Smart Systems and Green Energy (2022)
Clausius Scientific Press, Canada

DOI: 10.23977/ssge.2022.040103
ISSN 2523-904X Vol. 4 Num. 1

Research on the Water Use for Hydropower Generation Base on Upply and Demand Model

Mingwei Feng[1], Jiashuo Chen[2]

[1]*College of Information and Electrical Engineering, Heilongjiang Bayi Agricultural Reclamation University, Daqing, Heilongjiang, 163711, China*

[2]*College of Science, Heilongjiang Bayi Agricultural Reclamation University, Daqing, Heilongjiang, 163711, China*

Keywords: Water and Hydroelectricity; Subinterval Weights; Supply and Demand Model

Abstract: A supply and demand model is established to cope with different situations. Under the condition that the water level is known, the fair water use coefficient, subinterval weights and target weight model are improved, and the parameters are reconciled so as to determine the parameters of the supply and demand model, and the time-effective functions of flow rate and water level are established to determine the functional relationship of demand water use at different moments; on the basis of the supply and demand model, the water use for hydropower generation is taken as the object and combined with the basis of the supply and demand model, we analyze how long it takes to meet the demand without increasing the additional flow rate and satisfying the demand for hydroelectric power generation by using the hydropower plant power coupling model as the target and considering the influence of rainfall on the water quantity, establish the rainfall model, integrate the supply and demand model, and determine the additional water quantity required.

1. Introduction

In recent centuries, dams and reservoirs have been built on rivers. The presence of these facilities not only provides areas for recreational use and storage of water for various purposes, but also serves as a power generation system that converts the potential energy of falling or fast-moving water into mechanical energy [1]. But with global warming and insufficient local rainfall, these dams may not be able to meet water demand and power supply everywhere. Natural resource officials in five U.S. states and counties are in negotiations to manage water and power production at Glen Canyon and Huff Dams, which have unreasonable water allocations that could result in insufficient water to meet stakeholders' basic water and power generation needs in the future, and for which a reasonable water allocation plan is needed to deploy water needs and power demand. This paper is modeling to address the supply and demand of water under different conditions. Condition 1: How much water can be supplied to meet the specified demand, gave a fixed water level. Condition 2: How long does it take to meet the demand without considering additional water supply under a fixed demand. Condition 3: How much additional water needs to be supplied over time to meet the fixed demand?

2. Supply and demand model

Considering that the water volume of the dam needs to meet the demand for industrial, agricultural, and domestic water as well as hydroelectric power generation in different situations, the model is improved and classified for different situations.

2.1 Supply and demand model under the condition of knowing water level

The model allocates water to water (industrial, agricultural, domestic, surplus use) and hydropower from demanded water use needs.

STEP1: Improve the water use equity coefficient model, target weighting coefficient model to determine the allocation ratio of demand water use to water quantity and hydropower generation.

Determine the priority of water use for water quantity in order of strength and weakness: domestic water, industrial water, agricultural water, and surplus use

Determine the priority of water use for hydropower generation in order of strength: industrial power generation, domestic power generation, agricultural power generation

Using the water equity factor to convert to a water fairness factor:

$$\beta_j^k = \frac{1 + n_{max}^k - n_j^k}{\sum_{j=1}^{J(k)} (1 + n_{max}^k - n_j^k)} \tag{1}$$

The water use fairness factor and hydropower generation fairness factor were obtained as shown in the following table:

Table 1: Water use fairness factor

Use	Domestic water	Industrial water	Agricultural water	Residual water
Fairness factor	0.4	0.25	0.3	0.05

Table 2: Water use fairness factor

Use	Industrial power generation	Living power generation	Agricultural power generation
Fairness factor	0.45	0.45	0.10

The binary comparison method was used to determine the target weight coefficients.

The above fairness coefficients were used as important value indicators, which were normalized to obtain the individual target weights:

$$k_j = \frac{w_j}{\sum_{h=1}^{m} w_h} \tag{2}$$

Combining the idea of target weights and comprehensive evaluation thus determining the target weight coefficients for water quantity and hydropower generation, as shown in the following table:

Table 3: Target weighting factor

Classification	Water use	hydropower generation
Target weighting factor	0.55	0.45

STEP2: According to the dam release principle (shown in the figure below), from the amount of water released from the dam, allocated to water use and hydroelectric power generation:

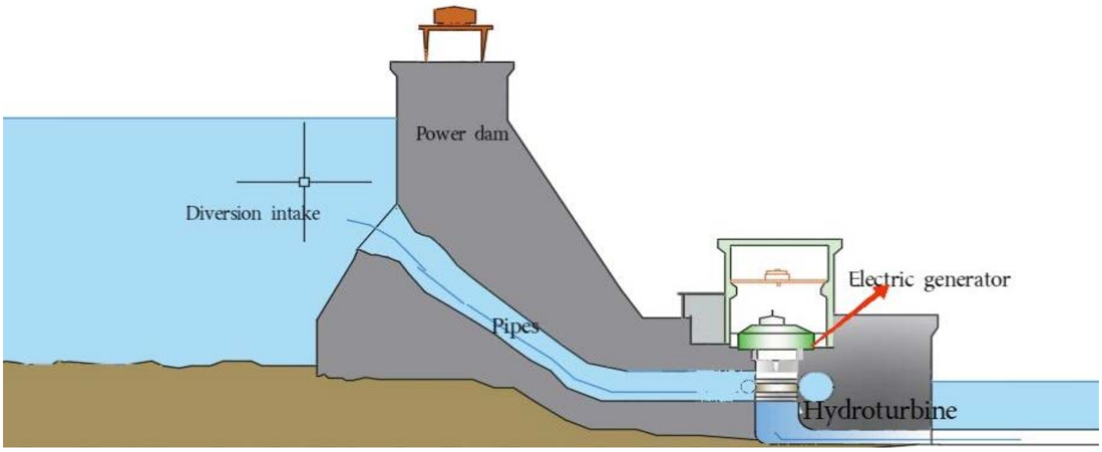

Figure 1: Diagram of the dam.

The starting water volume of the reservoir dam is known to be Q_0 and for different dams with known starting water levels, the quantitative reservoir area is determined based on the relationship between water volume and water level:

$$S=\frac{Q_0}{H_0} \tag{3}$$

The change in water level that is the dynamic process, and the existence of time, the establishment of time-varying functions: H(t)

The demand water model is as follows:

$$Q=k_1\left(Q_0-\frac{Q_0}{H_0}(H_t-H_0)\right)+k_2\left(Q_0-\frac{Q_0}{H_0}(H_t-H_0)\right) \tag{4}$$

$$k_1=0.55, k_2=0.45, H_0=\begin{cases} P\ \text{(Glen Canyon dam (Lake Powell))} \\ M\text{(The Hoover dam (Lake Mead))}\end{cases} \tag{5}$$

2.2 Demand is quantitative conditions, no additional water supply, find the required time

Since the focus is on time from the perspective of hydropower generation, the water target weighting factor is used to find the amount of water required for hydropower generation and thus the corresponding time in reverse.

STEP1: Determine the target weighting factor

STEP2: Modeling of hydroelectric power coupling:

$$\begin{cases} P=9.81Q_W H \\ E=\int_{to}^{t} P dt = P\Delta t \\ H=H_g-\Delta h \end{cases} \tag{6}$$

H_g -height difference between upstream and downstream Δh -Loss of water head (approximately3%-10%).

STEP3: Modeling the correlation function of time:

$$\Delta t = \frac{E}{9.81\left(k_2\left(Q_0 - \frac{H_0}{Q_0}(H_t - H_0)\right)93.5\% H_g\right)} \tag{7}$$

2.3 Additional supply to meet supply and demand requirements

STEP1: Establishing reservoir water volume change model and rainfall model:
Reservoir change model:

$$Q_{t+1} = Q_t + Q_e - Q + Q_r \tag{8}$$

Meet the requirements of supply and demand critical conditions: at this time Q_{t+1} just meet the primary supply and demand Q:

$$Q_e = 2Q - Q_t - Q_r \tag{9}$$

Considering the climatic influences and the impact of the degree of drought in each state:

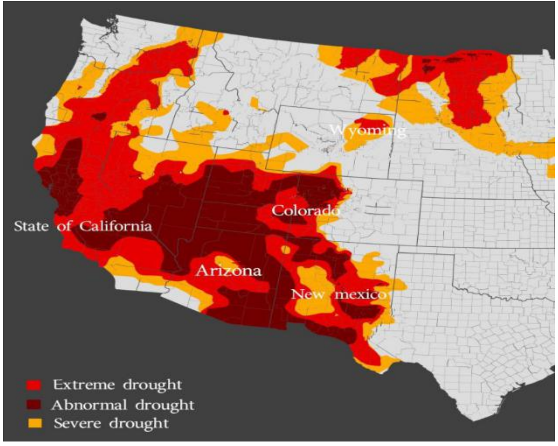

Figure 2: Climate diagram.

Figure 3: Climate diagram.

Reconciling traditional rainfall models:

$$Q_r = d(alnp + b)\begin{cases} d = 0\ Dry\ weather\ or\ not\ raining \\ d = 1\ Rainfall\ weather \end{cases} \tag{10}$$

STEP2: Supply and demand as a known condition, the amount of water is mixed with the influence of rainfall, so consider the supply and demand from the perspective of hydropower generation.

The following relationship is determined:

$$Q_e = \frac{2E}{k_2 9.81\Delta t 93.5\% H_g - (Q_0 - \frac{Q_0}{H_0}(H_t - H_0))} - Q_r \tag{11}$$

STEP3: Since there is no fixed multiplier to meet the demand, parameters need to be introduced to reconcile the model:

$$Q_e = \frac{nE}{k_2 9.81\Delta t 93.5\% H_g - \left(Q_0 - \frac{Q_0}{H_0}(H_t - H_0)\right)} - Q_r \tag{12}$$

References

[1] Zhao Xiaoqiang, He Zhi'e. Optimal scheduling of water resources based on improved chaotic genetic algorithm [J]. Journal of Lanzhou University of Technology, 2015, 41(04): 65-70. DOI: 10.13295/j.cnki.jlut.2015.04.014.