Study on the Development Prospect of Natural Gas Power Generation in New Power System

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Abstract. In the process of building a new power system with new energy as the main body and promoting the "double carbon" goal, natural gas power generation plays the role of auxiliary power balance and flexible regulation, since it has the advantages of low emission, fast start and stop as well as flexible regulation. This paper uses self-developed power planning software for optimization analysis, and studies the future development trend of natural gas power generation under the goal of carbon neutralization. The future layout of natural gas power generation will still be concentrated in the southeast coast, and the capacity in the central and western regions will gradually increase. The application scenario will be dominated by large-capacity centralized power station, supplemented by distributed utilization. In the next step, we should focus on solving the problems of gas source, gas price and key technologies, and give full play to the positive role of natural gas power generation in power safety and supply.

Keywords: natural gas power generation · new power system · carbon peaking and carbon neutrality

1 Introduction

At present, the implementation of the new energy security strategy of "four revolutions and one cooperation" is accelerating. China has made an international commitment to strive to reach the peak of carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060. Natural gas power generation (hereinafter referred to as gas electricity), as a clean, low-carbon, flexible and efficient power generation method, can effectively improve the flexibility of the power system and promote the consumption of new energy. On the other hand, it also faces practical problems such as difficulty in ensuring gas sources, high fuel costs, and core technology bottlenecks. Therefore, there are still significant differences in the industry's understanding of the positioning and development of gas electricity in building new power system and promoting the "dual carbon" process [1, 2].

On the basis of a detailed review of the current development status and existing problems of gas electricity, combined with the construction needs and characteristics of new power system, this article analyzes the functional positioning of gas electricity in

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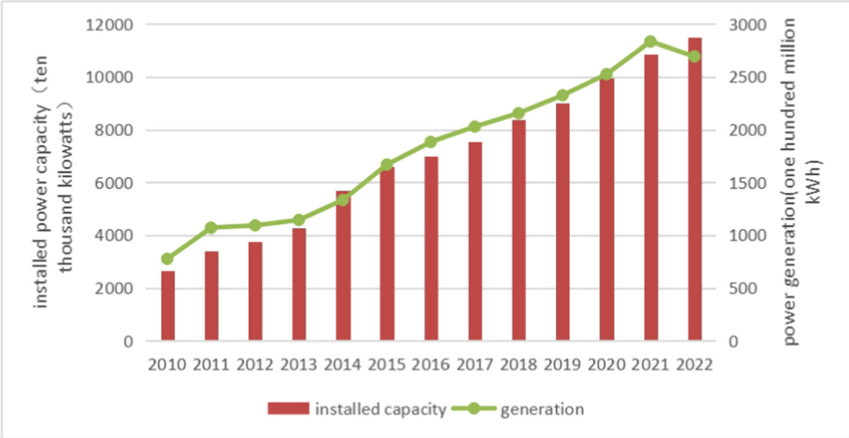

Fig. 1. The trend of the installed capacity and electricity of natural gas power generation in China.

new power system, evaluates the future development trend of gas electricity, and puts forward relevant suggestions, providing useful reference for the healthy development of China's medium to long-term natural gas power generation industry.

2 Current Situation and Main Issues of Gas Electricity Development in China

2.1 Development Status

China maintains a steady growth trend in gas electricity, but the proportion of installed capacity and power generation is relatively low. As of the end of 2022, the installed capacity of natural gas power generation in China reached 115 million kilowatts. Although the average annual growth rate has remained above 11% in the past decade as shown in Fig. 1, due to its low base, the overall installed capacity accounts for a relatively low proportion, only 4.5% of the total installed capacity, far below the world average which is around 25%.

2.2 Main Issues

The level of gas supply guarantee for power generation is not high. China's natural gas resources are limited, and natural gas only accounts for 0.6% of the identified fossil energy reserves. The resource endowment of "shortage of oil and gas" has determined that China's external dependence on natural gas has remained at a high level of over 40% in recent years. In addition, the domestic gas consumption in winter occupies the gas consumption of power generation, which further affects the stability of gas-fired power plant. For example, in the winter of 2020 in East China, the shutdown ratio of gas power units due to the gas shortage in the north exceeded 70%.

High fuel costs and incomplete mastery of core manufacturing technologies for gas turbines have resulted in weak market competitiveness. Due to upstream resource constraints and multiple gas supply links in the middle and lower reaches, the price of natural gas in China is relatively high. In recent years, the price of gas for power generation in most regions has been between 2.0 to 2.5 yuan/cubic meter, and the cost of gas electricity is about 0.55 to 0.65 yuan/kilowatt hour, which is 0.1 to 0.3 yuan/kilowatt hour higher than power sources such as coal-fired power, hydropower, and nuclear power. In addition, China still lacks the ability to independently design and manufacture key components such as gas turbine combustion chambers and high-temperature turbine blades. Unit maintenance, renovation and upgrading rely on original manufacturers, which is costly and further reduces the market competitiveness of gas electricity.

In recent years, the government has promoted the reduction of energy costs, and there is limited room for price adjustment of gas electricity, which has brought significant pressure to the operation of gas electricity enterprises [3]. Local governments mainly use higher sales electricity prices to divert higher gas electricity grid prices, but this conflicts with the requirement to reduce the cost of industrial and commercial energy consumption. With the increase in the proportion of electricity traded in the market, the amount of electricity that can be shared with high electricity prices has decreased. In addition, the increase in installed capacity of gas electricity has gradually increased the pressure on various regions to divert electricity, resulting in a continuous decrease in the hours of gas electricity utilization in some regions and difficulties in enterprise operation.

3 Research on the Development Trends of Gas Electricity in China

3.1 Model and Method

This article takes 2060 as the target year and aims to achieve zero carbon in the power system. It uses the Carbon Peak and Carbon Neutrality Power Planning Software Package (GESP-V) to optimize the development scale and layout of gas electricity in future new power systems. GESP-V is independently developed by State Grid Energy Research Institute Co., Ltd., with a multi-regional power planning model including new energy as the core. It can reflect the impact of key technologies such as electricity balance, carbon emission constraints, carbon capture transformation, hydrogen production, and new energy utilization. It integrates system tools such as power planning, production simulation, and policy analysis. Optimization analysis can be conducted on the development path of energy and electricity, the layout of power development scale, the scale of power flow, the capture scale of traditional power CCUS transformation, and the carbon reduction path of electricity in various scenarios.

The objective function of GESP-V is to minimize the total system cost during the planning period, including the total investment I during the planning period, the residual value S of newly added fixed assets during the planning period, the fixed operating expenses F of the system, the variable operating expenses V of the system, and external costs E of the system environment, namely

$$minZ = I - S + F + V + E \quad (1)$$

The investment cost includes the investment in new power sources and their supporting power transmission and transformation during the planning period, the investment in the expansion of inter regional interconnection lines, and the investment in CCUS equipment renovation. The operating costs of the entire system include fuel costs, fixed operating costs, variable costs, and demand side response call costs. Emission costs include carbon emissions and various pollutant emissions costs. The residual value of the new investment at the end of the planning period is deducted.

3.2 Scale and Layout

From the perspective of future installed capacity of gas electricity, according to model calculations, it is expected that under the zero carbon scenario, the installed capacity of gas electricity will reach 220 million and 400 million kilowatts respectively by 2030 and 2060 as shown in Fig. 2. The development of gas electricity is mainly focused on peak shaving. Around 2035, carbon emissions will be captured by equipping CCUS devices. It is expected that the scale of gas electricity that equipped CCUS will reach around 120 million kilowatts by 2060, with an annual carbon capture capacity of 120 million tons. From the perspective of the contribution of gas electricity to power balance, it is expected that the national electricity balance capacity demand will be 0.28 ~ 0.32 million kilowatts in 2060. Wind energy and photovoltaic can only meet about 15% of the electricity balance capacity demand, and the contribution of gas electricity to electricity balance capacity is about 10% as shown in Fig. 3.

From the perspective of future gas electricity development layout, continuing the current layout, the new gas electricity will mainly be distributed in the Yangtze River Delta, Pearl River Delta, Beijing Tianjin and other regions. There are two main reasons. Firstly, compared to other regions, these regions have easier access to infrastructure such as liquefied natural gas, and gas sources are more secure. Second, under the circumstances of high cost of electricity by source, regulated electricity prices and low utilization hours, the profitability of gas electricity will still face challenges. These richer provinces are able to provide subsidies for gas electricity enterprises. Moderate layout of gas electricity in the central region to address power shortages and insufficient regulatory capacity. Under the "dual carbon" goal, strict control of the installed scale of coal and electricity

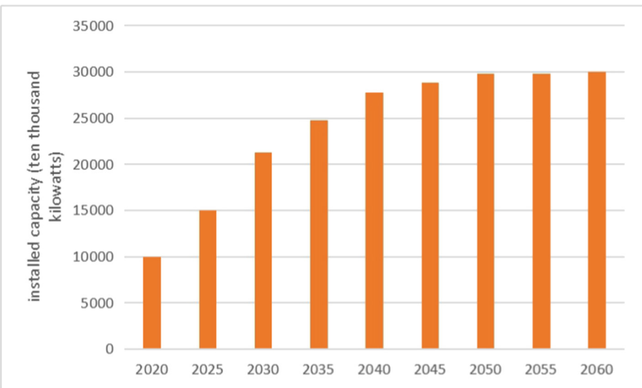

Fig. 2. Predictive trend of national gas electricity installed capacity from 2020 to 2060

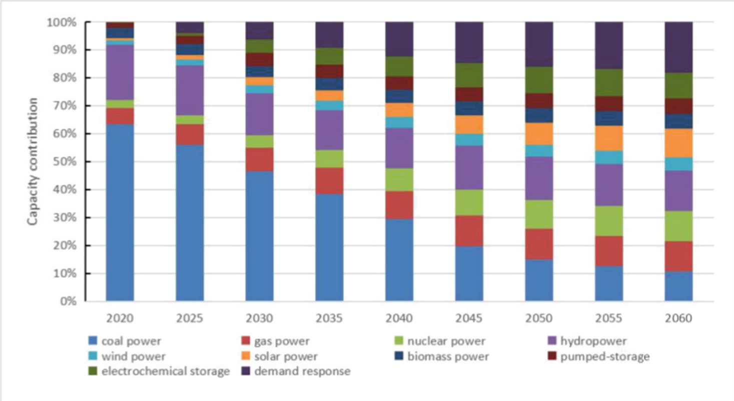

Fig. 3. Contribution diagram of power balance of various power sources in China

is the trend. Various provinces in central China will face the dilemma of both power and electricity shortages. Coupled with the instability of new energy, low-carbon and highly reliable gas electricity have become a practical choice for various regions. The areas in the western and northern regions with abundant gas sources and abundant new energy power generation should appropriately layout peak shaving gas electricity. Build a batch of gas peak shaving power stations in natural gas and wind resource rich areas such as Xinjiang, Qinghai, and Inner Mongolia, and establish a collaborative "gas wind complementary" or "gas solar complementary" power generation combination to further reduce wind and solar waste, improve the overall output level of renewable energy power generation, reliability of grid operation, and power transmission capacity.

Under the zero carbon scenario, there is still nearly 300 million kilowatts of incremental space for gas electricity, and attention needs to be paid to the issue of external dependence on natural gas. It is expected that the gas consumption for power generation will reach 150 billion and 135 billion cubic meters in 2030 and 2060, with a proportion to total natural gas consumption of 28% and 51% (14% in 2020). According to the prediction of China Petroleum Planning Institute, the scale of domestic natural gas can reach 230 billion cubic meters in 2060, and carbon cycle modes such as mixing hydrogen with natural gas, producing natural gas from hydrogen and carbon dioxide are considered as supplementary gas sources, which can basically meet the gas demand.

3.3 Functional Positioning

Gas electricity are an important component of the diversified power supply structure in the future. To achieve the dual carbon goal and accelerate the construction of a new type of power system with new energy as the main body, it is necessary to adhere to the diversification of power development [4], that is, the coordinated and inclusive development of multiple power sources, including the development of new energy sources such as wind power and solar power, as well as the development of hydropower, nuclear power, pumped storage, and new energy storage, as well as the promotion of coal, gas, and biomass power generation with the installation of CCUS. By complementing the advantages of various power sources and collaborating in operation, we will promote green and low-carbon transformation while ensuring power supply. According to calculations, in order to ensure the balance of electricity supply and demand in the next decade, gas electricity must bear a peak load of 6% -8%, taking into account coal power, hydropower, nuclear power, and new energy.

As the penetration rate of new energy generation increases, the pressure of peak shaving balance in the power system gradually increases, and more flexible regulation resources, including gas electricity, need to be allocated [5]. Since the beginning of 2021, the average maximum daily fluctuation of wind power output has reached 27% of the installed capacity, and the maximum daily fluctuation in some provinces has even reached over 80% of the installed capacity. It is expected that by the year 2025 and 2030, the daily fluctuations in new energy output will reach 430 million and 600 million kilowatts, respectively. The demand for flexible regulation resources for high proportion of new energy grid connection is increasing, and gas electricity will become a beneficial supplement to flexible regulation.

4 Conclusions

(1) Gas electricity are an important component of the future diversified power structure in the "dual carbon" process. According to the calculation of the power planning software model, under the zero carbon scenario of power industry, the installed capacity of gas electricity will reach 400 million kilowatts by 2060, and the contribution of gas electricity to the power balance capacity is about 10%. The development of gas electricity is mainly focused on peak shaving. Around 2035, carbon emissions will be captured by equipping CCUS devices. It is expected that the scale of gas electricity CCUS transformation will reach around 120 million kilowatts by 2060, with an annual carbon capture capacity of 120 million tons.

(2) The new layout of gas electricity in the future is mainly distributed in areas such as the Yangtze River Delta, Pearl River Delta, and Beijing Tianjin where gas sources are guaranteed and gas prices are strong. In the central region, gas electricity are moderately distributed to solve the problem of power shortage and insufficient regulation capacity. In the western and northern regions where gas sources are abundant and new energy generation is abundant, peak shaving gas electricity should be appropriately distributed.

(3) The future development of gas electricity needs to focus on solving practical problems such as difficulty in ensuring gas sources, high fuel costs, and core technology bottlenecks. It is recommended to strengthen the overall coordination of natural gas production, transportation, storage, and sales, and ensure stable supply through multiple channels, deepen the reform of the upstream, middle and downstream gas supply system and mechanism, timely and scientifically regulate gas prices, improve the gas electricity pricing mechanism, accelerate technological breakthroughs and master key core technologies of gas turbines.

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