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Overview of the China’s electricity market

By the end of 2019, China’s installed power capacity had reached 2,010,060 MW. The installed capacity of thermal power had reached 1,165,880 MW, accounting for 58.1% of the total installed capacity. The total installed capacity of renewable energy, including hydropower (356,400 MW), nuclear power (48,740 MW), wind power (210,050 MW) and solar power (204,740 MW), had reached 794,880 MW, accounting for 39.5% of the total installed capacity. The specific composition is showed in the following figure.

Figure 1 Composition of China's installed power capacity in 2019

According to the National Bureau of Statistics of China, power plants above designated capacity generated 7,142.21 TWh in 2019, including 1,153.44 TWh of hydropower, 5,165.43 TWh of thermal power, 357.74 TWh of wind power, 348.35 TWh of nuclear power, and 117.22 TWh of solar power.

Figure 2 Composition of China's electricity generation in 2019
In 2019, China's installed power capacity increased by 101,730 MW, including 4,170 MW of hydropower, 40,920 MW of thermal power, 4,090 MW of nuclear power, 25,740 MW of wind power, and 26,810 MW of solar power. The specific composition is showed in the following figure.

![Figure 3 China's electricity investment in 2019](image_url)

In 2019, a total of RMB 799.5 billion was invested in electric power nationwide. This includes RMB 313.9 billion for power plants (including RMB 81.4 billion for hydropower, RMB 63 billion for thermal power, RMB 33.5 billion for nuclear power, and RMB 117.1 billion for wind power) and RMB 485.6 billion for power grids.

Announced at the Paris Climate Conference in 2015, China pledged to peak CO\(_2\) emissions by around 2030 and strive to achieve it as soon as possible. On 22 September 2020, Chinese President Xi Jinping announced in his speech at the General Debate of the 75th Session of the United Nations General Assembly that China aims to have CO\(_2\) emissions peak before 2030 and achieve carbon neutrality before 2060. Therefore, coping with climate change and reducing carbon emissions will become the main driving force for China's strategic adjustment of energy structure in the near future.

On 21 December 2020, China promulgated the white paper "Energy in China's New Era". New concepts on energy policy included sticking to the direction of low carbon, optimizing energy production distribution and consumption structure, speeding up raising the proportion of clean energy and non-fossil energy consumption, greatly reducing carbon dioxide emissions intensity and pollutant emission levels, and speeding up the green low carbon energy transformation. In the next decade, clean energy will be the main direction of China's energy development.

The main problem of China's power system is that power generation centres are located far from consumers, so the main challenge in the power market is to balance supply and demand, and to maintain a stable operation of the grid. In the near future, China will further enhance the role of the market mechanism in the allocation of resources in the power system, strengthen the role of government, deepen the market-oriented power sector
reform for greater competitiveness in the energy sector, and establishing a high-standard energy market system.

Current status of pumped storage and development potential

PSH built and under construction in China are mainly in areas dominated by thermal power, such as South, Central, North and East China, serving as peakers in the power grids, while there are fewer PSH in provinces in Southwest and Northwest China. Due to the imbalance of China’s energy resource distribution and economic development, besides the economic development and power supply structure, the following factors were also taken into consideration during the planning and construction of PSH, including trans-regional, large-scale, and long-distance power transmission, optimization of power supply structure and smart grid development, and large-scale development of new and renewable energy sources such as wind power and nuclear power. By the end of 2019, the installed capacity of China’s PSH had reached 30,290MW, accounting for 1.5% of the total installed power capacity, which is far from meeting the needs of system development. PSH under construction is 50,630 MW.

Pumped storage plants in different regional power grids often perform different functions, for example, the East China Power Grid is characterised by large peaks and troughs in electricity demand, and hence pumped storage’s main function is to provide peak shaving operations, supplemented by frequency modulation and standby capacity. Whereas in Hunan and Hubei power systems, there is a lack of fast response power supply hence pumped storage plants are mainly responsible for frequency regulation and ancillary services, such as acting as standby generators. In Northeast and Northwest China Power Grids where there is a high share of intermittent wind and solar energy, the main use of pumped storage is to smooth energy output and provide energy storage for long-distance transmission.\(^1\) China has also started investigating seawater pumped storage, the latest survey in 2017 identified 238 potential sites with a total potential capacity of 42.08 GW.\(^2\)

Market design, ownership, and regulation of storage electricity

China categorizes energy storage into transmission and distribution assets, and grid companies are responsible for the construction of PSH plants. In China, the two state-owned grid companies are in charge of building, owning, and operating PSH. In 2014, the annual revenue of State Grid Corporation of China was US $333.4 billion. This financial depth allows for making huge financial undertakings in pumped storage projects. While many other countries categorise energy storage as power generation assets, they all face challenges with ensuring revenue certainty of energy storage.

Remuneration details of PSH stations

At present, there are a number of different revenue models and pricing mechanisms for the pumped storage projects in China:

**Capacity-based Lease Arrangements**

- Under this lease arrangement, an annual payment to the project owners is set to rent the facility to the grid company. The payment covers the total costs of the project (excluding the cost of electricity in pumping operation) and taxes, and generates approximately 5% rate of return.\(^3\) The amount of

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\(^2\) National Energy Administration: Resource Census Result Publishment of the Seawater pumped hydro storage(国家能源局关于发布海水抽水蓄能电站资源普查成果的通知) [http://zfxxgk.nea.gov.cn/auto87/201704/t20170405_2763.htm](http://zfxxgk.nea.gov.cn/auto87/201704/t20170405_2763.htm)

payment is irrespective of the amount of electricity generated, and the fluctuation of electricity price allows the grid operator to dispatch the pumped storage station in the manner that provides most benefit to the system. A number of pumped storage plants such as Guangdong Conghua (广东从化), Guangdong Huizhou (广东惠州), Shandong Tai’an (山东泰安), Hebei Zhanghewan (河北张河湾) and Shanxi Zilongshi (山西西龙池) have adopted this business model.  

**Generation-based Feed-in Tariff**

- The generation-based tariff mechanism can be used by pumped storage projects owned by IPPs or grid operators. Under this arrangement, the State Department sets a generation-based tariff for each pumped storage project with the aim of covering the project’s total construction and operation costs. For example, the Beijing Shisanling Pumped Storage Station (北京十三陵抽水蓄能电站), and Xianghongdian Pumped Storage Station (响洪甸抽水蓄能电站) each have a generation-based tariff of 0.8 RMB/kWh and 0.85 RMB/kWh respectively. Under this mechanism, project owners are motivated to increase revenue by generating more; whereas other services such as frequency response, voltage support, and operating reserves are not properly rewarded which can lead to the under-utilisation of PSH ancillary services. 

**Two-part Tariff**

- The two-part tariff is a combination of a fixed annual capacity-based payment and generation-based tariff, where both are approved by the NDRC (National Development and Reform Commission). The capacity payment will recover the majority of the fixed costs and related taxes, as well as the risk-return rate at 1% to 3% higher than risk-free rate (long-term government bond interest rate). The capacity payment also reflects the value of ancillary services provided e.g., system reserves, frequency and voltage regulations and black start capabilities. The generation tariff is designed to make up for the variable costs in operation, such as pumping and generation losses. Usually, the pumping cost is around 75% of the local coal-fired power benchmark electricity price. This mechanism can help to reduce investment risks and guarantee a reasonable rate of return, as well as to encourage the full utilisation of various ancillary services provided by pumped storage. This model is currently adopted in Zhejiang Tianhuangping Pumped Storage Power Station.

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In accordance with the Notice on Issues Concerning Improving the Price Forming Mechanism of Pumped Storage Power Plants issued by the National Development and Reform Commission in 2014, a two-part tariff system shall be implemented for pumped storage power stations before the establishment of competitive electricity spot market and ancillary service markets. China will gradually introduce benchmark capacity tariff prices for newly commissioned PSH stations. The capacity tariff and variable cost incurred shall be remunerated by the operational cost of the power grid at provincial level, and thus the electricity sales price shall be adjusted accordingly.

**Status of PSH under constructions or planning**

With the adjustment of China's social and economic structure and the improvement of people's living standard, consumers' demand for the power grid is getting higher. With the rapid development of renewable energy, such as solar energy and wind power and large-scale grid connections, the impact of uncertainties and intermittence on the power grid will be greater. With the implementation of trans-regional, large-scale, long-distance, and high-voltage power transmission planning, the problem of power network security will become more prominent. With the goal of creating a smart grid with a high degree of security, flexibility, adaptability and economic efficiency, the characteristics of PSH are destined to be one of the most effective means of solving these problems, and it is imperative to ensure a proper proportion of PSH in the power grid.

According to 2017 statistics, the capacity of China's PSH in operation reached 28,490 MW and the capacity of PSH under construction reached 38,710 MW. According to the national energy development plan, 60,000 MW of PSH plants have been started during the 13th Five-Year Plan period, which will reach about 62,000 MW by 2025 and 120,000 MW by 2030.

**Challenges, barriers and emerging opportunities for pumped storage development**

There are three problems in the development of PSH in China:

1) There is geographic mismatch between market demand and distribution of power plant resources;
2) The insufficient electricity price mechanism affects PSH operation;
3) The lack of supporting policies affects the healthy development of PSH.

Among those problems, the policy-based pricing system is the biggest obstacle for enterprises to develop PSH. The peak-valley pricing mechanism is not suitable, and the two-part pricing system is not fully implemented, which is not conducive to the development of PSH.

As the economic development shifts from a phase of rapid growth to high-quality development, energy consumption per unit of GDP has declined, and the growth of electricity demand has slowed down.

While some people believe that the most important role of PSH is to participate in the peak regulation of renewable energy, at present, there is an excess of renewable energy generation, and wind and solar power curtailment is very common. The economic benefit of PSH cannot be guaranteed, which greatly reduces the interest of enterprises on PSH investment and construction.

**Recent policies on PSH and its influence**

At present, PSH projects are mainly built and managed by the power grid, and a diversified market-oriented investment system has been established to introduce social capital.

On May 24, 2019, the National Development and Reform Commission and the National Energy Administration jointly issued the Measures for Cost Supervision and Examination of Electricity Transmission and Distribution
Pricing, which clearly stated that "the cost of PSH, electric energy storage facilities and power plants with a verified [feed in tariff (FiT)] that are owned by the grid shall not be included in the cost of transmission and distribution pricing". Before electricity marketization, the electrical capacity charge and pumping loss of PSH are remunerated by the operation cost of local provincial power grid (or regional power grid).

In May 2021, the National Development and Reform Commission (NDRC) of China released a new policy paper for the consolidation of pumped storage pricing mechanism and suggested to carry out further and optimize the two-part tariff mechanism based on capacity and energy.\(^{14}\)

In September 2021, China also set the target to put into production 120 GW of PSH by 2030 and develop a modern PSH industry system with advanced technology and management structure, which represents a fourfold growth in 10 years.\(^{15}\)

China will continue to adjust and improve the electricity pricing mechanism and formulate auxiliary service policies for the power system in line with the reform process of electricity market, so as to form an operation mechanism for PSH in which the market plays a decisive role.

**Newly operated PSH and its financial and project supports.**

According to statistics, by the end of 2019, there were 31 PSH facilities in operation nationwide, with a capacity of 29,990 MW, among which 26 were owned by power grid enterprises, with a capacity of 27,040 MW, accounting for more than 90% of the total capacity. This means that the investment in PSH lacks diversity. From the operational perspective, the PSH in operation faced, or will face, the problem of unrecoverable operation costs. If the current policy continues, the power grid enterprises are unable to continue to invest.

At the end of 2020, Hunyuan Pumped Storage Power Station Project in Shanxi, Pan’an Project in Zhejiang and Tai’an Phase II Project in Shandong were started. The three PSH plants have a total investment of RMB 26.717 billion and a total installed capacity of 4,500MW. The Hunyuan Pumped Project in Shanxi and Pan’an Project in Zhejiang are scheduled to be completed and put into operation in 2028, and the Tai’an Phase II Project in Shandong is scheduled to be completed and put into operation in 2029.

**Recommendations**

- Explore the technical feasibility of the hybrid of wind plus PHS, nuclear plus PHS and thermal plus PHS so as to achieve comprehensive benefits such as energy storage, reduction of coal consumption, energy saving and emission reduction.

- Conduct research on optimizing the operational mode of existing hydropower stations to enhance the stability of the power grid as a regulating power station and serve as an energy storage facility.

- Accelerate the economic compensation mechanism for the auxiliary services such as emergency standby, frequency regulation, phase modulation, black start, and energy storage of PSH plants in the power grid, in order to introduce a trading mechanism for PSH’s service of peak load regulating capacity and other auxiliary services in the power system.

\(^{14}\) https://www.ndrc.gov.cn/xxgk/zcfb/tz/202105/t20210507_1279341.html

\(^{15}\) http://www.nea.gov.cn/2021-09/09/c_1310177087.htm