Enlightenment of German Energy Decarbonization to Power System

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ABSTRACT
With the proposal of carbon neutralization and carbon peak strategy, power system decarbonization has become an important path to realize the strategy. This paper combs the experience of Germany in energy decarbonization and deconstructs the impact of German energy policy on energy structure from the road map of energy decarbonization. In order to better study the impact of the German power system on energy decarbonization, this paper studies how the German power market promotes energy decarbonization from the transaction mode, day ahead market, day in market and auxiliary service market of German power market. At the same time, this paper also studies the demand-side response, energy storage development and photovoltaic development cases in Germany. Finally, through the summary of the experience of German energy decarbonization, this paper obtains the effective experience and avoidable lessons in the implementation of the dual carbon strategy in the domestic power system.

Keywords: *Carbon Neutral; Carbon up to Peak; Decarbonization of Energy; The Power System*

1. INTRODUCTION

Most domestic studies are still in the theoretical design stage of power system decarbonization, and the transformation of energy structure in the process of decarbonization has not attracted enough attention. Foreign countries have successively announced the action route of carbon neutralization and carbon peak, Germany has released the road map for the equitable transformation of Germany from coal to renewable energy, and the Japanese government has published the draft road map for decarbonization. On May 18, 2021, the International Energy Agency (IEA) released net zero emissions in 2050: a road map for the global energy industry [1]. A net zero emission energy system will mainly rely on renewable energy rather than fossil fuels.

On the Whole, the attention on foreign energy decarbonization to the power system has been related to the impact of large-scale access to new energy on the power grid. Domestic research only focuses on the single energy grid connection, and rarely touches on the large-scale access of new energy. It is necessary to study the impact of foreign energy decarbonization on the power grid from the perspective of large-scale access of new energy to the power grid.

Based on the study of the practice of energy decarbonization in Germany, this paper takes the regulations, policies and practices of energy decarbonization as the starting point, pays attention to the impact of large-scale grid connection to new energy on power grid form, security and power market, establishes a power system suitable for domestic "carbon neutralization", and further constructs specific application scenarios of relevant experience, This paper further expounds the realization process of new energy in low-carbon goal with examples, so as to provide ideas and reference for the study of low-carbon economic operation of power system. [2]

2. DEVELOPMENT OF ENERGY DECARBONIZATION POLICY IN GERMANY

Since the 1990s, Germany has implemented its energy transformation policy. In 1990, the German government announced its plan to reduce carbon dioxide emissions to

25% of the 1987 levels by 2005. At the same time, the power grid accesses law promulgated stipulates the relevant subsidy promotion policies on renewable energy. In 1990, the German electricity supply law came into force, and in the same year, the electricity transmission law was promulgated, which came into force on January 1, 1991 and was revised twice in 1994 and 1998. Its purpose is to introduce the fixed electricity price system initiated by the United States into Germany, requiring German power grid operators to accept new and renewable energy power on the grid and purchase it at a fixed price, with remarkable implementation effect. Since the early 1990s, with the support and encouragement of national and local policies, Germany's new energy and renewable energy power, especially wind power, have developed rapidly, surpassing the United States and becoming the global wind power champion.

In September 2010, the German federal government issued the energy strategy to 2050 - "energy concept: for a good environment, reliable and affordable energy supply", and put forward corresponding measures from the aspects of developing new energy, upgrading the power grid and improving energy efficiency. In 2016, Germany promulgated the "climate protection plan". Germany's 2016 climate protection plan stipulated that by 2030, the carbon dioxide emission of the energy industry will be reduced by 60% - 62% compared with that in 2014. In order to achieve the specified goal, the significant reduction of coal-fired power generation by 2030 must make a decisive contribution, and set a key route for the significant reduction of coal consumption by 2030.[3]

On January 26, 2019, the German coal and electricity withdrawal Committee issued the German coal withdrawal report, suggesting that all coal and electricity should be withdrawn by 2038 at the latest. In September 2019, the German federal government issued the "climate protection plan 2030" to achieve the goal of reducing greenhouse gas emissions by 55% in 2030 compared with 1990. The draft has made specific arrangements and arrangements for the development of the photovoltaic industry in 2030. The goal of the German photovoltaic industry is to double the existing photovoltaic capacity in 2030 to reach the total installed capacity of 98gw, in order to meet the power generation gap caused by the phasing out of nuclear energy and coal. In April 2020, the German parliament announced that it would amend the renewable energy law and improve the renewable energy target. The industry expects that Germany's onshore wind power industry can usher in a new round of development opportunities.

The German government adopted the national hydrogen energy strategy on June 10, 2020, focusing on the development of "green hydrogen", set the goal of achieving climate neutrality by the middle of the 21st century, and planed to become a global leader in hydrogen technology. Germany's national hydrogen energy strategy predicts that due to the promotion of market growth, the demand for hydrogen will reach the initial growth target by 2030, which will be obvious in the industrial sector (chemical, petrochemical and steel industries), while the growth of the transportation industry is expected to be small at that time. German electrolytic cell industry will also develop rapidly. According to the confirmed deployment plan, Germany will install up to 5 GW of green hydrogen electrolyzer in 2030. This plan will promote the rapid development of electrolyzer industry. Compared with the current installation volume, this scale will increase 200 times in 10 years. By 2040, the deployment scale of electrolyzer in Germany is expected to reach 10 GW. If the "European 2x40 GW green hydrogen plan" is successfully implemented, the scale of electrolyzer in Germany will account for 25% of the total deployment in Europe by 2040.

3. DEMAND-SIDE RESPONSE DEVELOPMENT IN GERMANY

3.1.Current Situation of Demand-side Response In Germany

Germany's demand-side flexibility resources mainly come from industry, tertiary industry and residents, mainly price based demand-side management. Under the conditions of different market structures, the utilization fields of demand-side resources are also quite different. Under the guidance of energy transformation and power market 2.0 policy, the current typical application of demand-side resources in Germany is in three aspects: transmission network operators, distribution network operators and industrial and commercial users.

Transmission network operators: demand-side resources can provide frequency modulation services to transmission network operators through power auxiliary market, or participating in congestion management of system operators by signing negotiated demand-side response contracts. When the quantity of power supply is insufficient, the transmission network operator executes the signed demand-side response contract. In the German electricity market, demand-side resources as a whole can participate in the frequency modulation market. Germany puts forward clear provisions on the bidding of demand-side resources in the frequency modulation market and the interruptible load market. For the adjustable load market, the four major transmission network operators in Germany bid 3000 MW per month (1500 MW can be cut off immediately + 1500 MW can be cut off quickly), giving all large load enterprises equal bidding opportunities.

Distribution network operators: the uncertainty of demand-side resources will affect the power flow distribution of the power grid, which is not only reflected

in the voltage level of demand-side resources, but also affect the power grid at the upper level. Therefore, through the rational utilization of demand-side resources, the investment cost of distribution operators can be reduced. Based on the bilateral contracts signed between users and distribution network operators, users can reduce the paid distribution network service fees by adjusting demand-side resources, so as to realize the orderly coordination and management of market-oriented demand-side resources and grid oriented demand-side resources.

Industrial and commercial users: the traditional utilization of load demand-side resources is reflected in peak shaving. By adjusting part of the load during peak hours, corresponding compensation can be obtained. The power consumption characteristics of different enterprises are different. Only by adopting a reasonable load regulation strategy can we obtain the most economic benefits. In addition, at present, the demand-side resources of industrial and commercial users have also made certain applications in data analysis, data mining, participation in market regulation and other aspects, and achieved good results. Some large industrial enterprises (with balanced settlement units alone) reduce power purchase costs through effective demand-side resource balanced settlement management. The functions of German demand-side resources in distribution network operators and user systems are shown in Figure 1.

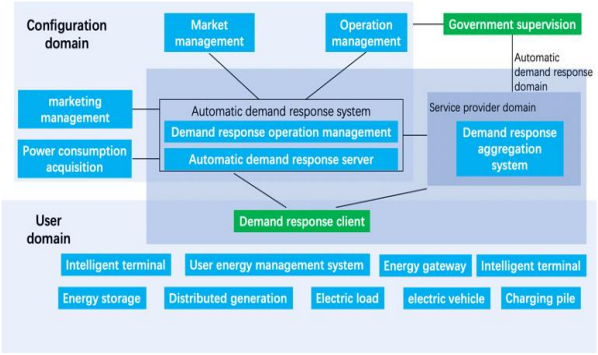

Figure 1 Internal relationship of demand-side resources between users and distribution network operators

3.2. demand-side resource application

The combined cooling, heating and power generation mode releases and matches the power supply and demand in real time through the Internet platform. For example, when there is surplus wind power, the power selling company will send a low price reminder to the large users of the power industry. The large industrial users choose to turn on the cold and heat storage equipment at this time, which not only balances the power supply and demand, but also reduces the power cost.

The concept of virtual power plant is introduced to realize the aggregation, coordination and optimization of distributed generation (DG), energy storage system, controllable load and electric vehicle through advanced information and communication technology and software technology, so as to participate in the power market and power grid operation as a special power plant. The application of the virtual power plant of the e-Telligence project reduces the power imbalance caused by the uncertainty of wind power treatment by 16%

Power demand-side management is achieved through "intelligent energy router" such as home energy storage equipment and intelligent electric energy meter. E-dema project in Rhine Ruhr region strengthens the interaction between users and power system, so that consumers can play the role of producers and consumers of power generation and power consumers at the same time, forming a trading market when producers and consumers have too much or insufficient energy.

Smart electricity meters collect electricity consumption data and introduce the policy of combining sectional electricity price and dynamic electricity price to encourage users to reduce peak electricity consumption. Meregio, an existing system application demonstration project led by enbw, one of the four major power companies in Germany, can realize effective resource scheduling by using smart meters and various ICT technologies.

Integrate user side resources (energy storage equipment, electric vehicles, smart home and distributed generation facilities), control the charging and discharging of energy storage equipment and the opening and closing of smart home according to the price signal. Reg Mod Harz project relies on the combined recycling of renewable energy to achieve the best combination of power supplies, and coordinates the decentralized renewable energy power generation equipment with pumped storage hydropower station to achieve the best effect.

4. ENLIGHTENMENT FROM GERMAN ENERGY DECARBONIZATION

Strengthening the guidance of policies and regulations and accelerate the implementation of the dual carbon goal. Strengthen top-level planning and design and lead the practice of a low-carbon society. In combination with the national carbon neutrality and action plan for peaking carbon dioxide emissions, with the development goal of vigorously developing renewable energy, reducing primary energy consumption and improving energy efficiency, formulate corresponding assessment indicators and accelerate the implementation of Zhejiang carbon neutralization and carbon peak action plan. Learn from the legislative experience of German renewable energy law, combined with the characteristics of energy and power development, make up for the lack of rights and

responsibilities laws and regulations of domestic renewable energy parties, improve the legal basis, try first in the legal system of renewable energy utilization, and provide legal guarantee for new energy utilization. We will make an overall plan for the road map of renewable energy development, promote the formulation of the implementation plan for the weight of renewable energy power consumption responsibility, clarify the weight of relevant parties, and advocate the energy transformation of green and low-carbon wisdom.

Accelerating the construction of flexible resources and promote the consumption of new energy. Give play to the role of the market in the flexibility adjustment of power generation, accelerate the establishment of the auction mechanism of the output market of dynamic units, and guide power generation enterprises to incorporate the flexibility adjustment into their own business work through price, so as to give better play to the peak shaving role of thermal power units.

Accelerating the development of diversified energy storage and promote the consumption of new energy. Striving for the energy storage construction and development mode with the grid side energy storage as the core and the power side energy storage and user energy storage as the supplement, actively connect with the competent government departments. And to promote the inclusion of the grid side energy storage module into the effective assets of power transmission and distribution. Installation subsidies are provided for household energy storage system to encourage the combination of user side energy storage and photovoltaic.

Improving the electricity and carbon market system and mechanism and reconstruct the industry business model. Give full play to the joint role of carbon market and power market to promote the long-term clean development of energy industry. Give full play to the role of carbon market in promoting the power market, reasonably control the carbon emission quota of thermal power units, and effectively encourage thermal power enterprises to promote technological innovation, strive to reduce the total amount and intensity of carbon emission, and regulate carbon transaction costs through rolling verification of power supply benchmark values. Promote the integrated development of electricity carbon market. Deeply integrate the trading products, participants and market mechanism of the power market and the carbon market, focus on promoting the linkage and collaborative allocation of cost factors such as energy resources and quota trading at both ends of supply and demand, form the market competitive advantage of low-carbon green "products" in all links, and further stimulate the driving force of emission reduction in the whole society.

5. CONCLUSIONS

Starting from the German energy decarbonization policy, this paper analyzes the application of Germany's energy decarbonization from the demand side, that is, transmission network operators, distribution network operators and industrial and commercial users, so as to further draw lessons for China in decarbonization of power system. China is the largest source of carbon emissions in the world. Its contribution to reducing carbon emissions and controlling global temperature rise will be very important. However, it will be a very challenging task for China to achieve net zero carbon emission in the next 40 years. China has only 30 years to achieve the goal from carbon peak to carbon neutralization. To achieve this goal, we need the joint efforts of the Chinese government, power and energy suppliers, financial institutions, users and other departments, more perfect and sound laws and policies to control and guide, and make full use of the market to play the role of flexible adjustment on the basis of the government's functions, reduce the cost of electricity carbon trading and improve the carbon emission trading system. Decarbonization in power industry is one of the key links to achieve carbon neutralization, which is of great significance for China to achieve the goal of carbon peak and carbon neutralization.

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