Analysis of development prospect and restrictive factors of pumped Storage Power Station

Lingjun Xu1, *, Gang Li2, Da Sang2, Na Zhong1

1Power china Hua dong Engineering Corporation Limited, Hangzhou, China
2East China Grid Company Limited, Shanghai, China

*Corresponding author e-mail: xulingjun@163.com

Abstract. The development prospect of pumped storage power stations (PSPP) in China is analysed in this paper on the basis of summarize of the development history of PSPP in China and abroad, and combined with the development characteristics of PSPP, and from the point of view of the geographical distribution, the development trend of future energy and national policy, then the factors restricting the development of PSPP are analysed from the aspects of incentive mechanism and electricity price policy. It also puts forward some suggestions to promote the healthy and sustainable development of PSPP, in order to provide reference for the related research of PSPP.

1. The development history of PSPP in China and abroad

The construction of PSPP started in Europe, and the emergence of foreign PSPP has a history of more than 100 years. In 1882, Switzerland built the earliest PSPP in the world—Netra PSPP in Zurich [1]. The construction of PSPP in Europe was booming from 1950s to 1980s. Western European countries began to lead the trend of PSPP construction in the world since 1950s. In the late 1960s, foreign PSPP entered a period of rapid development, including Japan, the United States, Italy and other countries. Especially in Japan and the United States, the total installed capacity of PSPP has exceeded 20,000 MW. Then the installed capacity of PSPP in the United States ranked first in the world and remained until 1990s [2] [3]. Japan overtook the United States to become the country with the largest installed capacity of PSPP after entering the 1990s, and kept this record until 2017 when the record was refreshed by China.

China began to research the development of PSPP in late 1960s. Compared with Europe, America, Japan and other developed countries, the construction of PSPP in China started relatively late [4]. 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 PSPP in China has initially entered a period of vigorous development. After the successful operation of large PSPP such as Guang-zhou PSPP in Guangzhou, the Shi-san-ling Tombs PSPP in Beijing and Tian-huang-ping PSPP in Zhejiang, China has accumulated a lot of experience in the construction of PSPP and mastered advanced unit manufacturing technology. The overall design, manufacture and installation technology of PSPP has reached the international advanced level. The installed capacity of China's PSPP has reached 27,730MW in May 2017, surpassing Japan to become the country with the largest installed capacity of PSPP in the world[5].
2. Development characteristics and prospects of PSPP in China

The PSPP is both a power plant and an electricity consumer, the function of valley filling is not available in any other type of power plant. It not only has the static benefit of peak regulation and valley filling, but also because of its rapid start and flexible operation, it is especially suitable to undertake dynamic tasks such as frequency modulation, phase modulation, load reserve and accident reserve in power system [6]. In the extreme case of the blackout of the whole power system, the restart of the power grid usually starts with the "match" of the PSPP, and finally "lights" the whole power grid. Therefore, the PSPP is also known as the "last match" of the power grid.

From the perspective of geographical distribution, the first batch of PSPPs in China are mainly distributed in east and central regions in China, the hydropower is rich in the west and wind energy and coal resources are rich in the north. The west and the north in China has the advantages of building large wind power bases, solar power bases and thermal power bases. The "power transmission from west to east" has the characteristics of long transmission distance and large transmission scale, in order to ensure the safe and reliable operation of power transmission from west to east. PSPPs of a certain scale with strong capacity of peak regulation which can improve the economy of transmission are needed in both the receiving side and the transmission side.

From the perspective of the development of new energy, with the large-scale development of new energy in China, such as nuclear energy, wind energy and solar energy, the configuration mode of PSPP has changed from a single focus on power load center in the past to the power load center, energy base, receiving side and the transmission side and so on. With the rapid development of new energy, it also puts forward higher requirements for accelerating the construction of PSPP. PSPP is an energy storage device with relative reliability, economy, long life cycle, large capacity and mature technology in the power system, and it is an important part of the development of new energy. Through the construction of PSPP, the operation and maintenance costs of thermal power and nuclear power units can be reduced, the life of units can be prolonged, the overall fuel cost of the power grid can be saved, and the impact of grid-connected operation of wind power, solar power and other new energy generation can be effectively reduced. The construction of PSPP can ensure the safe and stable operation of the power grid.

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 (Guo fa [2014] No. 60), and the guidance of the State Energy Administration on encouraging social capital investment in hydropower stations (Guo neng Xin neng [2015] No. 8) 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 PSPP, at the same time, the enthusiasm of social capital investment in the construction of PSPP is high, and the development and construction of PSPP in our country shows a good development trend.

We are making great efforts to develop new energy sources such as nuclear power, wind power, photovoltaic power, and so on. Power transmission from west to east across the country requires the construction of PSPP 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 PSPP in China is ushering in the most exciting part of a new round of construction.

3. The restrictive factors and countermeasures for the development of PSPP

By analysis of the development of PSPP in China, the investment return mechanism or electricity price mechanism of PSPP has become an important factor and core problem restricting its development, and it is also an important prerequisite for the further improvement of the construction system. At present,
the rate of return on investment of PSPP in China is far lower than that of other conventional power sources, and effectively solving the problem of electricity price mechanism has become an urgent task for the development of PSPP in China.

3.1. The operation mode of foreign PSPP
In 1989, The Britain first start up the power market reform. The power industry broke the monopoly, introduced the competition mechanism, and established the electricity market. The wave of privatization of power generation and power supply assets quickly swept across North America, Europe and other regions. From the practice of pumped storage electricity price in foreign countries. In the competitive environment of power market, PSPP can not only survive, but also be more advantageous, and will become a tool to provide low-cost and high-quality service for customers in the power market. The advantages of its survival are mainly reflected in the following two aspects: first, the electricity price competition is beneficial to the PSPP. For example, the valley electricity price in the United States is 2 cents / kWh, while the peak electricity price is 18 cents / kWh, It is 9 times difference between peak and valley price. The Helms PSPP operates in the California electricity market, and the highest electricity price has reached 250 cents / kWh, which is hundreds times of the valley price, which is beneficial to the PSPP which uses the valley to pump water and generate electricity at peak times. Secondly, the market payment for auxiliary services reflects the value of PSPP. After the power marketization in California, the auxiliary service income of the Helms PSPP accounted for more than 60% of its total income. Because the California electricity market provides "pay or not" contracts for some power load areas with weak external and external connections, resulting in excess base load capacity, and the electricity market transaction includes pumped unloading agreements. As a result, the income of the Helms PSPP has increased a lot.

3.2. The management mode of PSPP in China
The blackouts have occurred in the world such as the United States, Britain, Italy and Northern Europe Since 2003, which have caused huge economic losses and great social impact. Therefore, in order to ensure the safe and stable operation of the power grid, at the present stage, the management mode of PSPP in China will mainly be the unified accounting management mode of power grid and the independent management mode of power generation companies.

With the gradual deepening of the reform of the electric power system, the further activity of the electric power capital market and the further diversification of the main body of electric power investment, the PSPP is more likely to adopt other management modes. After the power market establishes a perfect auxiliary service compensation mechanism or auxiliary service bidding, with the advantage of quick start and stop, flexible and reliably operate mode, the PSPP can play an important role in the auxiliary service market and the cost of ancillary services is also considerable.

3.3. Electricity price mechanism of PSPP in China
Because of the particularity of PSPP, in the case of imperfect power market and lack of auxiliary service policy, the benefit of PSPP in China is difficult to reflect, that is, where the return on investment of PSPP comes from has not been solved. In recent years, several articles on the development policy of PSPPs issued by the National Development and Reform Commission have stressed that the construction cost of PSPPs has been incorporated into the unified accounting of power grid costs, and how to dredge the electricity price has not been fundamentally solved.

In 2014, the National Development and Reform Commission issued ‘the Circular on improving the Price formation Mechanism of PSPPs’ (Development and Reform Price [2014] No. 1763). This Notice makes it clear that the PSPP implements the two-part electricity price before the formation of the electricity market, and prescribes the pricing principles and methods of the two-part electricity price. it is reiterated that the construction and operation cost of the power station is included in the grid operation cost as a sales price adjustment factor to consider this price transmission mechanism as a whole, and puts forward the direction of gradually implementing the benchmarking capacity price in
the future. However, the regulation on the cost recovery mode of PSPP is more general and difficult to implement. In this paper, it is made clear that the capacity price and pumping loss of PSPP are only considered as a sales price adjustment factor, and there is a lack of effective targeted measures, which may also mean that if the sales price is not adjusted, the operating costs paid by power grid operating enterprises to PSPP are still borne by the power grid enterprises themselves and cannot be transferred to the relevant beneficiaries. Power grid enterprises still lack the enthusiasm to build and dispatch PSPP.

In the initial stage of China's power market reform, the separation of power plants and grids has been completed, the power market has not yet been established, and the transmission and distribution price mechanism is not yet perfect. Considering that the PSPP serves the whole power system, and the beneficiaries mainly include the power grid, the power generation side and the consumers, therefore, the PSPP should be established by the government according to the principle of "who benefits who is responsible" for the establishment of a reasonable electricity price mechanism for PSPPs, which will help to solve the problem of rolling investment in PSPPs and promote the sustainable development of PSPPs.

4. Conclusion

In the future, with the large-scale development of new energy in China, such as nuclear energy, wind energy and solar energy, the power system has faced huge challenges in terms of security, stability and economic operation. With its flexible operation mode, excellent peak regulation ability, fast response speed and economic investment, PSPP will become the most energy-saving and cheap power structure optimization development object to ensure the safety and economic operation of power system in the period of new energy structure.

In summary, if the role of PSPP is not enough recognized for a long time, a reasonable investment incentive mechanism cannot be formed, and there is no reasonable supporting electricity price policy, the healthy and sustainable development of PSPP still faces great resistance. Therefore, it is suggested that the national competent departments should strengthen the unified planning of PSPPs, study and implement the electricity price mechanism of PSPPs, and at the same time reform the investment system of PSPP to promote the healthy and sustainable development of PSPP.

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