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Research on the Power Source Development Strategy of Jilin Province Under the Background of Energy Transition

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Abstract

Against the backdrop of the energy transition and the Northeast Revitalization Strategy, profound changes will occur in all links of Jilin Province's power system, including power source, grid, load, and storage. These links will exhibit new characteristics, undertake new functions, and meet new requirements. On the power source side, it is essential to continuously optimize the structure and layout, and build a new-type power source system that is clean, safe, efficient, and intelligent. This system will support the construction of the new-type power system and the planning and development of the new-type energy system, thereby ensuring the high-quality economic and social development of Jilin Province. With the in-depth implementation of the carbon peaking and carbon neutrality strategy, China's power source structure is gradually developing towards cleanliness and diversification, with the proportion of wind energy and solar energy increasing day by day. Therefore, it is urgent to conduct research on the power source development strategy of Jilin Province in the context of energy transition.

Keywords

Energy Transition; Northeast Revitalization; Carbon Peaking; New-type Power System; Power Source Development Strategy

Introduction

In October 2022, the report of the 20th National Congress of the Communist Party of China emphasized that "we should actively and steadily promote carbon peaking and carbon neutrality, further advance the energy revolution, and accelerate the planning and construction of a new-type energy system" [1]. This has pointed out the direction and put forward higher requirements for the high-quality and leapfrog development of China's energy and electric power in the new era.

In the "14th Five-Year Plan for National Economic and Social Development of Jilin Province and the Long-term Goals for 2035", Jilin Province has proposed the "Onshore Three Gorges" project [2], aiming to build a national-level new energy production base in the western region. It will give full play to the advantages of abundant wind and solar resources and large areas of unused land in Baicheng, Songyuan, and other places, vigorously develop wind power and photovoltaic power generation, and construct three 10-million-kilowatt-level new energy production bases for in-province consumption, external transmission, and hydrogen production.

In August 2021, the National Energy Administration issued the "Medium- and Long-term Development Plan for Pumped Storage (2021-2035)" [3]. Under the new situation of global response to climate change, China's efforts to achieve the goals of "carbon peaking by 2030 and carbon neutrality by 2060", and accelerating the green and low-carbon transformation of energy, the accelerated development of pumped storage is imperative. Six pumped storage projects in Jilin Province, including the Tara River, Jingyu, Helong, Dasha River, Tonghua, and Wangqing, with a total installed capacity of 9.3 million kilowatts, have been newly included in the plan. Considering the already put into operation and under-construction pumped storage power stations, the total installed capacity of pumped storage power stations in Jilin Province will exceed 10 million kilowatts in the future.

Against the background of the transition and development and the superposition of the Northeast Revitalization Strategy, profound changes will take place in all links of Jilin Province's power system, including power source, grid, load, and storage. These links will present new characteristics, assume new functions, and meet new requirements. On the power source side, it is necessary to continuously optimize the structure and layout, build a new-type power source system that is clean, safe, efficient, and intelligent, support the construction of the new-type power system and the planning and construction of the new-type energy system, and ensure the high-quality economic and social development of Jilin Province.

1. Power Source Development Strategy before "Carbon Peaking"

According to the document "Implementation Plan for Carbon Peaking in the Energy Field of Jilin Province before 2030"[4], during the "15th Five - Year Plan" period, a clean, low-carbon, safe, and efficient energy system will be initially formed, significant progress will be made in the adjustment of the energy structure, the energy utilization efficiency of key industries will reach the international advanced level, the "Onshore Wind and Solar Three Gorges" will be fully completed, and the "Landscape Pumped Storage Three Gorges" will be basically completed [5]. By 2030, the carbon dioxide emission per unit of regional GDP will decrease by more than 65% compared with that in 2005, the proportion of non-fossil energy consumption will reach about 20%, and the total installed capacity of wind power and photovoltaic power generation will reach 60 million kilowatts. The carbon dioxide emissions in the energy field of the province will peak before 2030. By 2030, the proportion of non-fossil energy consumption will reach about 20%.

In February 2022, the People's Government of Jilin Province issued the "Special Plan for the 'One Main and Six Double' High-quality Development Plan". In the 11th item, "Development Plan for the Western National-level Clean Energy Base of Jilin Province", it is proposed to actively carry out the orderly and large-scale development of the western energy base of Jilin Province. By the end of the "14th Five-Year Plan" period, the total installed capacity of new energy in the base will reach more than 30 million kilowatts, including more than 22 million kilowatts of wind power installed capacity and more than 8 million kilowatts of photovoltaic installed capacity. According to the calculation, considering only the approved 22 million kilowatts of wind power and 8 million kilowatts of photovoltaic power generation (of which 4.4 million kilowatts are transmitted externally), the proportion of non-fossil energy consumption in Jilin Province will reach 20.4% in 2030.

According to the analysis conclusion of the power supply and demand situation, under the clear power source boundary, there will be no power gap in Jilin Province in 2030, and the utilization rate of new energy will be 92.5%.

2. Power Source Development Strategy after "Carbon Peaking"

2.1 Overview of Power Sources

2.1.1 Power Supply Guarantee Sources

Power supply guarantee sources are divided into two categories: those that provide power generation themselves and those that only transfer power without providing power generation themselves.

When there is a power gap in the system due to insufficient power generation, power sources that provide power generation should be selected [6]; otherwise, the type of power supply guarantee source should be determined through a comprehensive comparison of various factors. Power sources that provide power generation include coal-fired power, gas-fired power, nuclear power, and hydropower etc. Power sources that transfer power include pumped storage and new-type energy storage, etc.

2.1.2 New Energy Power Sources

The development of new energy in Jilin Province is dominated by wind power and supplemented by photovoltaic power. The geographical distribution of wind power resources is highly concentrated, and the simultaneous output rate of wind power in the province is relatively high. At the same time, there are many cases where the daily power generation of wind power and photovoltaic power is relatively low on the same day due to weather conditions, or the output of wind power in the province is relatively high on the same day due to weather conditions.

In some weather conditions where the wind force is low and the sunlight is weak, the daily power generation of wind power and photovoltaic power is relatively small. Even if the scale of pumped storage units or new-type energy storage is further increased, the newly added pumped storage units and new-type energy storage cannot further improve the power support capacity of the system because there is no electricity to charge. There are situations where the improvement of the power support capacity of pumped storage units and new-type energy storage is limited, or the newly added pumped storage units cannot be charged during the period of surplus new energy due to no discharge capacity.

2.2 Analysis of Power Source Output on a Typical Day

2.2.1 Analysis of New Energy Output on a Typical Day

On a typical day in 2040, the daily power generation of wind power is 2321 kilowatt-hours, and the equivalent daily power generation hours of wind power is 1.06 hours; the daily power generation of photovoltaic power is 571 kilowatt-hours, and the equivalent daily power generation hours of photovoltaic power is 0.71 hours. From the perspectives of the power generation capacity of wind power and photovoltaic power, and the equivalent daily power generation hours, the new energy output is relatively low.

2.2.2 Analysis of Pumped Storage Output on a Typical Day

As mentioned earlier, power supply guarantee sources are divided into two types: those that provide power generation themselves and those that only transfer power (without providing power generation themselves). On a typical day when there is a power gap in the system, the maximum output of the 4.1 million-kilowatt pumped storage units in the pumping mode is 4.1 million kilowatts, and the maximum output in the power generation mode is 3.21 million kilowatts. The pumped storage units pump 25.62 million kilowatt-hours of electricity throughout the day, with an equivalent pumping time of 6.25 hours; the power generation is 19.21 million kilowatt-hours, with an equivalent power generation time of 4.78 hours. Due to the lack of electricity in the system, the 4.1 million-kilowatt pumped storage units can only exert a power support capacity of 3.21 million kilowatts.

2.3 Analysis of Power Supply on a Typical Day

The power balance analysis and calculation in this study adopt the Power System Source - Grid - Load Integrated Production Simulation Software (PSD-PEBL V1.2 Version) developed by China Electric Power Research Institute.

The calculation principles adopted in this study mainly include: a) The output of wind power and photovoltaic power is considered as the smaller value between the output at that moment under the 95% confidence level in the current month (or current season) and the output at that moment on the output curve. b) The curtailment of coal-fired power units is considered as 15% in the heating season and 7% in the non-heating season. c) Gas-fired power units are not considered curtailment. d) Biomass units are considered to have a 25% curtailment. e) The output of conventional hydropower is considered under the condition of a dry year. f) The spinning reserve and shutdown reserve are considered as 7% and 3% respectively.

On a typical day, coal-fired power, gas-fired power, and biomass power units operate at full output for 24 hours (excluding the curtailed capacity), and hydropower units operate at an average output. From the calculation results, it can be seen that the power generation and consumption are in a tight balance throughout the day on a typical day, and all power sources that provide power generation operate at their maximum capacity, resulting in a reserve gap in the system. Even if the scale of pumped storage units or new-type energy storage is increased, the power support capacity of the system cannot be improved.

2.4 Development Plan of Power Supply Guarantee Sources

Based on the above analysis, Jilin Province should select power supply guarantee sources that provide power generation for the power supply guarantee in 2040 [7].

Combined with the actual situation of Jilin Province, three power supply guarantee source plans are formulated for 2040. Plan 1 is 2 million kilowatts of coal-fired power, Plan 2 is 2 million kilowatts of gas-fired power, and Plan 3 is 2.5 million kilowatts of inland nuclear power. All plans can meet the power supply guarantee needs. At present, the subsequent policies are not clear, and it is recommended to conduct timely research and confirmation in combination with the changes in the latest national policies. In this study, the coal-fired power plan (Plan 1), which has a medium-level regulation capacity, is temporarily adopted to carry out the research on the system regulation capacity demand and power grid planning.

2.5 Development Plan of New Energy

Considering the objective situations of Jilin Province, such as the shortage of fossil energy, the low development level of new energy, and the proportion of non - fossil energy consumption in Jilin Province being lower than the national average target in 2030, and taking into account the connection with the carbon neutrality level year, two carbon emission reduction scenarios, namely, steady development and active development, are set for the period from 2035 to 2040.

Under the steady development scenario, the self-used new energy in Jilin Province needs to increase by 6 million kilowatts and 5 million kilowatts, respectively, in 2035 and 2040; under the active development scenario, the self-used new energy needs to increase by 8.5 million kilowatts and 7.5 million kilowatts, respectively, in 2035 and 2040.

2.6 Development Plan of Regulating Power Sources

Through production simulation calculations, in order to make the utilization rate of new energy reach more than 90%, under the steady development and active development carbon emission reduction scenarios, if pumped storage is adopted as the new regulating measure, 1.2 million kilowatts and 1.7 million kilowatts of pumped storage units need to be added respectively in 2035 and 2040; if new-type energy storage is adopted, 2 million kilowatts and 3 million kilowatts of new-type energy storage (with a duration of 2 hours) need to be added respectively [8]. From the calculation results, it can be seen that the output fluctuation of new energy in Jilin Province is relatively large, and the required configuration scale of new-type energy storage is relatively small due to its more flexible operation.

2.7 Sensitivity Plan

2.7.1 Expanding the New Energy Scale in 2040

On the basis of the active development scenario, the new energy scale is further increased by 5 million kilowatts. When all the pumped storage projects included in the plan in Jilin Province are put into operation, that is, the installed capacity of pumped storage, the utilization rate of new energy is 89.1%. Even if the regulating capacity is further expanded, the utilization rate of new energy basically remains unchanged. Under this scenario, the new energy curtailment is an electric quantity-based curtailment, that is, the total power and electricity in the province are generally in surplus, the growth of power sources significantly exceeds the development level of load, and there is curtailment in most periods. For electric quantity-based curtailment, even if a large number of regulating power sources are configured, it is difficult to play a role. The results show that it is not necessary to further expand the scale of new energy and pumped storage.

2.7.2 Expanding the Pumped Storage Scale in 2040

Under the active development scenario, if all the pumped storage projects included in the plan in Jilin Province are put into operation, the total installed capacity of pumped storage will reach 12.1 million kilowatts, and the utilization rate of new energy will only increase by 0.9 percentage points compared with the mode of 7 million kilowatts of pumped storage installed capacity. That is, with the addition of 5.1 million kilowatts of pumped storage installed capacity, an additional 798 million kilowatt-hours of new electricity can be consumed. If the unit cost of pumped storage is calculated at 6000 yuan/kilowatt, the annual cost per kilowatt-hour of the newly consumed new energy electricity will reach 3.98 yuan, which is too high an economic cost. Therefore, it is not necessary to further expand the scale of pumped storage.

3. Power Source Development Strategy under the Background of Energy Transition

Comprehensively considering the connection with carbon emission reduction in the carbon neutrality level year and the economic costs under different carbon emission reduction paths, this study takes the active development scenario of new energy, the addition of 2 million kilowatts of coal - fired power, and the consideration of pumped storage units and new-type energy storage as regulating power sources, and forms the following two self - use power source installation plans for Jilin Province [9, 10].

In the Self-use Power Source Installation Plan 1 of Jilin Province, the newly added regulating capacity is mainly based on pumped storage units. 1.2 million kilowatts of pumped storage units will be added in 2035, and 1.7 million kilowatts of pumped storage units will be added in 2040. In the Self-use Power Source Installation Plan 2 of Jilin Province, the newly added regulating capacity is mainly based on new-type energy storage. 2 million kilowatts of new-type energy storage will be added in 2035, and 3 million kilowatts of new-type energy storage will be added in 2040.

4. Conclusion

Jilin Province is short of coal and oil, with insufficient oil and gas reserves and a high degree of external dependence. Externally imported coal has long dominated the energy development of the province. With the general trend of energy transition, the gap caused by the withdrawal of coal needs to be filled by other energy sources. From the current development status of renewable energy, nuclear energy, oil, and natural gas, the replacement of coal will be a long-term process. Considering the intermittent and volatile characteristics of wind and solar power generation, sufficient flexible power sources are needed to participate in peak shaving. With the continuous expansion of the scale of renewable energy power generation, power supply guarantee sources and regulating power sources will play an increasingly important role.

After the achievement of the "carbon peaking" goal, the layout of new energy should be optimized in accordance with the principle of simultaneous centralized and distributed development. The development and market consumption should be coordinated. Focus should be placed on actively promoting the development of wind power bases in areas rich in wind resources, comprehensively advancing the construction of photovoltaic bases, distributed photovoltaic systems, and "photovoltaic +" comprehensive utilization projects, strengthening the research on the integrated optimization and innovation of new energy application technologies, business models, and policy mechanisms, and promoting the comprehensive application of new energy. At the same time, efforts should be made to strengthen the construction of peak-shaving power sources to improve the contribution rate of new energy to ensuring power supply and demand; accelerate the construction of peak - shaving units such as pumped storage and thermal power flexibility transformation, and the upgrading and transformation of traditional technologies; strengthen the construction of thermal power emergency peak - shaving units; promote the development and construction of energy storage power stations, and gradually improve the energy storage power station technology.

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