Journal of Electronic Research and Application, 2026, Volume 10, Issue 7
http://ojs.bbwpublisher.com/index.php/JERA
Online ISSN: 2208-3510
Print ISSN: 2208-3502

The Peak Regulation Role and Application Prospects of Pumped Storage in the Construction of a New Power System

Boxuan Huang

School of Electrical and Power Engineering, Hohai University, Nanjing, 211100, China

Abstract: Against the background of the dual-carbon goals and sustainable development, renewable energy, as a substitute for traditional energy, accounts for an increasing proportion in the new power system. With the advantages of sustainability, low-carbon and environmentally friendly characteristics, it has become an important branch of the new power system. However, new energy power generation has caused a large waste of energy and electricity due to geographical, climatic, demographic, and economic factors. More seriously, extreme changes in climate are extremely detrimental to the stability of the power grid and the safety of generators. Based on domestic and foreign literature, this article reviews the role and application prospects of pumped storage technology in peak regulation in new power systems. Research shows that pumped storage technology can use water, a clean energy source, to store and release the electricity generated by new energy as a "natural battery" in a timely manner, so as to play the role of storing electricity during low-load periods and supplying electricity during peak-load periods. This research can provide theoretical reference for the study of solving the problem of power grid instability in new power systems.

Keywords: Pumped storage; New power system; Wind and photovoltaic power curtailment; Peak regulation

Online publication: Aug 13, 2026

1. Introduction

With the introduction and implementation of the carbon peaking and carbon neutrality goals, new energy power generation has received great attention. New energy power generation has more environmental protection advantages than conventional coal-fired power generation, which can reduce carbon dioxide emissions and reduce the release of harmful pollutants and particulate emissions; Secondly, it can reduce excessive dependence on fossil energy, which is conducive to maintaining national energy security and promoting sustainable development; In addition, we can promote the deep integration of new energy power generation and power systems, and promote the overall technological innovation [1]. Among them, wind power generation and solar power generation account for the largest proportion. As representative clean

energy sources, wind energy and solar energy play a crucial role in gradually replacing traditional power generation and reducing carbon emissions.

However, against the background of the rapid development of the new power grid, it should be recognized that the new power system still has some problems that are difficult to solve at present. Among them, system stability and security issues are particularly prominent. New energy power generation such as wind power and photovoltaics is greatly affected by natural conditions. The power generation of new energy is easily affected by natural changes and the seasonality of major energy sources on a time scale, and is also affected by its spatial availability [2]. Sudden changes in load and the surge or drop in "power supply" will cause problems such as power grid frequency and voltage fluctuations. At the same time, the volatility of new energy power generation will interfere with the evaluation of its market value, thus affecting electricity prices. Therefore, how to solve a series of technical and social problems caused by the mutation of the "inertia" of new energy power generation has become the primary task in the construction of the new power system.

Hydropower is one of the most widely used and technologically mature renewable energy application technologies [3]. As a technology that converts water energy into electricity, hydropower has the advantages of flexible dispatching and high efficiency. Today's research on hydropower technology continues to advance: in terms of equipment, the research of high-head Pelton turbines significant progress has been achieved, and the application of variable-speed pumped storage units has been completed; Ecological aspect: fish-friendly turbines (including finer blades, higher speed and more compact structure), fish passage facilities and other technologies and equipment to protect the direction of fish have been studied [4]. Multi-energy complementarity: the integrated development of hydropower, wind power, photovoltaic power, and energy storage systems in river basins is continuously progressing. Pumped storage power plants can use hydropower technology as an important solution in the construction of new power systems. A pumped storage power station is essentially a hydroelectric power station, and the principle of hydropower is also applied. Pumped storage can act as a "secondary power supply" in the new power system. It can store energy by pumping water during low-load periods and generate electricity by releasing water during peak-load periods. It can flexibly adjust the voltage fluctuation and power grid frequency in the new power system to ensure the stable operation of the new power system.

Based on the general lack of system stability in the new power system, this article reviews the peak regulation role and application prospects of pumped storage. It will explain the universality of the phenomenon of wind and photovoltaic power curtailment, the working principle and classification of pumped storage, the outstanding advantages and application potential of the traditional peaking method, the successful operation of pumped storage in China, and the future development direction of pumped storage.

2. Wind and photovoltaic power curtailment and the principle and development status of pumped storage as a solution

2.1. The increasingly significant problem of wind and photovoltaic power curtailment caused by instability in the new power system

In recent years, the proportion of installed capacity of wind and solar power generation in China has increased year by year. However, geographical and population restrictions have caused significant energy waste and electricity. According to the 11th Annual Bulletin of *China Wind and Solar Energy Resources issued by the China Meteorological Administration and the Wind Energy Solar Energy Center, the areas with the richest*

solar energy resources in China are distributed in most of Tibet, north-central Qinghai, and western Sichuan. The area with the richest wind energy is the "Sanbei Region". The common feature of these areas is that they are vast and sparsely populated, economically backward, and cannot effectively use the electricity generated. At the same time, the power generated by wind turbines and photovoltaic systems cannot be integrated into the power grid because it cannot be sent or stored, resulting in a waste of energy. It is worth noting that wind energy and solar energy are highly dependent on changes in the natural environment, and traditional generator rotors cannot synchronize the rotational inertia of these extreme changes. In order to protect the stability of the power grid and the safety of the generator, we have to stop power generation and other similar behaviors that cause "wind and photovoltaic power curtailment".

2.2. Working principle and classification of pumped storage

2.2.1. Working principle of pumped storage power stations

As a special hydropower station, the outstanding feature of the pumped storage power station is that there are upper and lower reservoirs, which can be regarded as the positive and negative poles of the battery. Wind power installation and photovoltaics can be used as the power supply for batteries, and the users of electricity are electrical appliances in the circuit. At the peak of electricity consumption, electricity generated from wind and photovoltaic power can be directly supplied to users; when the electricity consumption is low, there is no need to stop the operation of the generator. You only need to use electricity to lift the water from the low-altitude reservoir to the high-altitude reservoir, and the excess electricity generated will be converted into the gravitational potential energy of water for storage. When the power grid load becomes higher, this part of the water can be released from the upper reservoir and generated through turbines to supplement the vacant power. Make full use of the excess electricity generated by new energy power generation, and at the same time avoid insufficient power and even large-scale power outages in some areas caused by insufficient new energy power generation.

2.2.2. Classification of pumped storage power stations

In the water conservancy industry, the type of pumped storage power station is usually classified according to the presence or absence of natural runoff. Due to the different geographical conditions and functional needs of different regions, pumped storage power plants are divided into three categories, which will be described one by one below.

Pure pumped storage is the most common and mainstream pumped storage method at present. This method does not need to rely on runoff. It is only necessary to build the upper and lower reservoirs to form a height difference, and use its water circulation to achieve peak regulation and frequency regulation of the new energy power generation system. This kind of pumping equipment has strong adjustment ability to the power grid, and by using natural or existing artificial water bodies, there is no need to cut off natural rivers, which is environmentally friendly and conducive to ecological stability. More importantly, the site selection is flexible and does not need to rely on natural rivers.

Hybrid pumped storage is a hydroelectric power station with the functions of both pumped storage and runoff power generation. This method requires the existence of natural runoff near the upper reservoir, and conventional power generation can also be carried out while pumping and storing energy to achieve dual functions. This method can improve the utilization rate of water resources. While pumping electricity and

releasing electricity to generate electricity, natural runoff can be used to generate electricity, so that water resources can be used twice, and the power generation capacity is significantly higher than that of pure pumped storage.

Cross-basin water transfer to pump water and store energy. The cross-basin water transfer project is to guide the water resources from areas with abundant and surplus water resources to the areas where water resources are scarce [5]. For example, the northwestern region of China is rich in wind and light energy resources, and there are a large number of wind turbines and photovoltaic power stations. However, the shortage of water resources makes it difficult for the region to construct traditional pure pumped storage power plants to adjust the peak of new energy power generation. Therefore, the water transfer project has become the key to solving this problem. It is a way to realize the utilization of water resources in different time and space, effectively improving the utilization rate of water resources.

2.3. Advantages of pumped storage compared with traditional peak regulation methods

After the large-scale grid-connected new energy, its volatility and intermittency affect the stable operation of the power system, and thermal power generation, as a stable, controllable, adjustable, and mature power generation method, is widely used in new power systems as the most traditional peak regulation method. However, this peak regulation method has shortcomings that cannot be ignored, three of which are extremely detrimental to the health of the power system and contrary to the purpose of environmental protection and green energy. First, in the process of deep peak regulation, thermal power units will face a series of energy efficiency loss problems, especially when the unit is in low-load operation, the power generation efficiency, combustion efficiency and internal efficiency of various equipment such as boilers, turbines and generators will decrease significantly, resulting in lower energy conversion rate and greater energy consumption [6]. Second, the frequent change of load aggravates the loss of equipment. The sudden drop in load causes violent fluctuations in the processing of the coal grinder, which can easily cause the combustion port to be blocked, thus causing large-scale fires [7]. Third, the carbon emission problem of traditional thermal power generation is still difficult to ignore. At present, thermal power plants are still the main body of the national carbon market and face great pressure to reduce emissions, and incomplete combustion caused by lowering the combustion temperature during deep peak regulation will cause sulfide and a large number of solid small particle emissions [8]. In response to these problems, hydropower has corresponding advantages. First, changes in hydropower load will not cause excessive temperature changes. Just change the opening degree of the water flow channel to reduce energy consumption; Second, there is no high-temperature flammable medium in the hydropower peak regulation equipment, and the variable load will not cause sudden temperature changes, so it is not easy to cause fire; Third, compared with the traditional peak regulation method, carbon emissions are significantly reduced and basically do not produce harmful gases and small solid particles diverge in the air.

2.4. Typical cases of successful pumped storage power stations for peak regulation in China

In 2022, the Yangjiang Pumped Storage Power Station of China Southern Power Grid Peak Regulation and Frequency Modulation Power Generation Co., Ltd. officially lowered the floodgate to store water. The pumped storage power station is located in Bajiashan District, Guangdong Province. The height difference between the upper and lower reservoirs is 670 m, and the maximum moving water pressure in the lower flat hole and the fork section is as high as 11 MPa. Among them, many indicators, such as large capacity and

high speed, have reached the international lead. It plays the role of peak regulation in the power grid. After the first phase of the project is put into operation, it is expected to save about 165,500 tons of standard coal every year, reduce carbon dioxide emissions by 413,800 tons, and reduce the emission of harmful gases such as sulfur dioxide by 0.18 million tons [9]. At present, the unit starts up an average of 9 times a day, running at full load for more than 9 hours, and the power generation capacity is about 6.2 million kWh. The full-loaded water volume of the reservoir has accumulated enough energy for the peak of power generation, which can meet the peak electricity demand of nearly 600,000 residents.

In April 2026, three units of Zhejiang Tiantai Pumped Storage Power Station were put into operation. At present, as the pumped storage power station with the largest single capacity in China, it undertakes the role of power grid peak regulation, valley filling, frequency regulation, energy storage, and so on in East China. The annual power generation during peak-load periods of the pumped storage power station is about 1.7 billion kWh, and the annual pumping electricity consumption during valley-load periods is about 2.26 billion kWh, and the conversion efficiency basically reaches the typical pumping level. It will be of great significance to promote the consumption of new energy, optimize the regional power supply structure, ensure the safe and stable operation of the power grid, promote regional economic development, and realize the national strategic goal of "carbon peaking and carbon neutrality".

2.5. Problems and future development directions of pumped storage

First of all, the hydraulic conditions are not stable under natural conditions. Many new interference sources will lead to frequent start-ups and shutdowns, and speed changes, which is not good for the ideal operating state of conventional units; Secondly, hydraulic machinery is a typical flow-solid coupling system. The coupling of fluid in terms of inertia, damping, and elasticity will lead to changes in the original properties of mechanical parts and induce the resonance of components, which is not conducive to the health of the unit equipment. Therefore, on the basis of meeting the relative safety and stability, the hydroelectric power unit still needs to improve the flexibility requirements in the face of complex working conditions. Therefore, the future development direction of pumped storage is concentrated in the following points: First, enhance the research on the hydraulic stability of hydroelectric units, and find a new evolutionary law of hydraulic stability of variable-speed units under the action of guide blade and speed adjustment; Second, strengthen the improvement of hydraulic resource development technology. Because China's low-head and large-flow-rate economically developable hydropower resources have been exhausted, Pelton turbines have significant advantages in high-flow and low-flow water energy utilization. Therefore, Pelton turbines can be used as the in-depth research direction of China's pumping units, and find a way out in this direction to solve the peak regulation problem; Third, use modern three-dimensional modeling technology to model the water feed mechanism of the turbine. Through the reasonable design of the water feed structure, it can better guide and distribute the water flow and promote the uniformity of the water flow [10].

3. Conclusion

Through the expansion of the scale of new energy power generation and the construction of new power systems under the background of the carbon peaking and carbon neutrality goals, this article deeply analyzes the underlying reasons for the problem of wind and photovoltaic power curtailment caused by the instability of new energy power generation, and then explains the working principle and feasibility of pumped storage

as a method to solve the problem of wind and photovoltaic power curtailment, analyzes the advantages of pumped storage as a peak regulation method compared with the traditional peak regulation method, and lists two representative pumped storage power plants in China. Through this analysis, we found that pumped storage is an effective solution to the problem of peak regulation in new power systems, and the research on pumped storage should strive to improve flexibility in the face of complex working conditions. These findings are conducive to improving pumped storage equipment and technology, improving the ability to respond to emergencies and the level of peak regulation, thus helping to accelerate the achievement of the dual-carbon goal. This study can provide a reference for researchers and engineers in the field of pumped storage and renewable energy engineering. In the next ten years, pumped storage will increase the proportion of peak regulation applications and make great contributions to China's construction of a new power system.

Disclosure statement

The author declares no conflict of interest.

References:

[1] Yu J, 2025, Discussion on the Application of New Energy Power Generation in Power Systems. Papermaking Equipment & Materials, 54(9): 106–108.

[2] Vilanova N, Flores T, Balestieri J, 2020, Pumped Hydro Storage Plants: A Review. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 42(8): 1513–1524.

[3] Pan Q, Zou W, Zhang D, et al., 2026, A Novel Fish-Friendly-Twisted Blade Towards Low-Head Pumped Hydro Storage: Assessment of Flow Distortion-Induced Energy Loss and Operational Instability. Energy, 348: 140602.

[4] He R, 2025, Review of the Application of Meteorological Technology in the Hydropower Industry. Hydropower and New Energy, 39(7): 32–35.

[5] Huang J, Huang J, Lin X, et al., 2020, Joint Operation of Cascade Hydropower Stations Based on Inter-Basin Water Diversion. Journal of China Three Gorges University (Natural Sciences), 42(6): 28–32 + 39.

[6] Shan C, 2025, Mechanism of Energy Efficiency Loss and Energy-Saving Compensation Technology During the Whole Process of Deep Peak Regulation of Thermal Power Units. Energy Conservation, 44(9): 32–35.

[7] Li J, 2026, Research on Safety Operation Guarantee Technology of Fuel Coal Conveying Systems in Thermal Power Plants Under Deep Peak Regulation Conditions. Electrical Technology and Economy, 2026(3): 158–160 + 164.

[8] Shan S, Liu H, Liu M, et al., 2024, A Review of Carbon Footprint Assessment of China's Thermal Power Industry. Power Generation Technology, 45(4): 575–589.

[9] Electric World Editorial Department, 2021, The Pumped Storage Power Station with the Largest Single-Unit Capacity and Fully Domestically Produced Equipment in China Officially Begins Reservoir Impoundment. Electric World, 62(9): 56.

[10] Qiao X, Luo H, Su A, 2026, Analysis of Energy Loss in the Water Supply Mechanism of Plateau Pelton Turbines. Electric Power Equipment Management, 2026(8): 188–190.