Research on methods and scale of deeply exploitable hydropower resources

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Abstract. Deep development of hydropower is an important measure to optimize the structure of clean energy, meet the peak shaving and backup needs of the power system, and achieve the national dual carbon goals. This article conducts a systematic analysis of the development potential of developed and undeveloped hydraulic resources, including unplanned river sections, undeveloped planned power stations, unit renovation and capacity expansion, and the expansion of existing/ongoing power stations. We focused on studying the factors that affect the deep development of hydropower, including the reasonable operation mode of hydropower with different regulation performance in the power grid, the energy structure characteristics of the power system, and the comprehensive water use requirements. A calculation method for the reasonable installation and utilization hours and deep development resources of hydropower stations with different regulation performance after deep development has been proposed. According to calculations, Zhejiang Province can increase its scale by 3331MW, with great potential for deep development.

1. Introduction

According to the 2023 Global Climate Report released by the World Meteorological Organization at the end of 2023, multiple climate records were broken in 2023, with greenhouse gas levels reaching historic highs, sea level rise reaching historic highs, and sea ice extent in Antarctica dropping to historic lows [1]. China has also proposed voluntary emission reduction targets, achieving carbon peak before 2030 and carbon neutrality before 2060 [2-3].

Building a clean energy structure system consisting of wind power, solar energy, tidal energy, hydropower, biomass energy, and other clean energy sources is an important measure to promote economic development and achieve CCER goals [4]. Hydropower is widely recognized worldwide due to its mature technology, renewable energy, zero emissions, high energy efficiency, and strong comprehensive utilization functions [5]. At the same time, hydropower has the advantages of fast startup and shutdown speed, strong adjustable output, and can effectively suppress the random fluctuations of hydropower and solar power output. It plays a huge role in stabilizing the peak valley difference and load fluctuations of the power system, and improving the power generation efficiency of other power stations. Meanwhile, hydropower is also a key factor in building a "hydropower wind power photovoltaic energy storage" base.

The hydropower resources in the eastern and central regions of China have been basically developed. Many hydropower stations were built earlier and have encountered a series of problems that affect the safe operation of power plants, such as turbine wear, cavitation, decreased average efficiency of turbines, outdated electrical equipment, and low level of automation [6]. Meanwhile, some hydropower stations, especially those with better regulation capabilities, have higher utilization hours and smaller installed capacity, which suppresses the peak shaving advantage of hydropower in the power grid. Therefore, it is very necessary and urgent to carry out deep development of hydropower.

2. Main types of deep development

Hydraulic resources can be divided into undeveloped, under development, and developed according to their development status. Among them, according to whether the river has completed the hydropower planning, the undeveloped situation can be divided into two types: the undeveloped river section and the planned but not constructed hydropower station [7-8]. The key contents of deep development of hydropower mainly include: combining the current status of hydropower production and operation, further reviewing and adjusting the planning of rivers with development potential, expanding the existing hydropower stations with conditions, transforming and increasing the capacity of some old hydropower units, and constructing new hydropower stations in large water storage areas. There are four main methods for deep hydropower development:

(1) Unplanned development of river sections. Unplanned river sections refer to river sections that have not been developed or utilized, and have not undergone hydropower planning. For the utilization of such river
sections, the method of hydropower resource survey can be used to evaluate the amount of resources for deep development based on the water head, average flow rate, water utilization rate, etc. of the river section.

(2) Undeveloped planned power plants. Undeveloped planned power stations refer to hydropower stations that have undergone hydropower planning but have been delayed in construction due to difficulties in development and other reasons. For the tapping of potential in the absence of power stations, the main approach is to analyze the reasonable working positions of hydropower stations in the power system based on the development of power demand, and to analyze the installed capacity/guaranteed output ratio of hydropower stations from the perspective of reasonable capacity utilization; At the same time, it is necessary to analyze the amount of electricity that can be generated by increasing installed capacity, estimate the cost of electricity prices, and compare it with the marginal cost of new energy in the power system. Taking into account the analysis results of rational utilization of capacity and reasonable increase in power generation, combined with the specific situation of the power system and relevant engineering cases, this paper analyses the reasonable annual utilization hours of installed capacity for hydropower stations with different regulation performance in the power system after deep development, and then estimates the potential resources that can be tapped by the uncompleted power stations.

(3) Unit capacity expansion and renovation. Unit renovation is aimed at old hydroelectric power plants that have been built and operated for more than 20 years. After the unit renovation, the efficiency of the unit is improved, which can increase the output of the unit nameplate and achieve the effect of increasing the installed capacity. The amount of resources required for unit renovation and capacity increase can be estimated based on the improvement in efficiency after the unit renovation.

(4) Expansion of existing/ongoing power stations. Considering that with the development of the economy, the power supply structure has taken on diverse forms, and the external conditions during the design of the original power station have undergone significant changes. For example, in the 1980s and 1990s, the requirements of the power grid for hydropower stations were mainly electricity, so the installed annual utilization hours of hydropower stations were often higher. However, with the development of the economy, the power supply structure has undergone significant changes, and the demand for peak shaving power sources in the power grid is increasing day by day, the annual utilization hours of installed capacity of hydropower stations can be appropriately reduced. Therefore, it is necessary to conduct in-depth analysis of the installed capacity of existing/ongoing hydropower stations, and hydropower stations with conditions for expansion can be expanded.

3. Key factors for deep development

3.1. Reservoir regulation performance

With the increasing electricity load year by year, the requirements for electricity quality and reliability are constantly improving [9]. The proportion of renewable energy sources such as wind and solar power, as well as power plants with poor controllability and rapid response ability such as nuclear power, in the power grid is constantly increasing. The power system has put forward new requirements for the utilization of conventional hydropower stations [10]. In the power system, the role of conventional hydropower is gradually shifting from being primarily focused on generating electricity, to balancing power generation with auxiliary services such as peak shaving and backup.

For hydropower stations without regulating capacity, the output size depends on the natural inflow, so it is not suitable to bear variable loads. In order to reduce water loss, it is generally operated at base load. During periods of low electricity consumption, there may be water abandonment due to the minimum technical output of thermal power.

For hydropower stations with daily regulation capacity or above, the natural incoming water within a day can be regulated by the reservoir to adapt to changes in load. Therefore, in the power system, it is mainly responsible for peak or waist load work. It can fully leverage the operational flexibility and economy of hydropower stations, maximize the replacement of thermal power plant capacity, make more reasonable use of hydraulic resources, and reduce water waste; At the same time, it can improve the power generation efficiency of hydropower stations with poor regulation ability and reduce water waste during low electricity consumption periods.

For hydropower stations with annual or multi-year regulation, the regulation and storage of natural runoff flowing through reservoirs within or even between years can be redistributed according to load changes.

According to the requirements of ecological and environmental protection, there should be no dehydrated river section downstream of the hydropower station, and a certain amount of ecological base flow should be discharged to meet the ecological water use requirements in the river. Downstream power stations with good regulation capabilities usually have reverse regulation reservoirs or cascade hydropower stations with basic water level connections. Otherwise, it is also necessary to consider releasing ecological flow.

3.2. Peak shaving capacity demand in power systems

Take 2035 as the planning level year. On the basis of planning level year power load forecasting and clear power source planning, considering hydropower stations with regulating capacity as a whole, analyzing the suitable working positions and tasks of the hydropower station group in the power grid, in order to determine the
appropriate installed capacity/guaranteed output ratio (referred to as "installation guarantee ratio") of the hydropower station group.

For hydropower stations with regulating capacity, their winter output is usually small, and the working capacity for peak shaving in the system is relatively large. Therefore, based on the above principles, the winter power consumption of the system is balanced, and hydropower stations with regulating capacity are analyzed as a whole. After appropriately simplifying the above model functions, the following methods and steps can be used for calculation and analysis.

1) Determine the typical daily winter load curve L1 of the power system for the planning level year 2035.

2) Priority should be given to absorbing the electricity generated by wind and solar power plants, and the daily process of wind and solar power generation should be formulated. Deductions should be made on the typical daily load curve L1 to form a new daily load curve L2.

3) Using load curve L2, analyze the reasonable working positions of pumped storage power stations, gas turbines, nuclear power stations, unregulated hydropower stations and other power stations that are currently under development and have been clearly planned and developed in the power grid, and form residual load curve L3.

4) The residual load curve L3 is the combined load curve of a hydroelectric power plant group with regulating capacity and coal-fired power. The maximum peak shaving capacity of the hydroelectric power plant group is calculated, that is, the maximum working capacity of the hydroelectric power plant with regulating capacity is calculated under the daily guaranteed electricity quantity.

5) If the hydropower station is not considered to bear the rotating reserve, the maximum working capacity of the hydropower station group is its installed capacity. If it is considered to bear a certain amount of reserve capacity, its installed capacity can be increased by a certain amount in addition to the maximum working capacity. In this study, the hydropower reserve capacity is temporarily considered to not exceed 30% of the working capacity. For power stations with significant impact on the power grid, separate analysis should be conducted. For example, the reserve capacity of Xin'anjiang Hydropower Station should consider the allocation in the East China power grid of Zhejiang, Jiangsu, Shanghai, Anhui and other regions in 2035, as well as the total reserve capacity demand.

6) Based on the above analysis, the working position of a hydroelectric power plant group with regulating capacity on a typical daily load curve can be determined, and the installed capacity of the hydroelectric power plant group can be calculated according to step 5). The installed capacity to guaranteed output ratio of the entire hydroelectric power plant group can be calculated.

3.3. Other influencing factors

Based on the analysis of the installation guarantee ratio of hydropower groups in the power system, combined with the analysis results of the increased power generation of hydropower stations with different regulation capacity types, further analyse the reasonable installation and utilization hours of each regulation capacity type of power station, and use this as the discrimination basis and reference index for the deep development of power stations.

If the proportion of water and electricity in the power system is small, the installation and maintenance ratio calculated by the above analysis method is large, and some power stations bear the role of peak shaving. The daily electricity consumption in the control month is basically completed within 1 hour to 1.5 hours. In this case, it is necessary to reasonably consider adding other types of peak shaving energy, such as increasing the peak shaving capacity of the power system through air compression energy storage and solar thermal energy storage in the future. Therefore, the installation and maintenance ratio should not be too large, and the annual utilization hours should not be too low. The reasonable installed capacity of a specific power station should be determined through an economic rationality analysis of the expansion scale.

For low head hydropower stations, as the installed capacity increases, the power generation flow increases, the head loss increases, and the downstream water level rises, resulting in a decrease in the actual utilization head. Therefore, the rationality of the installed capacity utilization hours and the economic operation mode of the reservoir should be considered based on the specific situation of the project. If the comprehensive utilization requirements of the power station, such as irrigation, water supply, navigation, ecological water use, etc., are met, the rationality, feasibility, and economy of increasing installed capacity should be reasonably analysed on the basis of meeting the engineering comprehensive utilization requirements.

4. Method for estimating the amount of resources for deep hydropower development

4.1. Unplanned development of river sections

For unused river sections with development potential, the amount of hydraulic resources can be preliminarily estimated for power generation based on data such as utilization head and flow rate. Preliminary calculation of installed capacity is based on the reasonable water utilization rate of daily regulation power stations in the same basin, taking into account the daily regulation performance, and the reasonable installation and utilization hours of daily regulation power stations in the planned level year. The calculation formula for annual power generation \( E \) and installed capacity \( P \) is as follows:

\[
E = \eta A Q HT_1
\]

(1)

Where: \( E \) represents the average annual power generation over many years; \( \eta \) for water utilization efficiency; \( A \) is the comprehensive output coefficient; \( Q \) is the average annual flow rate at the dam site; \( T_1 \) is the number of hours in a year, which is 8760h.

\[
P = E / T_1
\]

(2)
4.2. Undeveloped planned power stations

Due to the fact that most undeveloped planned power stations were planned or designed earlier, and the current power system and expected construction and operation time have undergone significant changes, the electricity load demand and the role of hydropower in the planning level year have undergone significant changes. Based on the reasonable utilization hours of hydropower deep development in the power system, adjust the installed capacity utilization hours of uncompleted power stations and make reasonable adjustments to the installed capacity. The change in electricity quantity caused by the adjustment of installed capacity is determined by comparing and analysing the water energy parameters of similar hydropower stations of different types with the change in installed capacity. Due to differences in storage capacity regulation capacity, runoff characteristics, and other factors, the relationship curve between installed capacity and utilization hours also varies. Different watersheds should be analysed separately.

The original planned installed capacity of the undeveloped power station was $P_0$, with an annual power generation of $E_0$ and an installed utilization hour of $T_0$. Based on the analysis of the power system demand and the regulation capacity of the power station, the planned level year requires an increase in the installed capacity of the power station, resulting in a decimal value of $T_1$ for the planned utilization of the power station. The installed capacity $P_1$ and annual power generation $E_1$ of the power station in the planning level year satisfy the following equations:

\[
E_1 = E_0 + \Delta E = P_0T_0 + (P_1 - P_0)\Delta T = P_1T_1
\]  
(3)

Where, $\Delta E$ and $\Delta T$ represent the annual power generation and utilization hours of supplementary installed capacity $\Delta P = P_1 - P_0$.

According to equation (3), the installed capacity $P_1$ and annual power generation $E_1$ of the power station in the planning level year can be calculated:

\[
P_1 = P_0(T_0 - \Delta T)/(T_1 - \Delta T)
\]  
(4)

\[
E_1 = P_1T_1
\]  
(5)

4.3. Unit capacity expansion and renovation

The capacity expansion and renovation of the unit is only applicable to hydropower stations that have been put into operation for 20 years or more. The capacity expansion and renovation of other existing power stations will not be considered temporarily. Specific analysis will be conducted when the conditions are suitable in the later stage, combined with the needs of expansion.

Due to the utilization of the original water transmission line and volute position, the increase in installed capacity of the unit is relatively limited. Therefore, it is preliminarily considered that the installed capacity will increase by 15% after the unit capacity expansion and renovation.

After the renovation and capacity increase of the unit, due to the improvement of installed capacity and unit efficiency, as well as the increase in water utilization rate, the power generation of the power station increased after the renovation and capacity increase of the unit. In terms of the impact of improving unit efficiency on electricity consumption, the efficiency increase of different types of power plants is basically the same; In terms of the impact of improving water utilization efficiency on electricity consumption, for power plants with good regulation ability, there is less increase in electricity consumption, while for power plants with poor regulation ability, there is a greater increase in electricity consumption.

Based on the research results and implementation experience of similar power plant unit capacity expansion and renovation projects that have been carried out, the principles for unit capacity expansion and renovation of each power plant are proposed as follows:

1. After the unit capacity expansion and renovation, the increase rate of installed capacity $\rho$ Considering factors such as the actual operating efficiency of the power plant unit, the size of the water transmission pipeline and volute, this stage can temporarily take around 10% to 20%;

\[
P_1 = P_0 \times (1 + \rho) = P_0 \times (1 + 10\% \sim 20\%)
\]  
(6)

2. After the unit capacity expansion and renovation, the proportion of annual average power generation increase of the power station is determined based on its regulation performance $\xi$. Specific proportion values $\xi$ As follows: 5% is taken for years of regulating power stations; 7.5% for annual/quarterly regulation of power stations; Take 10% for daily/non regulated power plants.

\[
E_1 = E_0 \times (1 + \xi)
\]  
(7)

4.4. Expansion of Existing Power Stations

After analysing the capacity expansion and renovation of existing hydropower stations, compare the installation and utilization hours of different types of hydropower stations with the reasonable utilization hours of deep hydropower development in the power system in the planning level year, and analyse their unit expansion space. When the utilization hours of the installed capacity of the power station are less than or close to the reasonable utilization hours of this type of power station in the planning level year, no expansion will be carried out. For power stations with installed capacity utilization hours higher than the reasonable installed capacity utilization hours of this type of power station in the planning level year, power grid, by expanding the original power station and increasing the installed capacity, the installed capacity utilization hours of the power station will be close to the reasonable utilization hours of deep development of this type of hydropower station in the province. For low head through flow units with a power generation head of 20m or less, expansion should not be considered temporarily, as the increase in full head discharge may lead to an increase in downstream water level and a decrease in head, which may not have significant electricity benefits. If the expansion capacity of the hydropower station is less than
half of the unit capacity, it is considered to be reserved for future unit renovation and expansion, and not included in the expansion capacity.

The installed capacity of the original hydropower station is $P_0$, the annual power generation is $E_0$, and the utilization hours of the installed capacity are $T_0$. Based on the analysis of the power system demand and the regulation capacity of the power station, the planning level year requires an increase in the installed capacity of the power station, making the decimal of the installed capacity of the power station $T_1$. Based on the analysis results of hydropower stations of the same type in similar watersheds, the relationship between the additional installed capacity utilization hours $dT$ and the installed capacity utilization hours $dT = \frac{dE}{dP}_f(T)$ is used to determine the average additional installed capacity utilization hours of the power station from $T_0$ expansion to $T_1$ installation utilization hours $\Delta T$. According to the planning level year, the reasonable utilization hours of installed capacity $T_1$ and the decimal utilization of supplementary installed capacity are determined $\Delta T$.

4.5. Analysis of the scale of hydropower deep development in Zhejiang Province

Although there are many rivers in Zhejiang Province, the degree of development of hydropower resources is not uniform. Some easily developed sections and sites have been overdeveloped, while some remote or technically difficult sections and sites have been underdeveloped. The Changfeng–Misai section of Qiantangjiang having a head of 26 meters, the Qingshandian–Huaguangtan-II section of Fenshuijiang having a head of 123 meters, and the Dajun–Yongku section of Xiaoixi having a head of 46 meters that have not been utilized. However, due to limited information available, it is not yet possible to determine the limiting factors of this section of the river. Therefore, the utilization of these river sections will not be considered in this study.

There are four undeveloped hydropower stations (with an installed capacity of 50MW or above) in Zhejiang Province, namely Dajun (with an installed capacity of 250MW, the same below), Nanxijiang (64MW), Guihu (80MW), and Yangxi (80MW). The total installed capacity of the four power stations is 474MW. After calculation, by tapping the potential of the installed capacity of the undeveloped power stations, the installed capacity can be increased to 762MW. As shown in Table 1.

<table>
<thead>
<tr>
<th>Undeveloped planned power stations</th>
<th>Regulating ability</th>
<th>Planed Scale</th>
<th>Adjusted Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Installed capacity (MW)</td>
<td>Annual power generation (GWh)</td>
<td>Installed capacity (MW)</td>
</tr>
<tr>
<td>Dajun</td>
<td>Annual</td>
<td>250</td>
<td>433</td>
</tr>
<tr>
<td>Nanxijiang</td>
<td>Multi-annual</td>
<td>64</td>
<td>128</td>
</tr>
<tr>
<td>Guihu</td>
<td>Seasonal</td>
<td>80</td>
<td>211.1</td>
</tr>
<tr>
<td>Yangxi</td>
<td>Annual</td>
<td>80</td>
<td>220.4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>474</td>
<td>992.5</td>
</tr>
</tbody>
</table>

There are a total of 6 hydropower stations (with an installed capacity of 50MW and above) operating in Zhejiang Province for more than 25 years, namely Fuchunjiang, Hunanzhen, Huangtankou, Xin’anjian, Jinshuitan, and Shitang. Among them, Fuchunjiang and Xin’anjian underwent unit capacity expansion and renovation in 2003 and 2004, respectively. Therefore, only Hunanzhen, Huangtankou, Jinshuitan, and Shitang power stations will be considered for unit capacity expansion and renovation in this project. After the capacity expansion and renovation of the four power plant units mentioned above, the installed hydropower capacity can be increased by about 104MW, and the average annual power generation can be increased by about 101GWh. As shown in Table 2.

<table>
<thead>
<tr>
<th>Hydropower stations</th>
<th>Regulating ability</th>
<th>Present Scale</th>
<th>Adjusted Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Installed capacity (MW)</td>
<td>Annual power generation (GWh)</td>
<td>Installed capacity (MW)</td>
</tr>
<tr>
<td>Hunanzhen</td>
<td>Multi-annual</td>
<td>270</td>
<td>540</td>
</tr>
<tr>
<td>Huangtankou</td>
<td>Daily</td>
<td>82</td>
<td>176</td>
</tr>
<tr>
<td>Jinshuitan</td>
<td>Annual</td>
<td>300</td>
<td>490</td>
</tr>
<tr>
<td>Shitang</td>
<td>Daily</td>
<td>78</td>
<td>189</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>730</td>
<td>1395</td>
</tr>
<tr>
<td>Added scale</td>
<td></td>
<td>104</td>
<td>101</td>
</tr>
</tbody>
</table>
Nine hydropower stations (with an installed capacity of 50MW or above) have been built in Zhejiang Province. After analysis, the main hydropower stations that can be considered for expansion include Huaguangtan First Class, Tankeng, Hunanzhen, Huangtankou, and Xin'anjiang. The total installed capacity before expansion is 2130MW, with a total annual average power generation of 4060.8GWh. After expansion, the total installed capacity is 4475MW, with a total annual average power generation of 4542GWh, an increase of 2465MW compared to the total installed capacity before expansion, and a total annual average power generation increase of 576GkWh. As shown in Table 3.

<table>
<thead>
<tr>
<th>Hydropower stations</th>
<th>Regulating ability</th>
<th>Present Scale</th>
<th>Adjusted Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Installed capacity (MW)</td>
<td>Annual power generation (GWh)</td>
<td>Installed capacity (MW)</td>
</tr>
<tr>
<td>Huaguangtan I</td>
<td>Annual</td>
<td>60</td>
<td>127</td>
</tr>
<tr>
<td>Tankeng</td>
<td>Multi-annual</td>
<td>600</td>
<td>1021</td>
</tr>
<tr>
<td>Shanxi</td>
<td>Multi-annual</td>
<td>200</td>
<td>355</td>
</tr>
<tr>
<td>Hunanzhen</td>
<td>Multi-annual</td>
<td>300</td>
<td>567</td>
</tr>
<tr>
<td>Xinanjiang</td>
<td>Multi-annual</td>
<td>850</td>
<td>1896</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2010</td>
<td>3966</td>
</tr>
<tr>
<td>Added scale</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to the above research, the hydropower resources in Zhejiang Province can be further developed through four aspects: utilization of undeveloped river sections, tapping into the installed capacity of undeveloped power stations, increasing the capacity of existing power station units, and expanding and renovating existing/under construction power stations. This can increase the installed capacity of hydropower by 3331MW and the annual power generation by 1813GWh. There is great potential for deep development of hydropower. As shown in Table 4.

<table>
<thead>
<tr>
<th>Types of deep development</th>
<th>Installed capacity (MW)</th>
<th>Annual power generation (GWh)</th>
<th>Capacity ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unplanned development of river sections a</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Undeveloped planned power stations</td>
<td>762</td>
<td>1137</td>
<td>22.88</td>
</tr>
<tr>
<td>Unit capacity expansion and renovation of Existing Power Stations</td>
<td>104</td>
<td>100</td>
<td>3.12</td>
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<tr>
<td>Expansion of Existing Power Stations</td>
<td>2465</td>
<td>576</td>
<td>74</td>
</tr>
<tr>
<td>Total</td>
<td>3331</td>
<td>1813</td>
<td>100</td>
</tr>
</tbody>
</table>

5. Conclusion

Based on the analysis presented above, the conclusions are obtained as below:

(1) The deep development of hydropower has good capacity benefits. It plays a role in peak shaving, frequency regulation, and backup in the system, improving the safety, stability, and economy of power grid operation. It can also increase the inclusion rate of renewable energy such as wind power and solar energy, and promote the achievement of carbon reduction goals.

(2) There are four main methods for deep hydropower development, including: utilization of unplanned river sections, potential installed capacity of undeveloped planned power stations, capacity expansion and renovation of existing power station units, and expansion of existing and ongoing power stations.

(3) The scale of deep hydropower development should mainly consider the reservoir regulation performance, peak shaving demand of the power system, comprehensive water use requirements, and technical economy. After studying the hydropower development situation in Zhejiang Province, it is found that the scale of deep development is 3331MW, which can increase the annual power generation by 1813GWh and has great potential for deep development.

To further leverage the role of hydropower resources in energy transformation and sustainable development, it is recommended to establish a sound policy system and market mechanism for deep hydropower development, clarify the responsibilities and rights of each department, and coordinate the interests of all parties. At the same time, we will increase policy support and financial investment in the deep development of hydropower, encourage enterprises and social capital to participate in the deep development of hydropower, and promote the healthy development of the hydropower industry.
Acknowledgments

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