Discussion on the development direction of hydropower in China

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Abstract

Hydropower is the second largest conventional energy resource in China. It is a renewable energy with mature technology, flexible operation, cleanliness and low carbon. A hydropower project has flood control, a water supply, navigation, irrigation and other comprehensive utilization functions. The new era in China is guided by the new energy-security strategy of 'four revolutions and one cooperation' and the new development concept of 'innovation, coordination, green development, openness and sharing'. According to the dual nature of water and electricity, this paper deepens the basic understanding of hydropower from the experience of the world, the difficult problems of hydropower in China and the long-term development of hydropower enterprises. The future direction of hydropower development is explored from the following aspects: high-quality development of follow-up hydropower projects, innovative utilization of existing hydropower value, creative pursuit of hydropower-benefit growth and high-level promotion of hydropower international cooperation.

Graphical Abstract

Keywords: hydropower; high quality; hydropower enterprise; the development direction
Introduction

For the sustainable development of mankind, the development of renewable-energy technologies with low cost and high efficiency will guarantee the world-energy transformation and the direction of human society towards clean and low-carbon development. Hydropower is an important clean and renewable-energy resource, which plays an important role in the energy system of China and the world. China is rich in hydropower resources, and the rational development and utilization of hydropower resources is an inevitable choice to ensure energy supply, cope with climate change and achieve sustainable development. According to China’s 13th Five-Year Plan for hydropower development, the installed capacity of hydropower resources in China is ~660 million kW and the annual generating capacity is ~3 trillion kWh. In 2019, the total installed capacity of hydropower in China was ~356 million kW and the hydropower-development degree of China was 40% (calculated by generating capacity), which is still far behind that of developed countries. Hydropower, as the second largest conventional energy resource in China, is a renewable-energy source with mature technology, flexible operation, cleanliness and low carbon, and has comprehensive utilization functions such as flood control, water supply, shipping and irrigation. At present, China has entered a new stage of high-quality development. It has become the consensus of Chinese society to promote green development and promote harmonious coexistence between man and nature. The Chinese government has put forward a new energy-security strategy of ‘four revolutions and one cooperation’ and a new development concept of ‘innovation, coordination, green development, openness and sharing’. In this new situation, according to the dual basic properties of hydro and the power of hydropower, it is of great significance for us to summarize the development history of hydropower in China and study the development direction of hydropower in the future. This paper will discuss the development status of hydropower, the basic understanding of hydropower development and the possible direction of hydropower development in China, and put forward the idea of sustainable development of hydropower in China.

1 Development status of hydropower

1.1 World hydropower resources and development status

According to the 2011 statistics of the International Journal on Hydropower & Dams, the theoretical reserves of global hydropower resources are >4.02 × 10^7 GWh. The technological exploitability (i.e. the amount of hydropower resources that can be developed and utilized under the current technological level) is >1.46 × 10^8 GWh. Economic exploitability (the amount of hydropower resources with economic-development value under current technological and economic conditions) is >8.7 × 10^6 GWh. According to the 2019 Hydropower Status Report released by the International Hydropower Association, global hydropower capacity climbed to 1292 GW in 2018. China (352 GW), Brazil (104 GW), the USA (103 GW), Canada (81 GW), Japan and India (each 50 GW) are the top five countries in the world with installed hydropower capacity [1]. In 2018, hydropower generated 4.2 × 10^10 GWh, accounting for 16% of the global total of 2.67 × 10^10 GWh. In terms of the development level, by the end of 2018, the global development level of conventional hydropower resources was 27% of the technical exploitation amount (calculated by generating capacity) and the development level of hydropower on each continent is shown in Fig. 1. Developed countries generally have a higher degree of development of hydropower resources, as shown in Fig. 2. The average degree of development is ~80%.

1.2 China’s hydropower resources and development status

China’s total remaining recoverable reserves of conventional energy (hydropower is a renewable-energy source calculated by 100 years of use) comprise 61.6% raw coal, 35.4% hydropower, 1.4% crude oil and 1.6% natural gas. Hydropower ranks second only to coal among China’s conventional energy resources and is also an important part of renewable energy. China ranks first in the world in total hydropower resources and development volume. According to the 13th Five-Year Plan for hydropower development released by the National Energy Administration in China, the exploitation installed capacity of hydropower resources in China is ~660 GW and the annual generating capacity is ~3 × 10^6 GWh. China’s hydropower resources are concentrated in the south-west, accounting for two-thirds of the country’s total. Tibet province, Sichuan province and Yunnan province were in the top three, with the Jinsha River, Yalong River, Dadu River, Lancang River, Wujiang River, Upper Yangtze River, Nanpanjiang River, Hongshui River, upper Yellow River, Nu River, lower Yarlung Zangbo River and 10 other basins.

After >100 years of development, by the end of 2019, China’s total installed hydropower capacity was ~356 GW (including 30 GW of pumped-storage capacity) and the annual generating capacity was ~1.3 × 10^6 GWh (shown in Table 1). They accounted for 17.73% and 17.77% of the national total, respectively. China’s hydropower-engineering technology ranks at the world’s advanced level and has formed the ability to integrate the whole industrial chain, including planning, design, construction, equipment manufacturing, operation and maintenance. China ranks as first in the world in terms of total hydropower resources, installed capacity and annual electricity generation. China has established long-term cooperative relations with >80 countries in hydropower planning, construction and investment, and is a major force in promoting hydropower development in the world. The degree of hydropower development in China is 40% (calculated by power generation), which is still far
The development of hydropower on all continents

Fig. 1: The development of hydropower on all continents

Hydropower development ratio in major developed countries

Fig. 2: Hydropower development in major developed countries

Table 1: China’s installed power supply and generation capacity in 2019

| Power types    | Installed capacity (104 kW) | Installed proportion | Annual energy output (102 GWh) | Power proportion |
|----------------|-----------------------------|----------------------|---------------------------------|------------------|
| Hydropower     | 35 640                      | 17.73%               | 13 019                          | 17.77%           |
| Thermal power  | 119 055                     | 59.21%               | 50 450                          | 68.87%           |
| Nuclear power  | 4874                        | 2.42%                | 2950                            | 4.03%            |
| Wind power     | 21 005                      | 10.45%               | 4057                            | 5.54%            |
| Solar power    | 20 468                      | 10.18%               | 2238                            | 3.06%            |
| Total          | 201 066                     | 100.00%              | 73 253                          | 100.00%          |

*The data are provided by the 2019 National Power Industry Statistics Bulletin of the China Electricity Council [2].
behind that in developed countries and still has a broad development prospect.

2 Basic understanding of hydropower development

2.1 World hydropower-experience enlightenment

2.1.1 Hydropower is an important renewable energy to ensure energy security
First of all, hydropower is a comprehensive energy. Hydropower has accounted for >15% of the world’s electricity supply for >50 years. Experience in developed countries has shown the contribution that hydropower can make to social development. Through hydropower development and industrialization, some developing countries have achieved the goals of poverty alleviation and economic growth. Second, hydropower is the energy with the highest payback ratio [3, 4]. The energy-payback ratio is the ratio of all the energy produced by a power station during its operation period to the energy consumed to maintain its construction, operation and demolition during its construction, operation and termination periods. Third, the development of wind power and solar energy in developed countries is based on the priority and full development of water energy. Wind power and solar power are perfect partners. The intermittent deficiency of the former can be remedied through hydropower and become stable and high-quality energy.

2.1.2 Hydropower and water conservancy are closely related
First, the percentage of hydropower development should match the capacity of water-resources regulation. The gap between China’s capacity and that of developed countries is very large, which is reflected in the level of per-capita storage capacity. The average for developed countries is 3184 m³, compared with 4245 m³ for the USA and 692 m³ for China. With sufficient reservoir capacity and storage capacity, the USA can absorb more floods and withstand more severe droughts [5]. Second, hydropower development should be in line with local resources, and economic and social conditions. From 1933 to 1950, the comprehensive hydropower-development project in Tennessee Valley in the USA was basically completed. More than 50 cascade hydropower stations (>90% developed) realized multiple social benefits such as flood control, power generation, navigation, water supply and irrigation, guaranteeing the rapid development of the local economy [6].

2.1.3 Hydropower development can be in harmony with the ecological environment
First, there is no natural irreconcilable contradiction between hydropower development and ecological environment. More than 50 countries in the world account for >50% of electricity generation. The good ecological environment of many developed countries benefits from the full development of hydropower. It is a misunderstanding that hydropower development will inevitably lead to the deterioration of the environment and the deterioration of water quality [7]. Second, the original ecology of the natural environment is not ecological civilization. The Danube, the Rhine, the Mississippi and other famous rivers have been fully developed with cascade hydropower. The ecological environment of the rivers has not been destroyed because of being cut off; instead, a series of lakes have formed and become scenic spots. On the contrary, many developing countries with slow hydropower development are experiencing frequent floods of so-called original ecological rivers [8]. Third, to address climate change and meet emission-reduction commitments, it has become an international consensus to give priority to the development of clean energy, including hydropower. The resource endowment and rapid development of hydropower have become the basic guarantee for China to meet its emission-reduction commitments as well as the Paris Agreement. Fourth, Europe and the USA have never entered the ‘era of dam removal’, but are constantly consolidating and strengthening dam construction. About 1150 dams have been dismantled in the past 100 years, all of which are dams that have a height of <20 m, small installed capacity and are basically decommissioned. Over the past 10 years, >50 dams have been built in the USA—far more than the number of dams removed during the same period. Fifth, the green hydropower mechanism is worth promoting. Through comprehensive assessment and effective management of the risks brought by hydropower stations to the surrounding residents and ecological environment, the Swiss green hydropower certification system minimizes and controls the adverse impact and actively guides the market to absorb green electricity [9].

2.2 Difficult issues with hydropower in China

2.2.1 Ecological environment
On the whole, a hydropower station does more good than harm to the ecological environment. Due to the understanding of the stage of economic development, the early development of individual hydropower stations did not pay enough attention to the value of the ecological environment, which not only played an important role, but also caused some environmental damage. This kind of damage is mainly manifested as follows: unreasonable diversion development and operation leading to intermittent breaks in local river reach, dams blocking fish-migration channels, reservoirs inundating fish-spawning fields and water ecological degradation of local river reach. In the follow-up work, it is necessary to improve the coordination mechanism of hydropower development and the ecological environment, and implement the overall plan and action plan for watershed ecological protection and restoration, aiming at the overall and cumulative impact of cascade development.
2.2.2 Resettlement
Land acquisition and resettlement for hydropower projects are often multiprocedural and heavy in workload. Most of the flood areas are economically underdeveloped, with multi-industry coordination and long implementation cycles, and they are greatly affected by price changes and policy adjustments. However, hydropower development is packed with great opportunities for local economic and social development. Nowadays, many people involved in hydropower development often want to be resettled but, if the compensation costs or related demands have not been fully met, they will always find various reasons and express their demands in various ways. As a result, the construction schedule of some hydropower projects has been affected, some families have not been relocated after the reservoir is filled and some resettlement areas have had difficulties in production and development. In the follow-up work, it is necessary to improve relevant policies and standards, deepen the design work of land expropriation and migration, improve the coordination and implementation of the guarantee mechanism of land expropriation and migration, and innovate the benefit-sharing system of hydropower development and resettlement.

2.2.3 Safety emergency
The hydropower industry has established a strict safety-guarantee system, covering the planning, design, construction, acceptance, operation and other stages of the whole life cycle of the project. At the same time, it covers different types of disaster factors such as earthquake, flood and local disaster. Hydropower projects are designed and built to high-quality standards, often much higher than those of other types of infrastructure projects, although ground disasters can be handled safely by reasonable dispatching and all-out rescue. However, from the perspective of being safer, more economical and more efficient, it is necessary to establish an integrated management mechanism of river-basin safety and dispatch, and coordinate the work of safety management, information sharing, flood control and emergency management.

2.3 Long-term development of hydropower enterprises

2.3.1 Project investment
The engineering characteristics of hydropower stations determine that hydropower-project investment has the characteristics of large amounts, pertinence, difference, openness, dynamism and complexity. The problem of investment control is that it is difficult for project owners to control investment in an all-round and full cycle effectively (especially the investment in land acquisition and resettlement). ‘Over budget’ often occurs, which increases the development cost. The reasons are as follows: on the one hand, it is due to the changes in regulations and policies, the increasing demands of all parties, the deterioration of construction conditions, the insufficient design accuracy and depth, the increase in uncertainties such as rising prices and the power market, natural environmental risks and industry monopoly; on the other, for hydropower, it is often required to undertake comprehensive utilization tasks such as flood control, irrigation and navigation, and this part of the investment is not reasonably apportioned [10]. Despite the above problems, we should have a clear understanding of hydropower-project investment: scarce hydropower resources should be developed as an important strategic investment project. Early development is an effective means to reduce life-cycle investment. Improving the quality of preliminary work is the foundation of investment control. Strengthening land acquisition and immigration is the focus of investment control. Rapid response and overall planning and coordination are important methods of investment control, which urgently need scientific coordination of the long-term and short-term benefits.

2.3.2 Economic evaluation
At present, the on-grid electricity price of hydropower projects in China is the lowest among thermal power, wind power, solar power, biomass power and other power sources. Under the current electricity-price mechanism, hydropower projects with good economic benefits have been developed. The hydropower project to be developed is bound to have poor benefits, so enterprises have great difficulties in making investment decisions. Economic evaluation is the main basis for project-investment decisions. From the perspective of enterprises, they focus on financial evaluation and the internal rate of return on capital is the key indicator of profitability in financial evaluation. China’s large state-owned enterprises generally use it as the main basis for investment decisions. As hydropower projects are characterized by low operating costs and good cash flow, as long as the projects are put into operation normally, the long-term economic benefits are obvious [11, 12]. In addition, hydropower projects ensure the social benefits of comprehensive utilization of water resources, but it is difficult to quantify the social benefits as the economic benefits obtained by project owners.

2.3.3 Market consumption
In recent years, surplus water released from reservoirs occurred in Southwest Hydropower of China, which has a negative impact on the market consumption of hydropower. Taking the Sichuan Power Grid as an example in 2017, its main abandoned water is mainly concentrated in the Dadu River basin, accounting for >60% of the total abandoned water in Sichuan (55 billion kWh). This is mainly due to the centralized production of Sichuan hydropower, the electricity-market growth slowing down significantly, the construction of the transmission...
channel lagging behind, the partial section of the power grid being limited, the receiving end of the transmission not having a strong willingness to accept and other reasons. According to the analysis, in recent years, hydropower abandonment in Sichuan has been staged, temporary and low-level, caused by various factors. With the increase in the capacity of external transmission channels and the improvement in transmission-channel conditions in Sichuan, hydropower abandonment will be greatly alleviated. At present, the technological exploitability of Sichuan is 148 million kW, and 104 million kW has been built, accounting for 71% of the technological exploitability. Restricted by environmental requirements and technological and economic conditions, the actual development capacity is ~120–130 million kW. The remaining exploitable resources are mainly located in the middle and upper reaches of Jinsha River, Yalong River and Dadu River. It is predicted that Sichuan will reach the new power balance in 2025 and the hydropower development in Sichuan will be basically completed in around 2035. After 2025, the market consumption of Sichuan hydropower, one of China’s major hydropower provinces, is guaranteed. The consumption of hydropower in Tibet will be brought into the national power balance after 2025 with the construction of large-scale hydropower stations and delivery channels [13].

3 The future direction of hydropower development in China

3.1 Develop follow-up hydropower projects with high quality

3.1.1 Key area
According to China’s 13th Five-Year Plan for hydropower development, the total installed capacity of hydropower is expected to reach 380 million kW by 2020, including 340 million kW of conventional hydropower, 0.4 million kW of pumped storage and 1.25 trillion kWh of annual generating capacity. In 2025, China’s installed hydropower capacity will reach 470 million kW (including 380 million kW of conventional hydropower and ~94 million kW of pumped storage), generating 1.4 trillion kWh of electricity annually. At present, the key areas of hydropower development in China are Tibet (with 176 million kW of technological-development capacity) and Sichuan and Yunnan, which are mainly concentrated in the Jinsha River, Yalong River, Dadu River, Yarlung Zangbo River (including major tributaries), Lancang River and Nu River and other large river basins.

3.1.2 Development concept
Because the above basins are mainly in Tibetan areas, the ecological environment is very sensitive and the social environment is relatively special. Hydropower development needs to implement the requirement of a better combination of development and construction with ecological protection. In the development of hydropower in Tibetan areas, the principle of ecological priority, overall consideration and rational development will be followed, adhering to the new development philosophy of ‘innovation, coordination, green development, openness and sharing’, protecting the ecological environment and in land expropriation and resettlement for construction, giving consideration to energy-development strategies and economic and social development in Tibet, and rationally developing and utilizing hydropower resources.

3.2 Bring out hydropower value in an innovative way

3.2.1 Multi-energy complementation
Multi-energy complementation is to optimize the combination and allocation of hydropower, wind power, solar power, pumped storage, thermal power and other power sources so as to operate the power systems to complement each other and draw on each other’s strengths to better meet the power-load demand and ensure the safe and stable operation of the power grid. Conventional hydropower stations with regulating capacity, especially large hydropower bases, have set up cascade hydropower stations with multi-year regulation, annual regulation, seasonal regulation, weekly regulation, daily regulation, run-off and other ways in a reasonable way, and operate with wind-power and photoelectric compensation, so as to exert greater capacity benefits. The unit has a fast response speed, which can adapt to the fluctuation of wind power and photoelectric output, and ensure the safety of power-grid operation [14].

3.2.2 The dispatching of water
Water-resources shortage, and uneven spatial and temporal distribution are two of the major bottlenecks in China’s economic and social development. The groundwater in North China is seriously overexploited and depleted, and the task of water ecological restoration is very heavy. With the increase in population-bearing capacity, the contradiction between water supply and demand will be further aggravated. The pattern of water resources determines the pattern of development. Hydropower stations have the capacity of water storage and can play a greater role in water-resources regulation. China is working on the South-North Water Diversion Project, which will focus on water transfer along the Yangtze and Dadu Rivers. In addition, China has been actively promoting the joint operation of the Yangtze River, Jinsha River, Wu River, Dadu River, Yalong River and Yellow River to bring into full play the overall benefits of cascade hydropower development in the river basin.

3.2.3 Combined development of conventional hydropower and pumped-storage power stations
The combination of regular storage is the development of conventional hydropower and pumped-storage power...
stations, and the use of existing hydropower stations to add reversible units or expand installed capacity and add pumps to give conventional hydropower stations the function of pumped storage. There are generally three forms of development: one is to make use of the existing conventional hydropower-station reservoir as the upper reservoir and to build a new lower reservoir downstream; the second is the way of using the conventional hydropower-station reservoir as the upper reservoir of the pumped storage and the lower reservoir as the adjacent conventional hydropower-station reservoir or the newly built lower reservoir; third, in a conventional cascade power station that has been built, the underground powerhouse and water-conveyance system are excavated within the mountains on both sides by using two adjacent cascade reservoirs to build a pumped-storage power-station development mode [15].

3.2.4 Hydropower and the tourism industry
After the completion of the hydropower station, it will often form a scenic reservoir. The hydropower station itself also has the foundation for industrial tourism; the general natural and cultural landscapes along the hydropower basin gather together, and also have superior conditions for tourism development. Sichuan has issued the Guidance on Promoting the Integrated Development of Hydropower and Tourism Development, which points out that, with the development and production of hydropower bases along the Jinsha River, Yalong River and Dadu River, they have their own characteristics in the Panxi area and the Western Sichuan Plateau, which make people feel shocked and are very valuable tourism resources. Hydropower tourism plays an important role in enriching the people and promoting the development of characteristic industries, which is worthy of special attention.

3.3 Creatively seeking the growth of hydropower efficiency

3.3.1 Intelligent hydropower
At the 19th National Congress of the Communist Party of China, major strategic plans were made to build a strong internet, a digital China and a smart society. According to the characteristics of the enterprise management of CHN Energy Dadu River Hydropower Development Co., Ltd, the theory of intelligent enterprise was put forward to guide the intelligent management of enterprises. At the same time, according to the characteristics of hydropower enterprises, the construction method of four business units including intelligent power plants, intelligent maintenance, intelligent dispatching and intelligent engineering is proposed based on the system framework of smart enterprise, forming a new management system that integrates information technology, industrial technology and management technology [16]. China has numerous hydropower stations that can collect huge amounts of data from four operational units, establishing an analysis model and ‘cloud-brain’ platform for more scientific and efficient management, while achieving its own management benefits, constantly excavating and developing the digital economy model of the hydropower industry.

3.3.2 Clean trade
Carbon trading is a clean-development-market mechanism adopted to promote the global emission reduction of greenhouse gases and reduce global carbon-dioxide emissions. The world and China are also working hard to improve the clean-development mechanism. China has established the China Carbon Emission Reduction. Recently, the Ministry of Ecology and Environment has been organizing relevant units to carry out basic work according to the Provisional Measures for the Management of Carbon Emission Trading and the Construction Plan of the National Carbon Emission Trading Market (Power Generation Industry) [17]. At present, the global and Chinese carbon-trading markets are being demonstrated and prepared. Hydropower will reap steady benefits under the clean-energy-development mechanism and in carbon-trading markets.

3.3.3 Hydrogen production of hydropower
Hydrogen is a clean and efficient fuel, which cannot be produced, stored and transported at low cost on a large scale by existing technologies. Hydropower is cheap to go online during the wet season and there is water abandonment. The establishment of a trading platform for the production of hydrogen from abandoned water will provide hydropower enterprises with additional electricity-price income, power grids with additional overpass fees and hydrogen-production enterprises that can obtain cheap clean electricity and produce competitively priced hydrogen [18]. In addition, some hydropower stations can be jointly developed with hydrogen-production projects, so that hydrogen can be used as an energy-storage carrier. The combination of hydroelectricity and hydrogen energy can find a new growth point of benefit.

3.3.4 Energy management
In the future, China’s electricity-sales-company business model can learn from the world’s hydropower experience. Its core business is to sell electricity from the generation market and power companies to consumers. A value-added service is to provide users with optimization of electricity strategies and energy management and other services. Many foreign energy-management companies have emerged and many traditional energy enterprises, such as Schneider Electric, E.on, etc., are also transforming to energy management by using information technology [19]. In general, they integrate information, power, energy storage, electronics, distributed energy and other technologies; build internet energy infrastructures, intelligent integrated energy networks, and information and communication infrastructures [20];
develop internet energy-trading systems; and innovate energy-trading business models.

3.4 Promoting international cooperation on hydropower at a high level

3.4.1 International rivers of southwest China development

International rivers in southwest China include: Irrawaddy, Lancang-Mekong, Zhujiang, Salween, Brahmaputra, Sengtangpo (Indus), Bajirati (Ganges) and Yuanjiang-Honghe. These international rivers flow through South Asian countries such as India, Nepal, Bangladesh and Pakistan; and Southeast Asian countries such as Laos, Myanmar, Thailand, Cambodia and Vietnam. These rivers are the material basis for China’s cooperation with other river-basin countries in hydropower, shipping, irrigation and flood control. However, at the same time, the interest demands of countries in the basin and the degree of interaction between China and these countries are different, and China and these countries are very likely to have potential conflicts in the above fields [21]. The international rivers in southwest China are particularly important to the common development of China, Southeast Asian and South Asian countries. Future international river management and hydropower development will continue to improve in line with the open inclusive, win-win cooperation and sustainable development concept by actively building dialogue and cooperation platforms in these countries and by seeking converging interests more broadly.

3.4.2 Hydropower cooperation based on the ‘One Belt And One Road’ initiative

Plagued by flood, drought, water shortage, power shortage, water-environment deterioration and other problems, most countries along the ‘One Belt And One Road’ take water-resources and hydropower development as the primary task of national economic and social development. In recent years, by virtue of comprehensive advantages in planning, survey, design, construction, operation, management, equipment manufacturing, power transmission and transformation, Chinese hydropower enterprises have built dozens of large and medium-sized hydropower projects in countries along the ‘One Belt And One Road’, occupying >50% of the international hydropower market. In the future, ‘One Belt And One Road’ cooperation will pay more attention to the quality of cooperation and accelerate the development of sinohydro technologies, standards, equipment and management in foreign markets. The role of intergovernmental cooperation should be brought fully into play and the superior resources of international organizations, multinational companies and the countries in which the projects are located should be brought into play through investment driving, planning and design, consultation and evaluation, project construction and operation management [22], so as to promote overseas hydropower development with high quality.

4 Conclusion

In the new historical period of China’s economic and social development, it can be predicted that the development of hydropower in China in the future has four main directions: first, high-quality hydropower projects in the western region under the guidance of the concept of green development and ecological civilization; second, giving full play to the existing value of hydropower, represented by multi-energy complementation, the dispatching of water, the combined development of conventional hydropower and pumped-storage power stations, and hydropower and the tourism industry; third, seeking new economic growth points in the direction of intelligent hydropower, clean trading and hydrogen production from hydropower; fourth, integrating the hydropower industry into high-level international cooperation centered on the ‘One Belt And One Road’ initiative in a comprehensive and efficient manner.

Hydropower development in China has entered a mature stage of development. It is suggested that hydropower-development enterprises should deeply integrate their technical and management advantages accumulated over years of development with the development direction of hydropower and constantly optimize their development strategies, focusing on exploring solutions from three aspects: first, the comprehensive management of large hydropower basins is based on the new model of the integrated development of hydropower, water conservancy and environmental protection; second, the construction of intelligent enterprises with the orientation of the intelligent transformation of traditional business and participation in intelligent energy management; third, diversification represented by the integration of hydropower and international development.

The future development direction of hydropower is discussed in this paper, but it is still limited to hydropower itself. In future studies, further research and discussion should be made on the capacity benefit, energy-storage efficiency and the stabilizing role of hydropower in the integrated development of hydropower, wind power and solar power within the framework of renewable energy, as well as the important role of hydropower in resisting climate change.

This paper is a summary article, and the summarized experience and exploration direction are only limited to the author’s personal understanding, which may be different from the ideas and research ideas of other authors. The research results only represent personal views and are only for the reference of insiders.
Conflict of Interest

None declared.

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