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Study on the Prediction of Runoff Usability in Kaihua County

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Abstract

Small hydropower is an important infrastructure for people's livelihoods and clean renewable energy, but there are still many weak links in the planning, design, construction, operation, and management of small hydropower in some regions. Kaihua County is located at the source of the Qianjiang River, and the rational development and utilization of its water resources are of great significance for protecting the water ecological environment at the source of the Qianjiang River and achieving the development strategy goal of "ecological county and characteristic county" in Kaihua County. To alleviate the water reduction caused by the development and utilization of watershed hydropower and rural hydropower interception and diversion, and further provide data support for the assessment of small hydropower cleaning and rectification in Kaihua County, At the same time, it also provides data basis for the ecological flow management of small hydropower discharge. This article conducted a study on the available amount of runoff in Kaihua County. This article uses the ANFIS model to predict the runoff at Misai Station in Kaihua County. The simulation and prediction relative errors of this model can meet the error requirements, and this model can be applied to predict the runoff at Misai Station in Kaihua County. Using the simulated model for prediction, the runoff depth of Misai Station in Kaihua County in 2022 is approximately 2450.420. In 2023, the runoff depth of Misai Station in Kaihua County is approximately 2146. In 2024, the runoff depth of Misai Station in Kaihua County is approximately 771.16. The predicted results can provide a reference basis for the development of hydropower resources in Kaihua County and the regulation of discharge flow of the hydropower station in Kaihua County.

Keywords

Kaihua County; Water Energy Development; Runoff Rate; Forecast.

1. Introduction

Small hydropower is an important infrastructure for people's livelihoods and clean renewable energy [1], but there are still many weak links in the planning, design, construction, operation, and management of small hydropower in some regions [2]. Water resources are a shared resource, and the protection of natural rivers and water resources is a shared responsibility of humanity. The development of hydropower resources for commercial and economic purposes may lead to the deterioration of the water ecological environment in natural rivers and nearby areas. Kaihua County is located at the source of the Qianjiang River, at the junction of seven counties in Zhejiang, Anhui, and Jiangxi provinces. It is an area with superior water resources conditions. The reasonable development and utilization of its water resources are of great significance for protecting the water ecological environment at the source of the Qianjiang River and achieving the development strategy goal of "ecological county and characteristic

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county" in Kaihua County. To alleviate the water reduction phenomenon caused by the development and utilization of water resources in the basin and the interception and diversion of rural hydropower, Further providing data support for the evaluation of small hydropower cleaning and rectification in Kaihua County, and also providing data basis for the management of ecological flow of small hydropower discharge. This article conducted a study on the available amount of runoff in Kaihua County. By analyzing the trend of changes in the available runoff in Kaihua County, reference is provided for the development of hydropower resources in Kaihua County and the regulation of discharge flow of hydropower stations in Kaihua County.

2. General Situation

2.1. Natural Resource Conditions

Kaihua County is located in the west of Zhejiang Province, at the source of Qiantang River, with the location coordinate of 118 ° 01 east longitude ′~ 118°38 ′, 28 ° 54 North Latitude ′~ 29°30 ′, The length from north to south is 66km, and the width from east to west is 59.2km. Kaihua County is located in the western Zhejiang mountainous area, with towering mountains and a typical topography characterized by the strong rising mountains of Jiangnan ancient land. Kaihua County has a mild climate, abundant rainfall, and a long frost free period. According to the observation results of meteorological stations, the annual average temperature is around 16.3 ℃, with an extreme maximum temperature of 41.3 ℃, which occurred on September 8, 1967 and August 1, 1971. The extreme minimum temperature of -11.2 ℃ occurred on January 16, 1967. The distribution of precipitation is uneven throughout the year, with March to July being a relatively concentrated period of precipitation. July to September is controlled by the subtropical high pressure, with low precipitation and often affected by typhoons, resulting in typhoon rainfall. This period accounts for over 15% of the total annual precipitation. The average annual precipitation is 1840.0mm. The rivers within the territory are all mountain streams, flowing from mountainous areas into plains. They have the characteristics of short source, rapid flow, abandoned water, large riverbed gradient, abundant hydraulic resources, and uneven distribution of precipitation between and within years, with significant changes in flood and dry seasons.

2.2. River System

Table 1. Characteristics of Main Rivers in Kaihua County

river system	River	Overview of the watershed			
		Basin area (KM2)	within the county (KM2)	River length (KM)	River gradient (‰)
Qiantang river	Majinxi	1067.46	975.04	104.17	5.92
	Chi Huai Xi	413.03	406.80	53.8	9.27
	Longshan Creek	332.85	286.54	40.27	14.91
	Maxi River	278.78	278.78	56.7	6.26
	Changshan Port	2092.11	1947.16		
Rao river	Suzhuangxi	226.52	226.52	40.60	9.36
	Xiazhuang Creek	35.33	35.33	10.7	18.69
	Raohe	261.85	261.85		

Kaihua County is divided into Qiantang River (Qujiang River) basin and Yangtze River (Poyang Lake) basin by basin. The Qiantang River drainage area accounts for more than 90% of the total area of the county, with a drainage area of 2036.6km2; Ma Jinxi is the source of Qujiang River, the main stream of Qiantang River, with a drainage area of 1011.3km2, connecting Anhui Province at the top and Changshan Port at the bottom. Ma Jinxi originates from Qingzhi Daijian in Xiuning, southern Anhui. After entering the country, it flows through six townships including Qixi, Majin, Yinkeng, Chengguan, Industrial Park, and Huabu, and flows into Changshan County from the lower boundary of Huabu Town; The river has a length of 102.2km and a gradient of 2.3 ‰. There are seven major tributaries of Qiantang River in Kaihua, including Qixi River, Cuntou River, Zhongcun River, Hetian River, Ma River, Chi Huai River and Longshan River. The drainage area of the Yangtze River (Poyang Lake) basin is 261.86km2, mainly including Suzhuang Creek and Xiazhuang Creek. The characteristics of the river are shown in Table 1.

3. Analysis of the Available Amount of Runoff in Kaihua County

Based on the data collection, this certificate selects the rainfall runoff depth data of Misai Station in Kaihua County as the representative data of Kaihua County. The station has a controlled catchment area of 797km2, and has measured rainfall from 1957 to 2019 and measured runoff data from 1957 to 1996 and 2005 to 2019. This time, the ANFIS model was introduced to analyze the runoff of Misai Station, in order to indirectly calculate the available water resources in Kaihua County.

3.1. Calculation Method

The ANFIS model, also known as an adaptive fuzzy inference system, is a J- S. A method proposed by R. Jang in the 1990s [5]. Assuming a multi input single output fuzzy neural network composed of an L layer, the i nodes of the K layer output O_i^k , assuming that the expected output of the output layer nodes is R_i^L , and the actual output is O_i^L .

Assuming that the membership function used in the second layer is Gaussian type:

$$\mu_A(x) = \exp\left\{-(\frac{x-c_i}{a_i})^2\right\} \tag{1}$$

Among them, c_i and a_i represent the center and width of the Gaussian type, respectively. Let k have $\#k$ nodes, with (k,i) representing the i th node and O_i^k representing the node output. Then:

$$O_i^k = O_i^k(O_1^{k-1},\cdots,O_{\#(k-1)}^{k-1},a_i,c_i) \tag{2}$$

Assuming there are input and output signals from the P group, define the number of errors in the $p(1 \le p \le P)$ group signal as:

$$E_p = \sum_{m=1}^{\#k}(R_{m,p} - O_{m,p}^L)^2 \tag{3}$$

$R_{m,p}$ is the m component of the target output of the p group signal, and $O_{m,p}^L$ is the m component of the actual output vector corresponding to the input vector of the p group. Then the error function of the whole model is:

$$E = \sum_{p=1}^{P} E_p \tag{4}$$

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In order to improve the training speed, a gradient descent learning method is introduced to calculate the first derivative of the input vector of the p group with respect to O:

$$\frac{\partial E_p}{\partial O_{m,p}^L} = -2(T_{i,p} - O_{i,p}^L) \tag{5}$$

The error change rate of (k,i) node is:

$$\frac{\partial E_p}{\partial O_{i,p}^k} = \sum \frac{\partial E_p}{\partial O_{m,p}^{k+1}} \frac{\partial O_{m,p}^{k+1}}{\partial O_{i,p}^k}, 1 \le k \le L-1 \tag{6}$$

If a is a parameter of the model, then:

$$\frac{\partial E_p}{\partial a} = \sum_{O^* \in S} \frac{\partial E_p}{\partial O^*} \frac{\partial O^*}{\partial a} \tag{7}$$

Among them, S is the set of nodes related to output, and the error indicator function of the entire model regarding a is:

$$\frac{\partial E}{\partial a} = \sum_{p=1}^{P} \frac{\partial E}{\partial a} \tag{8}$$

Taking a as an example, its parameter update formula is:

$$\begin{aligned} \Delta a &= -\eta \frac{\partial E}{\partial a} \\ a_{i+1} &= a_i + \eta \frac{\partial E}{\partial a} \end{aligned} \tag{9}$$

η is the learning efficiency.

$$\eta = \frac{k}{\sqrt{\sum_a (\frac{\partial E}{\partial a})^2}} \tag{10}$$

k is the step size, which is the length of the gradient's variation in the function space.

3.2. Result Analysis

This time, the measured runoff data from Misai Station from 1957 to 2017 were used as the simulation series, and the data from 2017 to 2019 were used as the test series to predict future runoff. The model has been trained 50 times to achieve the set error target. The comparison table between measured data and simulated predicted data is shown in the following figure:

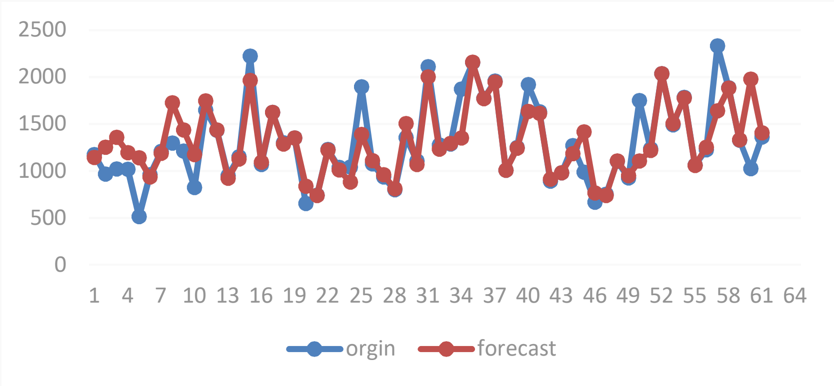

Figure 1. Comparison between the original sequence and the predicted sequence

According to statistics, 88% of the simulated and predicted relative errors are less than 30%, and 81% are less than 20%, which meets the error requirements. This model can be applied to predict the runoff of Kaihua Misai Station. Using the simulated model for prediction, the runoff depth of Misai Station in Kaihua County in 2022 is approximately 2450.420. In 2023, the runoff depth of Misai Station in Kaihua County is approximately 2146. In 2024, the runoff depth of Misai Station in Kaihua County is approximately 771.16. It can be seen that the runoff in 2022 and 2023 is relatively sufficient, while the runoff in 2024 is relatively low. It is necessary to prepare in advance for the situation.

4. Conclusion

Small hydropower is an important infrastructure for people's livelihood, water conservancy, and clean renewable energy. In areas with superior water resources in Kaihua County, the rational development and utilization of its water resources are of great significance for protecting the water ecological environment at the source of the Qianjiang River and achieving the development strategy goal of "ecological county building and characteristic county revitalization" in Kaihua County. This article conducted a study on the available amount of runoff in Kaihua County. By analyzing the trend of changes in the available runoff in Kaihua County, reference is provided for the development of hydropower resources in Kaihua County and the regulation of discharge flow of hydropower stations in Kaihua County. By using ANFIS to predict the runoff of Misai Station in Kaihua County, it was found that 88% of the simulated and predicted relative errors were less than 30%, and 81% were less than 20%, meeting the error requirements. This model can be applied to predict the runoff of Misai Station in Kaihua County. Using the simulated model for prediction, the runoff depth of Misai Station in Kaihua County in 2022 is approximately 2450.420. In 2023, the runoff depth of Misai Station in Kaihua County is approximately 2146. In 2024, the runoff depth of Misai Station in Kaihua County is approximately 771.16.

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