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Multi-objective River Ecological Dispatching Algorithms Using NSGA-III

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Abstract. In order to restore the ecological health of the Jinsha River Basin, the NSGA-III algorithm is applied to adjust and optimize the flow and water level of the Jinsha River Basin to ensure the ecological and sustainable development of the Jinsha River Basin. With the continuous development of human society, people' s influence on society is getting bigger and bigger, and the contradiction between man and nature is becoming more and more prominent. As an essential barrier in the upper reaches of the Yangtze River, the Jinsha River Basin has a great impact on the national ecosystem. Non-dominated Sorting Genetic Algorithm, the Third Version (NSGA-III) algorithm can be used to solve multi-objective optimization problems due to its excellent problem solving capabilities. It is well applied in solving standard constrained optimization problems and has good effects. There are few studies on ecological scheduling. Therefore, considering the current ecological situation of the Jinsha River Basin, the Ningnan County section of the Jinsha River Basin is used as the research area. Furthermore, the NSGA-III algorithm is used to solve the multi-objective model of the Jinsha River Basin during the dry season, thus obtaining the specific situation of the water level, ecological flow and power generation in the area, and finally giving a better scheduling plan to ensure the sustainable development of the ecological health of the Jinsha River Basin. Using NSGA-III algorithm to study the multi-objective ecological scheduling of the Jinsha volume is helpful to the ecological health of the Jinsha River Basin and the economic development of the region. It also has a positive effect on the ecological protection of new water conservancy projects, and also for other domestic watersheds. The ecological scheduling problem provides a certain idea.

Keywords: Jinsha River Basin, multi-objective optimization, NSGA-III algorithm, ecological scheduling

1 Introduction

With the continuous development of human society, effect of human activities on environment is increasing. It is also a variety of problems in the ecological environment. Since then, the contradiction between human beings and the ecological environment has become more and more prominent, which affects the development of social and ecological sustainability. As a very important section of the Yangtze River Basin, the Jinsha River Basin has strong links to the vegetation and climate around the river. Ningnan County is located in the middle reaches of Jinsha River. Towns and villages on both sides of the river are relatively concentrated, and the population density is relatively high. Therefore, there are many infrastructures, more developed economy, more frequent activities of people in the region, and more intensive use of river water, which makes the water level in the region decline seriously, and may also affect the ecological health of the downstream basin [1]. However, the current river management system and dispatching operation mode mainly consider how to deal with and coordinate the

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contradiction and interests of flood control and water conservancy, and neglect the ecosystem demand in the downstream and reservoir areas of the reservoir, which has a severe impact on the river ecosystem.

Moreover, with the continuous advancement of water conservancy construction, many reservoirs in China have emerged, which enables China to rely on reservoirs to regulate water storage and use hydropower to benefit humanity. However, with the continuous operation of the reservoir, it is found that the physical properties, ecological environment and species diversity of many rivers are also affected, so the ecological regulation of the reservoir has become the focus of the relevant departments. It is hoped that the operation of the reservoir will be improved by formulating reasonable dispatching measures so as to protect the river ecosystem. Conventional reservoir dispatching methods are often single-objective problems, without considering the coordinated development of multiple objectives.

The rapid development of computer technology has also led many researchers to conduct more research on multi-objective optimization theories and methods. Non-Dominated Sorting Genetic Algorithm, The Third Version (NSGA-III) is derived from the Non-Dominated Sorting Genetic Algorithm–II (NSGA-II) basic mountain. It is a multi-objective evolutionary algorithm, which has the ability to perform fast non-dominated sorting genetic algorithms [3].

Therefore, NSGA-III algorithm is used to optimize the multi-objective model in the ecological dispatch of Jinsha River Basin, so as to ensure the sustainability of ecological health and promote the economic development of the region.

2 Literature Review

2.1 Reservoir Ecological Operation

The reservoirs established within the rivers are mainly water conservancy projects that block flood storage and regulate water flow, and can be used for irrigation, power generation, flood control, to control the rise and fall of the water level. Wu Shuyue and Zhao Jianshi et al. found that the climate change has a certain impact on the Xinanjiang reservoir dispatching through quantitative assessment of the monthly runoff in the Xin Anjiang area, and propose corresponding adaptive countermeasures.

Zhu Lingling, Yang Xia et al., established the correlation between water level and riverbed by statistically comparing the characteristics of different forms of dry water level. The results showed that the water supply scheduling of the Three Gorges Reservoir has a certain impact on water level and riverbed erosion [4]. Through the analysis of river water pollution emergency response, Xiaohui et al. found that the optimal reservoir scheduling scheme and treatment effect are consistent with the actual situation, and the effectiveness of the reservoir scheduling scheme is verified [3]. Pan Qiquan analyzes the water regime and flood dispatching process in Qingshui River Basin, finds problems in reservoir dispatching and puts forward relevant suggestions [5]. Ren Kang (2017) et al. take the reservoir operation of the Hanji-Weihe Project as an example, use the standardized precipitation index to divide the long series of runoff data into typical annual series, use the stochastic runoff diachronic curve to calculate the corresponding ecological flow, and then establish the optimal dispatching model with the largest power generation. The results show that the demand of ecological flow can be basically met in different typical years, but not in specific dry season, which needs to be focused on [6].

2.2 Multi-objective Optimal Scheduling

Nagesh Kumar used the constraint method to transform the reservoir-oriented optimization model into a single-objective problem. The results showed that this method is closer to the actual situation than the simple single-objective optimization result. It also simplified the calculation, but it requires multiple calculations and takes a long time [7]. Du Shoujian analyzed the problem of goal optimization of net power generation, annual power generation and water supply for power generation in reservoirs, and also transforms multi-objective problems into single-objective problems, which are solved [8].

2.3 NSGA-III Algorithm

Kim employed the NSGA-II algorithm to solve the optimal scheduling model for maximum reservoir power generation and maximum water demand. The results show that the NSGA-II algorithm can perform optimization well [9]. Tian et al. combined wind power with hydrothermal scheduling to test the ability of NSGA-III algorithm to solve problems. The results showed that the NSGA-III algorithm can effectively solve the problem of hot water scheduling in discharge water [10]. Kalyanmoy Deb and Himanshu Jain analyzed the multi-objective problem and found the proposed NSGA-III algorithm is suitable for multi-objective testing problems and can produce satisfactory results more than other methods [11].

In conclusion, NSGA-III algorithm can effectively solve multi-objective scheduling problem. However, in the existing literature, there are few studies on ecological scheduling. Therefore, in this study, NSGA-III algorithm is applied to multi-objective River Basin Ecological dispatching problem, in order to find a better scheduling scheme to ensure the ecological health and sustainable development of the river basin.

3 Relevant Expressions and Methods

3.1 Jinsha River Basin overview

As the upper reaches of the Yangtze River, the Jinsha River originates from the Zhimenda of Yushu Prefecture at the junction of Qinghai Province and Sichuan Province. It flows through Yushu, Ganzi, Chengdu, Diqing, Lijiang, Liangshan, Dali, Chuxiong, Panzhihua, Kunming, Qujing, and Zhaotong. It ends at the mainstream of the Yangtze River in Hejiangmen (Sanjiangkou, Hejiangkou), Cuiping District, Yibin City, Sichuan Province. It has a total length of about 3,500km, a total drop of 5,100 meters, and a drainage area of about 500,000 square kilometers. It is named after the yellow sand in the river, also known as rope water, flooding, drowning [12-13]. Due to the geographical advantages of the Jinsha River Basin, it has become the main channel and shelter of the Eurasia biological species from the south to the north. It is the most concentrated area of the Eurasia biome, with many unique and advantageous resources such as water, forest, minerals, biology, and tourism. The Jinsha River Basin is affected by the topography of the Hengduan Mountains. It is confined to the narrow strip in the north-south direction. It is adjacent to the Lancang River basin on the left and adjacent to the Minjiang River basin on the right [14]. The Jinsha River Basin is mainly located in the eastern part of the Qinghai-Tibet Plateau, and the eastern part of the Qinghai-Tibet Plateau is a transitional area between the plateau and the eastern plains. It is affected by the tropical monsoon, subtropical monsoon, and plateau monsoon, and the climate is complex.

Ningnan County is taken as the research area, and the situation of this basin is analyzed. Ningnan County is located at the junction of Sichuan and Yunnan provinces. There are six townships in the study area: Hulukou Town, Pasha Town, Baihetan Town, Qiyugou Township, Baoge Township, and Jingxing Township. This area belongs to the tropical monsoon climate. The annual temperature is high, the seasons are not clear, the temperature difference is small, the daily difference is large, the frost-free period is long, the officer season is obvious, the rainfall distribution is concentrated, and the vertical climate zoning is obvious. The annual temperature data shows that the annual average temperature in the region is about 19°C, the relative humidity can reach 60%, the annual evaporation is 1900mm, the annual sunshine hours are 2350h, and the average annual rainfall is 1024.2mm [15].

The Jinsha River has a vast river basin with steep bank slopes and narrow riverbeds. However, it has many tributaries and abundant river runoff. It is an important and stable water supply on the Yangtze River. The rainy season in the region is mainly concentrated in June-October, with rainfall in September and October being more concentrated [16].

3.2 Ecological Scheduling

Ecological scheduling is to incorporate ecological factors into the traditional reservoir scheduling mode. In the process of dispatching, more people want to maintain the original form of the river, thus establishing a harmonious relationship between man and nature, man and water. This is also the necessary conditions of water conservancy and ecological development. In order to meet the scheduling of river basin water resources and river ecological health, to optimize the structure of personnel and improve the efficiency, many researchers in this field have begun extensive research on ecological scheduling. Reservoir ecological dispatching is a measure to reduce the negative impact of dam construction and operation on the river ecosystem. Because of its relatively low cost, it can effectively improve the traditional reservoir dispatching mode, rationally operate dam construction, and restore some waters to the original. Some natural landscapes play an important role in maintaining the ecosystem and crop structure upstream and downstream of the river [17]. There are many cases of using reservoir ecological dispatching abroad, especially in the United States. Therefore, China needs to conduct further research on ecological dispatching to enable the sustainable development of various river basins in China [18].

The establishment of the dam has a certain impact on the river ecosystem. On the one hand, the negative impacts caused by the dam and the reservoir itself will cause changes in the geomorphological characteristics of the upstream and downstream rivers of the dam. On the other hand, in the process of dam operation, the stress on the ecosystem will also cause the artificialization of the natural hydrological cycle [19]. Therefore, in order to reduce the negative impact of dams on river ecology, the current reservoir scheduling methods in China should be changed, so that its impact on rivers and surrounding things are minimized.

In order to realize ecological dispatching, the basic principles of ecological dispatching should be followed. First, the near-natural water flow situation recovery criterion, i.e., considering the current human and natural development status in China, it is necessary to fully understand the water situation, river ecological response, and society. On the basis of economic capacity, the flow groups with greater influence on the river ecosystem should be retained as much as possible to maximize the shape of the near-natural water flow and restore the ecological integrity of the river as much as possible. Second, due to the principle of time, location, and species, it is necessary to determine the problems faced by each river according to different geographical characteristics, different levels of development, and different human environments. The event and its ecological effects are identified, the corresponding ecological flow components are determined, and the ecological scheduling is finally achieved [20].

Although the application of ecological scheduling is less in China, there are some typical ecological scheduling cases. Among them, the water quality of the Pearl River will seriously affect the drinking water safety of the residents in the Pearl River Delta. Therefore, the state implements the flood control of the Pearl River for emergency flood control. In the dispatching process, the method of pre-continuation and replenishment for the leading reservoir is adopted to ensure the scheduling of water volume. The method of avoiding the tide, the pressure of the tide, and the more storage is adopted. The method of scheduling adopts the method of “monthly plan, ten-day dispatch, weekly adjustment, and daily tracking,” and is tracked daily to implement fine scheduling. The effective implementation of the salty and salty subsidy guarantees the safety of water supply in cities such as Macao and Zhuhai. Through continuous summing up experience, it explores the combination of flood resource utilization and salt and salt filling, and minimizes the economy caused by water diversion in the leading reservoir. The loss has initially achieved a win-win situation of water supply, power generation, shipping, and ecology. For the Yellow River Basin, the characteristics of “unsatisfactory water and sand and uncoordinated water and sand” in the downstream area have also significantly reduced the water volume in the upstream area. Even in the flood season, the water quantity has not increased but has been reduced more greatly. Sedimentation in the river channel causes the channel to shrink. After the national and local related parts of the water and sediment adjustment experiments, the downstream river reaches the largest flood peak in the past decade, and the problem of river channel shrinkage is also treated. The Yellow River estuary wetland has also been flooded, effectively protecting the wetlands and replenishing freshwater resources [21, 23].

3.3 NSGA-III Algorithm

The NSGA-III algorithm follows the framework of the NSGA-II algorithm and is one of the most popular multi-objective genetic algorithms. It reduces the complexity of the non-inferior sorting genetic algorithm, and has the advantages of fast running speed and good convergence of the solution set. It becomes the benchmark for the performance of other multi-objective optimization algorithms. The NSGA-III algorithm replaces the selection of crowded distances in the NSGA-II algorithm by using a uniformly distributed reference point selection operation, thus maintaining the diversity of the population [24].

In practical work in many fields, it is often necessary to optimize multiple objectives. Therefore, multi-objective optimization has become the focus of research by experts and scholars as well as related personnel. The NSGA-III algorithm has been studied by many experts and scholars. The algorithm can deal with multi-objective optimization problems well. The multi-objective test function is used to verify the effectiveness of the algorithm, and it has a useful application in engineering problems and industry [25, 28].

The basic flow of the NSGA-III algorithm is shown in Fig. 1.

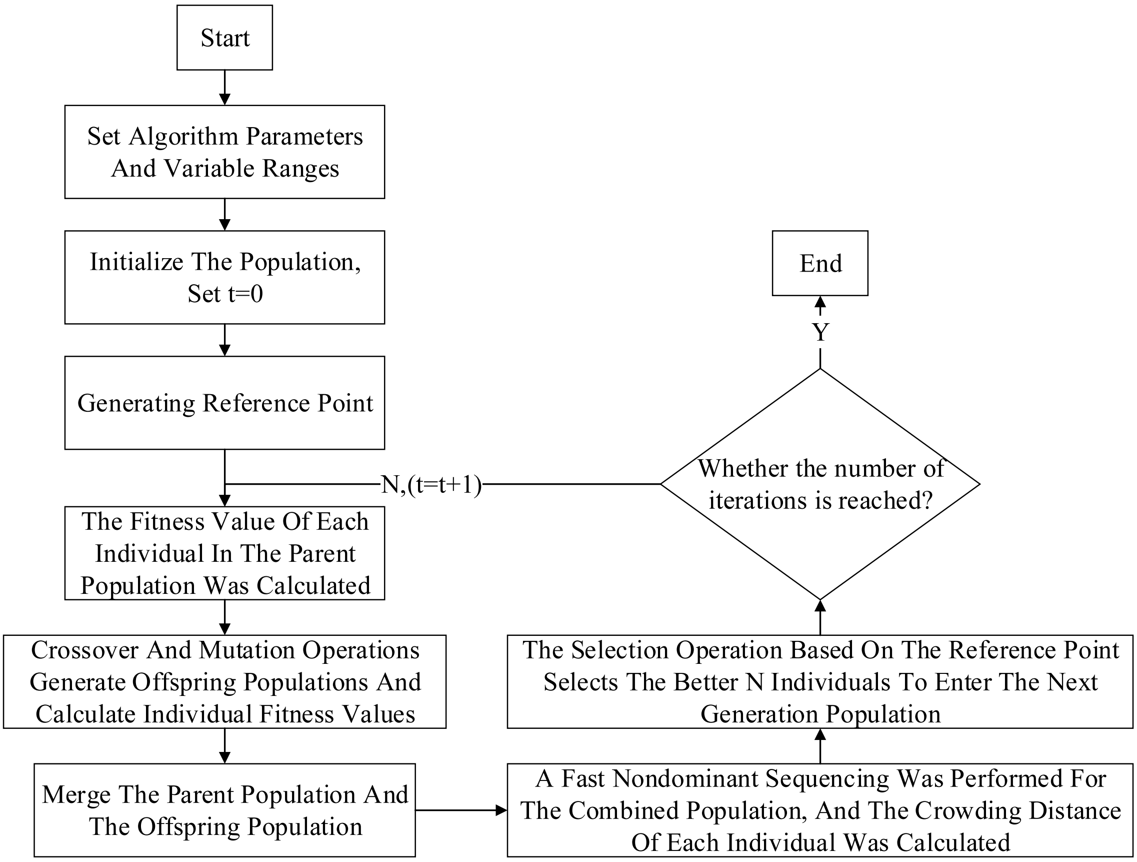

Fig. 1. NSGA-III algorithm flow

In the NSGA-III algorithm, there are two main operator operators, which are update operations and selection operations. The update operation refers to the generation of progeny populations of the same size by the parent population through cross mutation. The selection operation is based on reference points to maintain the diversity of non-dominated connections. The information of the reference point, the objective function, the association operation of the reference point, and the small living mirror in the saving operation are the key considerations in the algorithm process. Determining the reference point of the hyperplane is to use the existing method or provide the desired reference point according to the preference of the decision maker. When certain preference information is lacking, a certain method can also be used to generate a deterministic reference point, thereby maintaining the diversity of non-dominated solutions [29, 31]. Therefore, for M targets with equal score a, H reference points can be obtained, the size of which can be expressed as:

$$H=\binom{M+a-1}{a} \quad \textbf{(1)}$$

When M is 3 and the equal score is 4, 15 uniformly distributed reference points in the hyperplane can be obtained, as shown in Fig. 2:

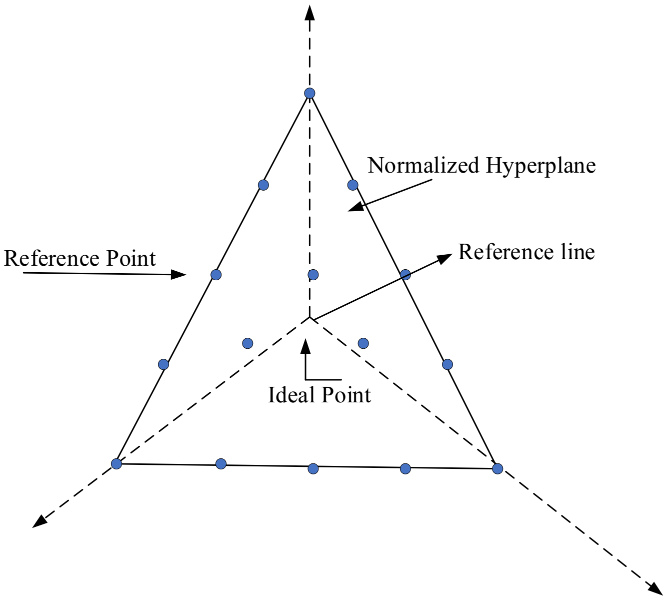

Fig. 2. Schematic diagram of the reference point

For the objective function, it needs to be normalized, that is, to determine the ideal point, the extreme point, and the truncation point, so as to standardize the objective function. The ideal point formula is as follows:

$$\overline{Z} = \left(Z_1^{\min}, Z_2^{\min}, \cdots, Z_M^{\min}\right) \tag{2}$$

Before determining the extreme point, it is necessary to scalar the resulting set of ideal points, which means

$$f_i^{'}(x) = f_i(x) - z_i^{\min} \tag{3}$$

The scalar value is then processed with the ASF function, which can be applied to the objective function of each dimension, namely:

$$ASF(X, W) = MAX_{i=1:m} \frac{f_i^{'}(x)}{W_i} \tag{4}$$

After traversing each function, the smallest individual of ASF can be found, that is, the extreme value is obtained. According to the specific function value of these points, the intercept on the corresponding coordinate axis, which means the corresponding coordinate value, can be obtained, and it is recorded as b_i. After the specific values of b_i and z_i are obtained, the normalization operation [32-33] is performed, namely:

$$f_i^n(x) = \frac{f_i^{'}(x)}{b_i} \tag{5}$$

Therefore, according to Fig. 2 and the above formula, the reference point is successively decremented step by step. When constructing the reference point vector, the reference point needs to be connected to the origin to obtain a reference line. At the same time, the M-dimensional super dimensional plane is constructed according to the M-dimensional extreme points, and then the truncation point is calculated, namely:

$$\begin{bmatrix} \left(c_1 - z_1^{\min}\right)^{-1} \\ \cdots \\ \left(c_M - z_M^{\min}\right) \end{bmatrix} = E^{-1}u \tag{6}$$

In the formula,

$$E = \left(z_1^{\max} - z_1^{\min}, z_2^{\max} - z_2^{\min}, \cdots, z_M^{\max} - z_M^{\min}\right), u = (1, 1, \cdots, 1) \quad \textbf{(7)}$$

When the matrix E is not full of rank, there is no inverse matrix, and the truncation point cannot be obtained. Generally, the maximum value of each objective function is used instead of the truncation point. Then, the objective function is obtained, as shown in formula 8:

$$f_j^n(x) = \frac{f_i(x) - z_j^{\min}}{c_j - z_j^{\min}}, j = 1, 2, \cdots, M \quad \textbf{(8)}$$

After normalizing the objective function, it is necessary to find the associated reference point corresponding to the front L layer. If an individual is found to have the shortest vertical distance from the corresponding reference line of a reference point, the associated reference point of the individual is considered to be the reference point, so the vertical distance formula is as follows [34, 36]:

$$d^{\perp}(s, w) = \left\| \left(s - \frac{w^T s w}{\|w\|^2} \right) \right\| \quad \textbf{(9)}$$

In the formula, s is an individual in the population and w is the reference line.

Therefore, the system framework of the article can be summarized as shown in Fig. 3.

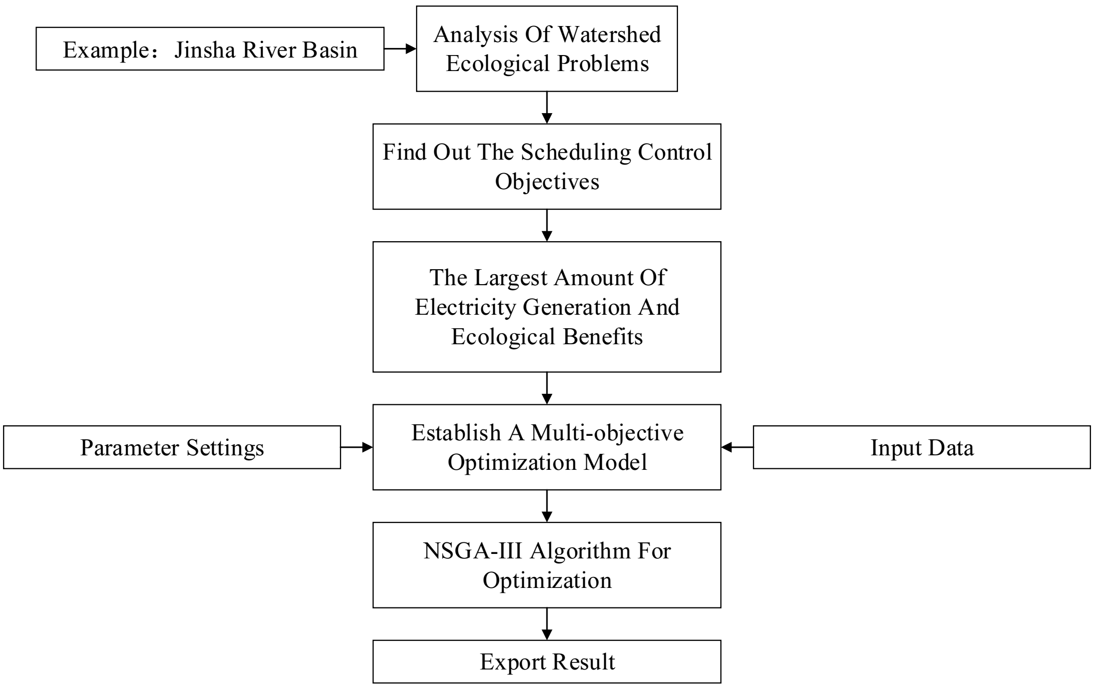

Fig. 3. System framework

4 Experiments

The multi-objective regulation model of runoff adaptability in Ningnan County of Jinsha River Basin involves two targets of maximum power generation and maximum ecological benefit, and three scheduling models are established in the technical length of these two targets, i.e., there are three objective functions. It is to ensure that the node has the largest amount of power generation, the monthly average ecological value is the smallest; the ecological change is the smallest when the cascade power generation is the largest.

4.1 Model Establishment

To ensure maximum cascade power generation, the objective function of (I) is:

$$MaxE_1 = \frac{1}{T}\sum_{t=1}^{T}\sum_{m=1}^{3} N(m,t)\Delta t + \min\left(\left(N_b - N_m\right),0\right) \quad \textbf{(10)}$$

In formula 10, E1 represents the multi-year average power generation of a cascade hydropower station, and the unit is 100 kWh. t and T represent the number of the dispatch period and the total number of time periods, respectively, and the unit is a month. Δt represents the minimum calculation period. m represents the hydropower station number. N (m, t) represents the average output of m hydropower station in t period, and the unit is 10,000kW. N_b represents the average output during the dry season. N_m represents the design guarantee treatment of hydropower station, and the unit is 10,000kW. The constraints are as follows.

Water balance constraint is as shown in equation 11, where V represents the reservoir capacity of the hydropower station, and Q_I and Q_O represent the inbound and outbound flows of the hydropower station t.

$$V(t+\Delta t) = V(t) + \left[Q_I(t) - Q_O(t)\right]\Delta t \quad \textbf{(11)}$$

The reservoir discharge flow constraint is as shown in equation 12, and Q represents the discharge flow:

$$Q_{\min}(m,t) \le Q(m,t) \le Q_{\max}(m,t) \quad \textbf{(12)}$$

Reservoir water level control is as shown in equation 13, and Z represents the water level of the hydropower station at a certain time:

$$Z_{\min}(m,t) \le Z(m,t) \le Z_{\max}(m,t) \quad \textbf{(13)}$$

Hydropower station output limit is as shown in formula 14, and N indicates the output of hydropower at a certain time:

$$N_{\min}(m,t) \le N(m,t) \le N_{\max}(m,t) \quad \textbf{(14)}$$

The unit generates a reference flow limit, as shown in equation 15, and Q_F indicates the unit’ s power generation reference flow:

$$Q_{F\min}(m,t) \le Q_F(m,t) \le Q_{F\max}(m,t) \quad \textbf{(15)}$$

Minimum shipping flow control is as shown in formula 16, and Q represents the minimum shipping flow downstream of the hydropower station:

$$Q \le Q(m,t) \quad \textbf{(16)}$$

The reservoir guarantees the ecological target downstream by controlling the ecological flow of the basin. Therefore, the objective function of the model (II) is as follows. Among them, the value of D_t is 0-1, and E_2. It is the monthly average ecological change in a certain period:

$$E_2 = \min\left\{\frac{1}{T}\sum_{t=1}^{T} D_t\right\} \quad \textbf{(17)}$$

Therefore, considering the model (I) and the model (II), the relative equilibrium state with the largest average power generation and the smallest change degree can be obtained, so as to realize the comprehensive benefit of the hydropower station on the basis of meeting the ecological health and establish the model (III) [26-30]. The objective function is as follows:

$$\begin{aligned} B(i,t) &= \max\left(\lambda_1 E_1(i,t) - \lambda_2 E_2(i,t)\right) \\ &= \max\left(\lambda_1\left(\frac{1}{T}\sum_{t=1}^{T}\sum_{m=1}^{3} N(m,t)\Delta t + \min\left(\left(N_b - N_m\right),0\right)\right) - \lambda_2 \frac{1}{T}\sum_{t=1}^{T} D_t\right) \end{aligned} \quad \textbf{(18)}$$

In the formula, B (i, t) is the equilibrium solution of the multi-objective function. λ_1 and λ_2 are weight values.

4.2 Algorithm Implementation

The NSGA-III algorithm is used to optimize the multi-objective model [31-35]. Algorithm implementation steps are as follows: Firstly, the population P is initialized, and the population size is N. Secondly, the binary operator in the genetic algorithm is used to cross-operate and iterate continuously to obtain a new number of individuals, and record the non-dominated level L at that time. Thirdly, each process uses the fast non-dominated sorting method to divide the combination into different non-dominated levels. Fourthly, each process uses a reference point-based selection operation to enter the next generation of the population. Fifthly, the judgment is enough to send the original number of iterations. If the constraint is satisfied, the population is retained, and the different non-dominated layer levels are continued. Sixthly, the reference point-based selection is finally adopted. The operation retains a certain number of preferred individuals.

The relevant parameters are set as follows. The number of different processes is set to 1, 3, 5, and 7. The transaction frequency is 10. The number of intersections is 5, 10, 15, and 20 times, and the number of processes per process is 8. The population size is 96. The number of iterations is 500.

5 Conclusion and Discussion

5.1 Data Collection and Analysis

Through the collection of relevant data of 2010, 1995 and 1994 in the Ningnan County section of the Jinsha River Basin, the data of Table 1 and Table 2 are obtained:

Table 1. Water level data of Ningnan County section of Jinsha River Basin

Year with rich-water			Year with general water volume			Year with less water		
Water level (m)	Outbound traffic (m^3/s)	Power generation (100 million kWh)	Water level (m)	Outbound traffic (m^3/s)	Power generation (100 million kWh)	Water level (m)	Outbound traffic (m^3/s)	Power generation (100 million kWh)
313.29	2300	4.57	313	727	2.88	309	986	3.79
313.34	1799	5.88	321	1399	4.02	309	252	1.02
311.2	1100	4.67	322	682	2.56	305	243	0.98
315.9	211	0.32	328	287	1.21	313	855	3.68
302.31	387	0.62	320	249	1.06	303	677	3.2
308.29	978	3.26	301	309	1.53	301	275	1.31

Table 2. Average flow rate of the drytest month

Time	1988-1998	1998 -2008	2008-2018
Flow rate (m^3/s)	63	62	64

According to the relevant data, the runoff data of the Ningnan County section of the Jinsha River Basin in 2016 is shown in Fig. 4:

According to the water use of different ecological functions, the characteristics of precipitation in each period, and the above data, the optimal ecological flow process is shown in Fig. 5. The most suitable ecological flow process is shown in Fig. 6, and the minimum ecological flow process is shown in Fig. 7.

The basic ecological runoff is selected as the ecological goal, and the actual impact of the life around the basin and the water demand of the plant on the reservoir dispatch is analyzed. Facing different ecological targets, they also have different degrees of impact on the actual power generation efficiency. By collecting the inflow data from 1970 to 2018, the actual annual average outbound traffic is obtained, as shown in Fig. 8:

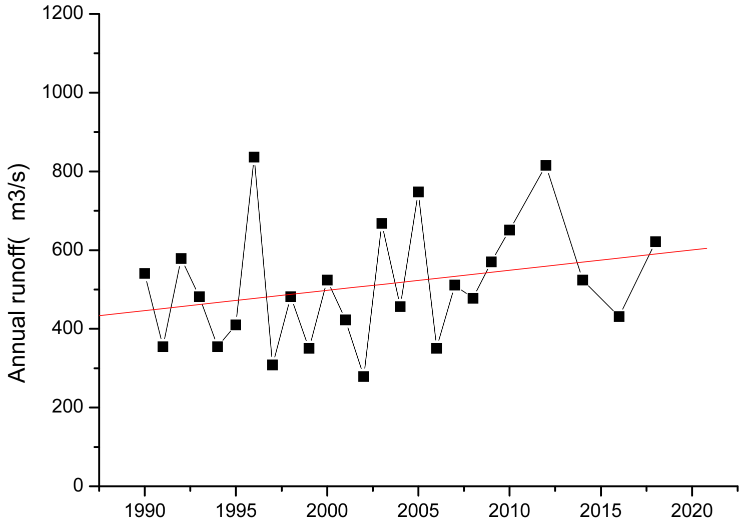

Fig. 4. Ningnan County runoff

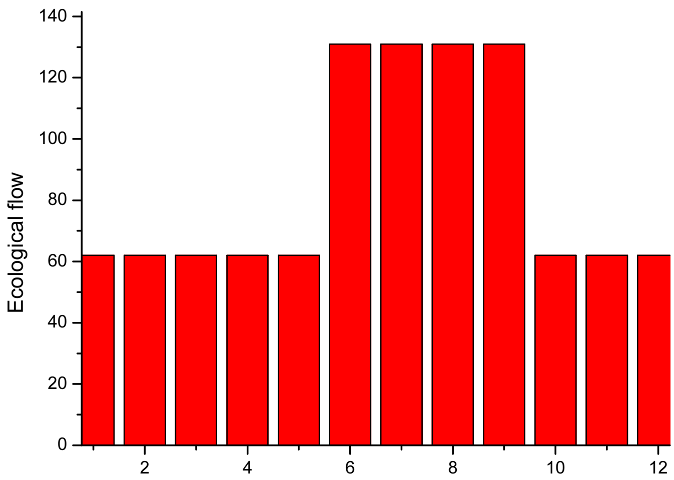

Fig. 5. Optimal ecological flow (unit: m3/s)

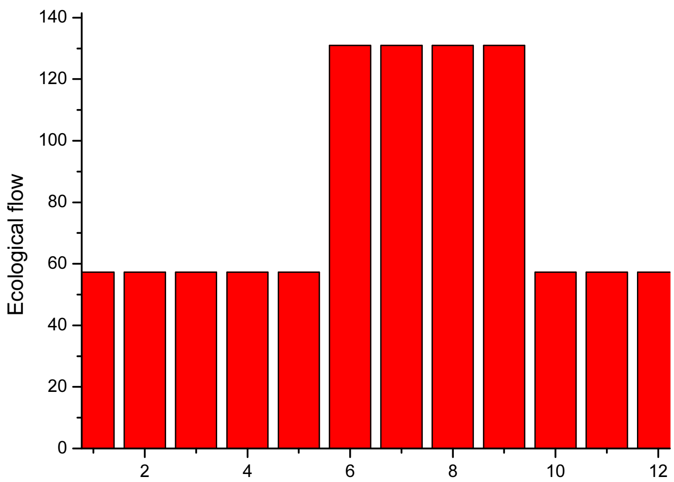

Fig. 6. Suitable ecological flow process (m3/s)

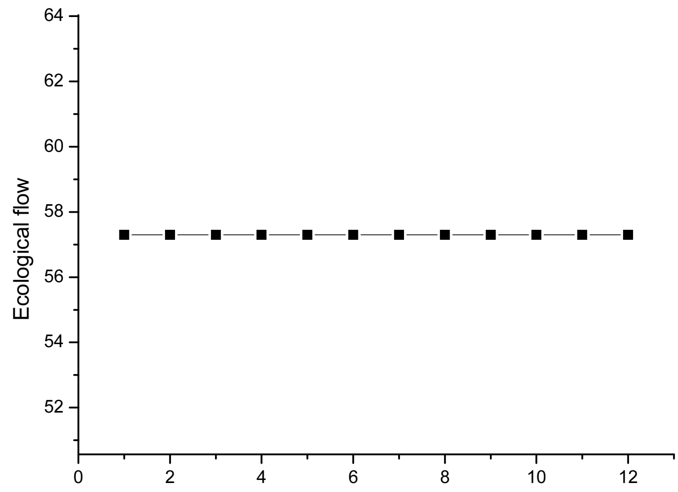

Fig. 7. Minimum ecological flow process (m^3/s)

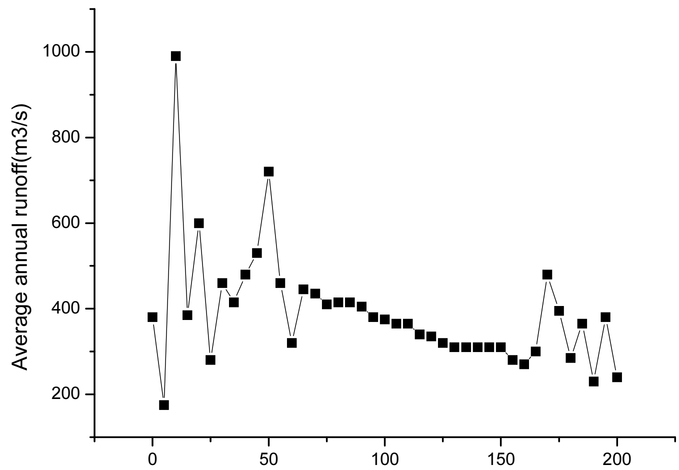

Fig. 8. Inflow data from 1970 to 2018

5.2 Performance Evaluation

The performance of this method is evaluated before specific research. The commonly used Q90 method is adopted, which is based on 90% of the lowest monthly average flow. This method is suitable for the ecological water requirement of Huaning River in China.

One tenth of the average annual discharge in the Jinsha River Basin from 1990 to 1995 is selected as the basic ecological water demand in the river. Diachronic flow method and Q90 method are used to simulate respectively. NSGA-III algorithm is used to carry out multi-objective optimization, and the ecological base flow in Jinsha River Basin can be obtained. The results are shown in Table 3 and the maximum generation capacity is shown in Table 4.

Table 3. Calculation results of base flow in Jinsha River Basin

Methods	Diachronic flow method	Q90 method
Eco-base flow (m^3/s)	55.88	68.17

From the above results, it can be seen that the ecological torrent discharge calculated by Q90 method is closer to 10% of the average annual discharge, and the basic ecological water demand flow will basically be the description of the extreme state of the river.

Table 4. Simulation results of maximum power generation

Year	Actual power generation	Model I power generation	Model II power generation
1990	11.1405	23.84574	24.3166
1991	9.73483	19.46053	18.99022
1992	22.76126	28.56487	28.72145
1993	23.23766	27.00095	26.21803
1994	16.97011	19.00986	20.73562
1995	19.32884	21.21146	22.4658

From the above results, it can be seen that the actual generation capacity and the trend of the model are basically the same, so this method can be considered to have good optimization performance.

5.3 Results and Discussions

According to the actual situation, the model I and model II constructed in this study are consistent with the actual power generation, and the trend is consistent. It can be used as a model to optimize the scheduling of the Jinshajiang Reservoir, as shown in Fig. 9:

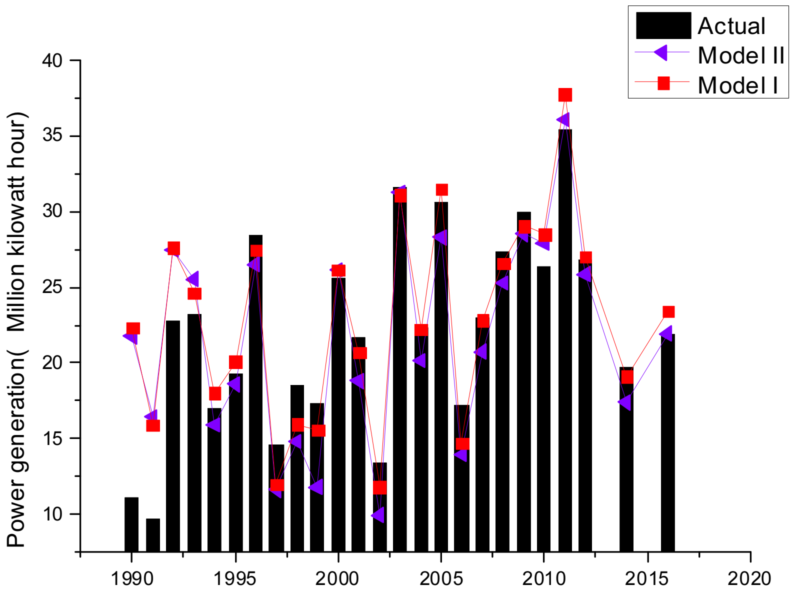

Fig. 9. Comparison analysis of power generation in each year

Comparing the model power generation data with the actual power generation data, there is a certain gap between the theoretical value and the actual value. The main reason is that there is a power station before the dam is built, and the reservoir is discovered as the ecological status of the river changes. The amount and power generation capacity become smaller. Therefore, in order to maintain the ecological health of the Jinsha River Basin, it is necessary to dispatch the ecology of the Jinsha River Basin to achieve sustainable ecological development. It can be seen from Fig. 8 that compared with the model 2, the power generation of the model two is slightly insufficient, but the difference from the actual power generation is small, so the ecological water demand can be satisfied. On this basis, more benefits are generated.

On this basis, the water levels in the years with rich water are also compared and analyzed, as shown in Fig. 10. The flow rate of the flood year is shown in Fig. 11:

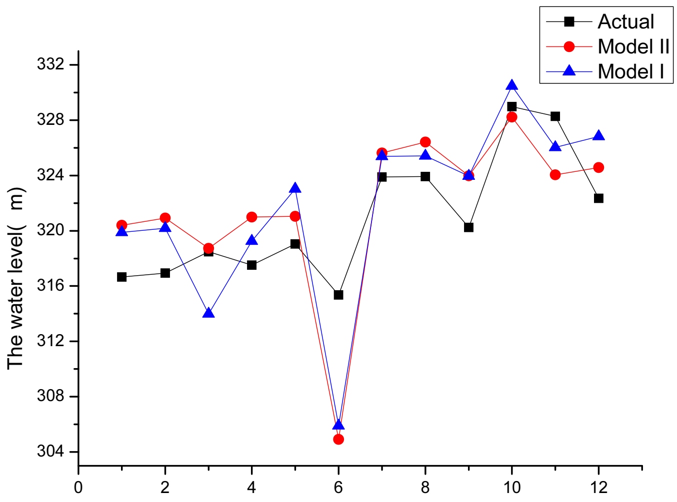

Fig. 10. Water level changes in Fengshui

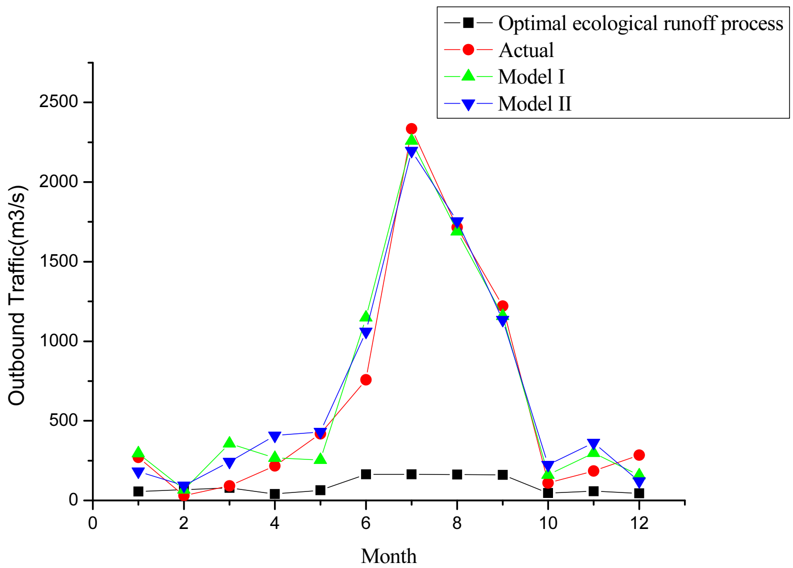

Fig. 11. Outbound flow process in the years with rich water

As can be seen from the above figure, the power generation before and after the flood season is larger than the actual value. This shows that in the actual operation process, the water is not fully utilized, the utilization rate is reduced, and the power generation is also reduced. It is necessary to make certain adjustments to the scheduling measures in the flood season to maximize the use of water energy.

In summary, the target model established for the Jinsha River Basin can simulate the actual operation well, and find the part that needs to be scheduled through relevant data, and further verify the feasibility of the model and algorithm through the water level, the outflow flow, and the power generation.

6 Conclusions

In this study, taking the Jinsha River Basin as an example, the NSGA-III algorithm is used to study the multi-objective ecological dispatching problem, and a multi-objective programming model is established to obtain the specific situation of water level, ecological flow and power generation in the region. Finally, a better scheduling scheme is given to ensure the ecological health and sustainable development of the Jinsha River Basin. The results also show that the trend of the established model is in good agreement with the actual value, and the key dispatching parts are found. Therefore, NSGA-III algorithm is effective in ecological scheduling. However, in the course of the study, only the water level, outflow and power generation during the flood season are analyzed, but the situation in the level and dry season is not analyzed. In the subsequent study, the specific situation of the plain water period and dry water period will be further analyzed, so as to conduct a more comprehensive ecological regulation of the Jinsha River Basin. Using NSGA-III algorithm to carry out multi-objective planning for ecological dispatching of river basin can promote the finding of better dispatching scheme and the realization of ecological health and regional economic development of river basin. It also has certain reference significance for the ecological protection of water conservancy projects later, and also provides ideas for ecological dispatching besides rivers.

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