of power grid load is scattered. More than 80% of wind energy resource and 77% of the installation of wind power in the country are concentrated in the "Three North" areas (Northwestern, Northeastern and Northern China). The national...
centralized installed capacity of wind power accounts for 97%, and distributed wind power installed capacity accounts for 3%. Similarly, 80% of the country's solar energy resources and 84% of photovoltaic power generation is installed in the northwestern and northern regions in China. The power load of the "Three North" areas is small, so the capacity of local consumption is limited. About two-thirds of the country's power load is in the eastern part of China, which is remote from the wind and solar bases in the "Three North" areas. And the distance is more than thousands of kilometers.

Secondly, due to the shortage of trans-provincial and cross-regional transmissions and the absence of the trans-provincial and cross-regional mechanism, large scale optimal allocation of renewable energy is limited. The state promulgated the special plans of wind power, solar power and so on in the “12th Five-Year Plan”. But power grid planning in the five year plan has not been introduced, so the delivery channels of renewable energy bases haven’t been implemented. Power grid project approval lags behind renewable energy projects. Different levels of renewable energy-enriched regions have the problem of “strangulation” in the power grid and lack of ability to build the trans-provincial and cross-regional channels. All these problems have become rigid constraints on renewable energy consumption.

With the changing of power grid form, power supply, demand situation and policy environment, problems of the trans-provincial and cross-regional power consumption mechanism in China gradually emerged. For example, there are barriers to trans-provincial transactions, imperfect interest coordination mechanism, market-based price mechanism, single market structure, etc. The existing mechanism and management mode restrict the development of trans-provincial power consumption. And it has been unable to meet a wide range of optimal allocation of the demand for renewable energy.

Thirdly, as a result of unreasonable power supply structure and the shortage of auxiliary service mechanism in renewable energy-enriched area, large scale optimization of renewable energy is limited. China's power supply structure is dominated by thermal power, with a total percentage of 67%. Especially in the "Three North" areas, the percentage of thermal power reached 73%. The proportion of the national flexible regulating power supply, such as pumped storage and gas, is only 5.1%. And in the "Three North" areas, the proportion is less than 3%. Among them, the proportion of pumped storage and other flexible power sources in northeastern China is only 1.3%. Although a large number of gas power plants have been built in northern China, they are all co-generation units, which means they do not participate in peak shaving. And the proportion of pumped storage is only 1.9%. The structural problem of power supply in the "Three North" areas is prominent. The space of accepting renewable energy is slow, and it is forced to abandon a large amount of wind power and solar energy. In addition, the proportion of problem is again very prominent. Large-scale integration of wind power and photovoltaic power generation should base on the deep participation and collaboration of all sectors of the power system. At present, no peaking compensation mechanism has been established. The margin of spare capacity cannot fully meet the needs of renewable energy sources. Market mechanisms must be adopted to enhance the enthusiasm of all parties to provide auxiliary services. Because wind power is a fluctuating power source, there are higher requirements for auxiliary services in large-scale access to power grid, such as peak shaving, frequency modulation, voltage regulation and spinning reserve. Other generating units, such as thermal power and hydropower, must undertake a large number of auxiliary services such as peak shaving and backup. The auxiliary service market mechanism needs to be established as soon as possible so as to enhance the enthusiasm of all parties in providing auxiliary services.

Fourthly, the analysis of renewable energy consumption and the technology support for power generation forecast are not perfect. There is no uniform standard and calculation method to support the analysis of renewable energy consumption in China. The existing simulation platform for renewable energy production still need to be studied and improved in order to adapt to the analysis of renewable energy consumptive ability, power grid operation mode, computational efficiency and accuracy and so on. At the same time, renewable energy is deeply influenced by weather and external factors. The uncertainty of power and electricity is large. Accurate forecast of renewable energy is still a worldwide problem. At present, the forecast of renewable energy power generation is the responsibility of the company's dispatching. Generally speaking, power generation enterprises and other renewable energy
generators pay little attention to the forecast of renewable energy generation. The document for new power system reform is not clear about the responsibility in the forecast of renewable energy generation. This has also increased the difficulty of renewable energy generation forecast in the system. [2]

2. Market mechanisms for promoting renewable energy consumption

2.1. Propulsion Steps
Within the framework of the unified national market, China's renewable energy resources will be allocated optimally on a large scale, mainly through participation in the electricity market and through medium and long-term transactions across provinces and regions. Through flexible short-term transactions, the volatility of renewable energy peak modulation issues can be eliminated. And it will gradually transit to a complete market system, including the medium and long-term market and spot market, achieving priority acceptance by taking advantage of the low marginal cost of renewable energy.

Short-term measures: establishing multiple types of medium and long-term interprovincial trading mechanisms to facilitate transmission of renewable energy across provinces and regions; improving interprovincial auxiliary service compensation and trading mechanism to promote all types of thermal power units for renewable energy to peak shaving; implementing renewable energy incremental spot market transactions across provinces and regions and making full use of channel space and receive-side peak shaving resources.

Relying on the existing interprovincial transmission channels, it is necessary to organize the "Three North" regions and the central and eastern regions to carry out interprovincial power rights trading, renewable energy and self-owned power generation rights trading, interprovincial renewable energy direct trading, interprovincial renewable energy outsourcing transaction, gradually liberalize cross-provincial power generation plan, guide renewable energy to bring its price advantage into full play, and realize priority delivery through market competition. At the same time, it is also critical to establish and improve the medium and long-term peak displacement exchange, low valley renewable energy and pumping electricity trading, emergency support transaction and other mechanisms, mobilize the enthusiasm of thermal power and pumped storage power stations for peak shaving of renewable energy, and ensure adequate peak-shaving resources for power grids. Constructing a trans-provincial and outward spot market for renewable energy increment and flexibly consuming abandoned wind and abandoned photoelectric quantity are also very important.

Medium and long-term measures: gradually transiting to the "medium and long-term market + spot market" model in national electricity market system, promoting renewable energy generation forecasting accuracy through market competition, achieving power balance in real-time market by using renewable energy and thermal power, utilizing the advantage of low marginal cost of renewable energy, and achieving renewable energy priority through market competition.

2.2. A market mechanism to promote renewable energy consumption
For provinces where renewable energy has not yet been fully liberalized and with smaller market space, the transaction mode of inter-provincial renewable energy and the generation rights trade are adopted to develop outbound trade of the renewable energy. With the release of the inter-provincial power generation and electricity plan, the inter-provincial outbound trade of renewable energy and the direct trade between the renewable energy providers and users are developed. According to the actual situation in different places, we should carry out medium and long term peak load shifting trade, renewable energy and pumped capacity and emergency support transactions, flexibly regulate the external energy transmission of renewable energy. Trans-provincial outbound cash market for increment of renewable energy is also developed.

2.2.1. The trade of inter-provincial renewable energy and the generation rights trade. At present, the transfer transaction of generation rights are mainly carried out in the provincial power market. With the pressure on renewable energy consumption gradually increased, the trade share of inter-provincial
generation rights needs to be further expanded in order to promote the consumption of renewable energy electricity. When renewable energy enterprises in the province have reduced to the minimum operating power, they still face the risk of eliminating wind energy (solar energy) and power restriction, due to lack of consumption market. Meanwhile, thermal power enterprises in other provinces have the intention to reduce the operating power and space. Then renewable energy enterprises can give priority to the use of surplus power transmission channels to buy trans-provincial index of generating capacity of thermal power generation and replace their power generation in a market-oriented way. In this way, on the one hand it can promote renewable energy consumption, on the other hand it also gives regular energy some compensation. As a result, it can effectively balance the interests of all parties through the market.

2.2.2. The trade of renewable energy and the generation rights of captive power plant. A captive power plant is a small-scale power plant that is set up by some high energy consumption enterprises or enterprises which are rich of thermal energy in order to reduce the production costs. The power plant is dominated by thermal power units, and the power supply mode is that "The power grid provides electricity when the power is short and excess electricity is uploaded to the power". The captive power plant appeared in the historical period of the shortage of power supply. It reduces the number of power restriction and power outage, and plays a certain role in supporting the power grid. However, there is an oversupply of power, and the power plant has no power to support the power grid. At present, there are two major problems in the management and development of captive power plants. [3]

2.2.3. The direct trade of inter-provincial renewable energy. It is not good for the safe and stable operation of the power grid because of the poor economy of the remote transmission and the frequent irregular fluctuation of renewable energy. Therefore, where renewable energy resources are rich, the coal resources are also rich. After we take this factor into consideration, if wind power, photovoltaic and thermal power are sent outside by binding method, and the power of external transmission is regulated, the fluctuation of line power can be reduced, which is conducive to the safety and stability of power grid and the reduction of transmission cost. At the same time, the price of renewable energy is lower after subsidy. The desire of users to buy renewable energy will be promoted. And the direct trade with renewable energy which should be liberalized is conducive to the promotion of renewable energy consumption by means of the market to meet the needs of customers. [4] [5]

2.2.4. The outbound trade of inter-provincial renewable energy. China's wind and solar energy are mainly concentrated in the “Three North” areas, where the level of power load is low and the scale of the system is small. As a result, renewable energy can't be digested locally. In order to fully tap the potential of the existing medium and long term transactions, under the condition of the existence of space in the inter-provincial channel, the trans-provincial/trans-regional short-term and temporary transactions of renewable energy based on market bidding or bilateral consultations should be given priority. The renewable energy in the "Three North" areas should be guided during off-peak and surplus power period so as to achieve optimal allocation. Meanwhile, the developing cost of renewable energy will be reduced consistently, the large-scale development of renewable energy will be promoted, and finally renewable energy utilization will be guaranteed.

2.2.5. Emergency support transaction. Due to the difference in power supply structure, load condition and power grid operation mode of each province in the range of synchronous grid, the adjusting capacity of power grid of each province also has a certain complementarity. In an emergency, during off-peak period such as the Spring Festival particularly, a province that still has a regulative capability should support other provinces with serious discarding of the wind power and solar energy. Province which provides such support can receive a certain economic compensation through pre-bidding conditions by the market and balance the power generation according to the actual power use afterwards. Emergency support transaction is a pre-bidding transaction which aimed at medium and long term negative
regulating capacity of thermal power and when supporting provinces has serious discarding of the wind power and solar energy peremptorily. [6]

3. Conclusion
Under the framework of a unified national market, China's renewable energy can mainly realize large-scale optimal allocation of resources through medium and long-term transactions across provinces. Specific means include participating in the electricity market and eliminating the problem of peak regulation and frequency modulation brought by the fluctuation of renewable energy through flexible short-term transaction. Thus gradually transform it to a complete “long-term + spot” market system.

In the short term, China can promote renewable energy participation in medium and long-term transactions in various forms such as outgoing deliveries of renewable energy, direct trans-provincial deals and replacement transactions of power generation rights. In the meantime, China should establish a flexible short-term transaction adjustment mechanism to give full play to the market advantage of optimizing allocation of resources on a large scale and promote the transfer of deserted wind and solar power in the "Three North" regions to the central and eastern regions. China’s wind and solar energy are mainly concentrated in the “Three North” regions, where the level of electricity load is low, the system size is small, and renewable energy sources cannot be digested locally. In order to fully tap the potential of existing medium and long-term transactions, it is suggested that priority should be given to the outgoing delivery of renewable energy based on market bidding or bilateral negotiation, direct trade across provinces and exchange transactions of power generation rights, etc.. Given the space available in provincial inter-provincial channels in the form of long-term trading, resources can be fully used. For example, pumped storage power station can carry out short-term emergency transactions to provide ample trading options for cross-provincial consumption of renewable energy. A variety of trading mechanisms should be simultaneously developed.

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