Exploration on planning and development of pumped storage power stations in China

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Abstract. Our country has a vast territory and a large population, with the rapid development of economic society, electricity load continues to grow, and the difference between peak and valley load continues to grow also. Pumped Storage Power Station is the most mature large-scale energy storage method at present, and it is an important part of the new power system with new energy as the main body. In order to adapt to the rapid development of wind power, solar power and other new energy, and meet the requirements for safe and stable operation of nuclear power, ensure the safe and reliable operation of the power system, it is necessary to reasonably support and accelerate the construction of pumped storage power stations.

1. Introduction
In the middle 1980s, in order to relieve the difficulty of peak shaving, North China Power Grid, East China Power Grid and other regions organized a survey and planning work which focus on pumped storage power station resources in key regions, A group of pumped storage power stations such as Guang dong Guangzhou, Beijing Shi san ling, Zhejiang Tian huang ping, Shandong Tai an and so on. After entering the 21st century, the economic and social development in China continues to accelerate, and industrialization level is increasing year by year, the development of the power system has entered a new period. In order to improve the proportion of non-fossil energy, the development and utilization of hydropower resources are speed up, new energy sources such as wind and solar energy are actively developed, nuclear energy is rationally used. In order to achieve the national energy resource optimization configuration, the development strategy of "National Network, power transmission from west to east, mutual supply from north to south" is formulated. In order to actively absorb the wind power and solar power generation electricity with characteristics of unstable and intermittent output, ensure the safe and reliable operation of the power system, the demand for pumped storage power stations keep growing, and the planning of pumped storage power stations in China urgently need to be standardized and strengthened.

From 2009 ~ 2013, the National Energy Administration organizes many units to carry out the planning work of the pumped storage power stations. based on previous work, a batch of pumped storage sites with suitable scale and good construction conditions were selected in 22 provinces. According to the approval of the National Energy Administration, there were 59 pumped storage sites in the planning work, the total installed capacity was 74.85GW.
During the "13th Five-Year Plan" period, according to the arrangement of the National Energy Administration, the 2th planning work of pumped storage power stations was carried out, and there were 22 pumped storage sites in the planning work, the total installed capacity was 29.70GW.

As of the end of 2019, the planning work of the pumped storage power stations in 25 provinces were carried out, the approved total installed capacity of planned sites is approximately 120GW.

2. Development path of pumped storage power station
China began to research the development of pumped storage power station in late 1960s. Compared with Europe, America, Japan and other developed countries, the construction of pumped storage power station in China started relatively late. After the preliminary exploration in the 1970s, the in-depth research and planning and design in the 1980s, the vigorous construction in the 1990s, the pumped storage power station in China has initially entered a period of vigorous development. After the successful operation of large pumped storage power station such as Guang zhou pumped storage power station in Guangzhou, the Shi san ling pumped storage power station in Beijing and Tian huang ping pumped storage power station in Zhejiang, China has accumulated a lot of experience in the construction of pumped storage power station and mastered advanced unit manufacturing technology. The overall design, manufacture and installation technology of pumped storage power station has reached the international advanced level.

From the late 1990s to the present, with the deepening of our country's reform and opening up, the economic and social development in the central and western regions has continued to increase, and the construction scale of pumped storage power stations has continued to increase, and the distribution area has also continued to expand. During this period, Shandong Tai an, Zhejiang Tong bai, and a lot of pumped storage power stations were constructed or under constructed.

There are 32 pumped storage power stations and the installed capacity of China's pumped storage power station has reached 30.29GW in the end of 2019, surpassing Japan to become the country with the largest installed capacity of pumped storage power station in the world. There are 37 pumped storage power stations and the installed capacity is 50.63GW, the total installed capacity of pumped storage power stations is 80.92 GW.

3. Function of pumped storage power station
The pumped storage power station is a supportive power supply for the construction of a modern smart grid, which is an important part of the modern power system for the construction of a modern smart grid. Pumped storage power station has a variety of functions such as peak shaving, valley filling, energy storage, frequency modulation, phase modulation, emergency reserve, black start and so on. It is an effective way to ensure the safety, reliable, stable and economic operation of power system.

As a supporting power source for the load center region or power delivery, the pumped storage power station can enhance power system to respond to accidents and ensure the safe and reliable operation of the power system. It can provide physical rotation inertia, enhance system antibiotics. For pumped storage power station configured with black start capability, the power system can restore power supply in a short time without external assistance.

Pumped storage power station is flexible, the adjustment speed is fast, and the ability to climb the slope is strong, it is currently the most flexible power supply. The pumped storage power station can give full play to the role of peak shaving, valley filling, energy storage, frequency modulation, phase modulation, emergency reserve and reactive adjustment, and can achieve the purpose of improving the quality of system power supply.

Combined coordination with new energy, the pumped storage power station can Significantly improve the resource utilization of new energy, and relieve the abandonment effectively. Combined coordination with nuclear power, the pumped storage power station can safeguard the stable operation of nuclear power and improve its operational benefits, safety and economy. The pumped storage power station can reduce peaking range and improve the operating conditions of thermal units by peak shaving
and valley filling, then reduce system fuel consumption and operating costs, improve system operation economy.

4. Development achievements of pumped storage power station
As the end of 2019, the total installed capacity of pumped storage power stations in the world is 158 GW, the installed capacity of pumped storage power stations in China accounts for 19% of the world, ranking first in the world. In addition, the top ten countries in the world also include as follows: 27.6GW in Japan, 22.90 GW in United States, 7. GW in Italy, 6.4GW in Germany, 6.1GW in Spain, 5.8GW in France, 5.6GW in Austria, 4.8GW in India, 4.7GW in Korea.

In terms of pumped storage units, our country's post-development advantages is obvious. Large pumped storage power stations in the first batch of construction such as Guangzhou, Tianhuangping and so on all adopted the high-head, high-speed, large-capacity reversible units, which reached the world's advanced level. The maximum lift of Xi long chi pumped storage power station which put into operation in 2009 reached to 750m, and it is the third in the world. The single capacity of Xianju Pumped Power Station which put into operation in recent reached to 375MW, and it is the maximum single capacity unit constructed in the world. The single capacity of Yangjiang pumped storage station under construction reached to 400MW, and it will be the maximum single capacity unit.

The early pumped storage power plant units rely on foreign manufacturers. Since the 2004 Baoquan and other pumped storage power station units introduced the engineering and development and design technology through unified bidding and skills, the speed of localization of unit equipment of pumped storage is accelerated. Subsequently, the pumped storage unit and other pumped storage units such as the Heimifeng, Pu River and so on are mainly supplied to domestic manufacturers, further improve the manufacturing level of the unit. At present, domestic manufacturers have reached the industry's advanced level in the independent research and development of large-capacity, high-speed pumped storage units with a head section of 600 meters and below.

5. Development prospect of pumped storage power station
Take the construction progress of pumped storage power stations into account, it is initially estimated that the annual production scale during the "14th Five-Year Plan" period will be about 5~6GW. By 2025, the total installed capacity of pumped storage power station will reach to 65 GW. It is expected that the total installed capacity of pumped storage power station in 2035 will exceed 120 GW. During the "14th Five-Year Plan" period, it is estimated that 30 to 40 GW of new pumped storage power stations will be started.

From the perspective of national policy, with the introduction of the relevant regulations of the State Council on encouraging social capital investment in hydropower construction, the guidance of the State Council on innovating investment and financing mechanisms in key areas to encourage social capital investment, and the guidance of the State Energy Administration on encouraging social capital investment in hydropower stations clearly introduced that social capital in the field of pumped storage construction, and the main body of the development is determined by bidding. At present, the state holds a positive attitude towards the construction of pumped storage power station, at the same time, the enthusiasm of social capital investment in the construction of pumped storage power station is high, and the development and construction of pumped storage power station in our country shows a good development trend.

We are making great efforts to develop new energy sources such as nuclear power, wind power, solar power, and so on. Power transmission from west to east across the country requires the construction of pumped storage power station of a certain scale to ensure the safe and stable operation of the power grid. In the future, there is still uncertainty in the large-scale construction of natural gas power stations in China. The hydropower resources in central and east China have been basically developed, and there is a greater demand for peak regulation resources. The state is also encouraging social capital to invest in hydropower construction, so it can be seen that pumped storage power station in China is ushering in the most exciting part of a new round of construction.
According to the demand analysis of the pumped storage power station, combined with planning site resources and related influencing factors, it is estimated that by 2035, the pumped storage demand is approximately 1.4 to 1.6 GW. Overall, the development scale and construction schedule have lag behind system demand. It is imperative to develop pumped storage power station actively.

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