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Double dam coordination model based on Lake Mead and Lake Powell

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Abstract: *With climate change, water supply from dams and reservoirs is decreasing in many regions. For centuries, people have built dams on rivers and streams to hold back water, and reservoirs have been built as a means of managing water supply. In this paper, we established a double-dam coordination and cooperation model. We abstracted the lake into a cuboid, and established a physical model of hydropower supply and demand based on the water levels of Lake Mead and Lake Powell. Next, we established a hydropower conversion rate model, taking into account The cooperation between the power stations has established a short-term optimal scheduling mathematical model of the hydropower system. Through the constraints, we have reached the relationship between the hydropower conversion efficiency and the lake water level. We established a short-term optimal scheduling model for hydropower systems, which addresses t he competing interests of general agricultural, industrial residential water use and water availability for water power and electricity production. The electric energy is the largest and the unification of the rules that the electric energy is the largest and the water consumption is the smallest is realized. Combined with the water consumption constraints of the target power station, the water balance constraints of the reservoirs of each hydropower station, and the reservoir capacity constraints, the water level height reduction model is established. On the basis of the previous model, we established an optimization model based on particle swarm optimization, and brought it into matlab for simulation through particle swarm optimization, and calculated the hydropower conversion efficiency of Lake Mead and Lake Powell with the height of the water level under constraints.*

Keywords: *Double dam coordination and cooperation model, Short-term optimal scheduling mathematical model, Particle swarm optimization algorithm*

1. Introduction

Reservoirs store water for various uses (e.g. agriculture, industry, residential), provide recreational and recreational opportunities (e.g. fishing, boating), assist in preventing downstream flooding, and supply water to turbines that generate electricity[1]. Hydroelectric power is the electricity produced by these turbines as they convert the potential energy of falling or fast-flowing water into mechanical energy[2].

Natural resource officials in Arizona (AZ), California (CA), Wyoming (WY), New Mexico (NM) and Colorado (CO) are currently negotiating to determine the best way to manage water use and electricity production. Glen Canyon and Hoover Dam to address these competing interests. Agreements from centuries ago continue to influence water management regulations, policies and practices today. These agreements distribute more water from the Colorado River system than there is in the system. The system may continue to work because some users are not fully assigned. If the Colorado River Basin continues to dry up, at some point there will be insufficient water to meet the basic water and power generation needs of stakeholders. Therefore, it is crucial to develop a rational and rational water allocation plan for current and future water supply conditions.

2. Background

We established a double-dam coordination and cooperation model. We abstracted the lake into a cuboid. According to the water levels of Lake Mead and Lake Powell, we established a physical model of hydropower supply and demand. Next, we established a hydropower conversion rate model. With the cooperation between the two, a short-term optimal scheduling mathematical model of the hydropower system is established. Through the constraints, we have reached the relationship between the hydropower

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conversion efficiency and the lake water level. A short-term optimal scheduling model for hydropower systems is established, which solves the competing interests of water availability in general agriculture, industrial residential water, and water power and electricity production. An optimization model based on particle swarm optimization is established[3], which is brought into Matlab simulation is carried out to calculate the optimal situation of the hydropower conversion efficiency of Lake Mead and Lake Powell with the height of the water level under the constraint conditions[4][5].

3. Establishment and solution of model

3.1. Establish a model of coordination and cooperation between two dams

Abstracts the lake into a cube, the bottom S of the cube$_{i.}$ It is the bottom area of the lake, the height of the cube is the water level height of the lake, noting that the operation of Glen Canyon Dam (Lake Powell) and Hoover Dam (Lake Mead) should be closely coordinated, because the water from Glen Canyon Dam provides some water input to Hoover Dam.As can be seen from the figure above, the Colorado River passes through these two lakes, so model assumptions can be proposed:

The water from the Glen Canyon Dam provided Hoover Dam with part of the water input weight of .λ_1. It can be assigned to: $\lambda_1 = 0.9$

Assuming x_i at month i from Lake Powell, the water of $\lambda_1 x_i$ flows into Lake Mead, when the water level rises to Δ_{up} with the expression of:

$$\Delta_{up} = \frac{\lambda_1 x_i}{S_2} \tag{1}$$

At this point the water level of Lake Meade becomes:

$$H'_{1i} = H_{1i} + \Delta_{up} \tag{2}$$

The above is the main content of the double-dam coordination and cooperation model.

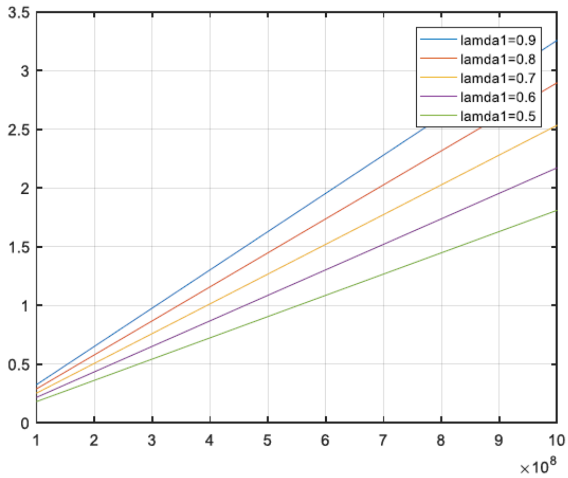

Figure 1: The water level rise of Lake Mead corresponding to different Lake Powell pumping amounts under different weights

3.2. Establish a hydropower conversion rate model

The mathematical model of short-term optimization scheduling of hydropower system is as follows:

The objective function is the formula of:

$$max\{\sum_{K=1}^{N}\left(E_K + \beta_K W_{\tau_K}/\gamma_K\right)\} \tag{3}$$

Water flow transfer constraint in the river basin

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$$
\begin{aligned}
& I_{K,t} = f(Q_{K_j}, IC_{K,t}) \ (t = 1 \sim T,\ j \in \Omega_3) \\
& V_{K,\min} \leqslant V_{k,t+1} \leqslant V_{k,\max} \\
& (K = 1 \sim N, t = 1 \sim T) \\
& \begin{cases} Z_{K,0} = Z_{K0} \ (K \notin \Omega_2) \\ Z_{K,T+1} = Z_{K\,\text{end}} \end{cases} \\
& Z_{K0}, Z_{K\,\text{end}} \\
& P_{K_t} \geqslant 0 \, (\in \Omega_{1K}, K = 1 \sim N, t = 1 \sim T)
\end{aligned} \tag{4}
$$

According to the above model, the function relationship between the hydropower conversion efficiency ξ and the lake water level height H can be obtained as follows:

$$\xi = f(H) \tag{5}$$

About Lake Powell: Data Points exist (171,0.8), (20,0)

For Lake Meade, the data points (153,0.8) and (20,0) are shown

3.3. Establish a water level and height reduction model

A large cuboid with a bottom area of S, then the overall water level drop value of Δwithin 1 month is:

$$\boldsymbol{\Delta = G/S} \tag{6}$$

Optimization and solution algorithm (particle group algorithm):

The particle group algorithm process is roughly shown in the following figure:

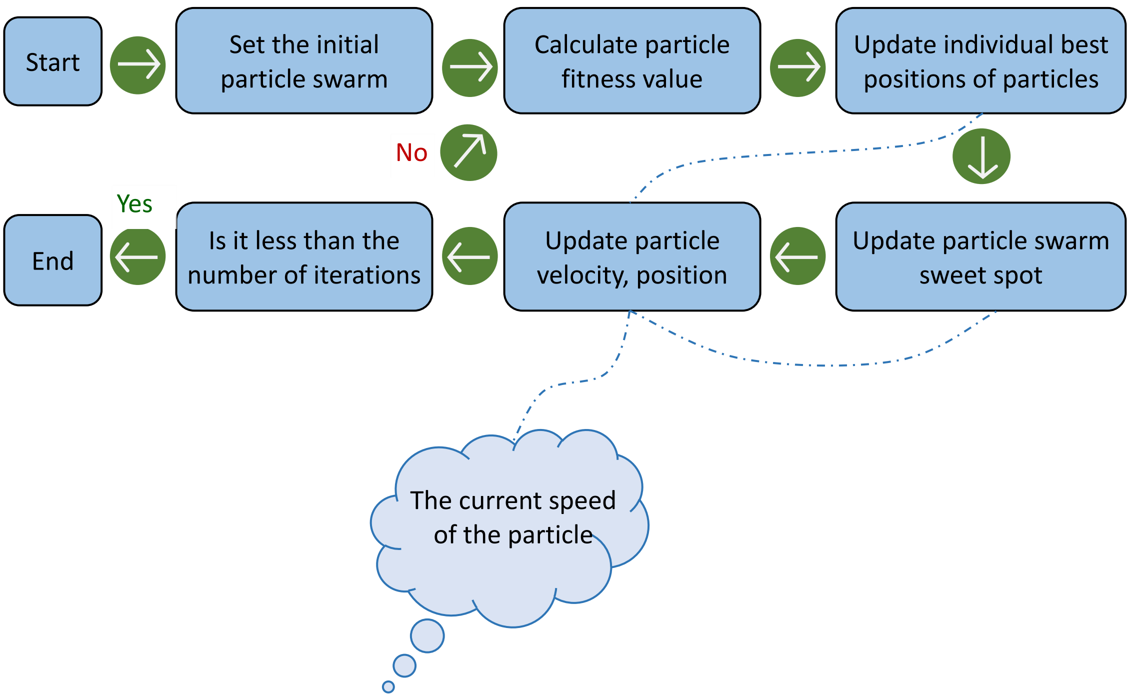

Figure 2: Schematic diagram of the particle group algorithm

4. Model solution results

Subin data for simulation: The initial data is: P=150, M=130; The partial solution results are as follows:

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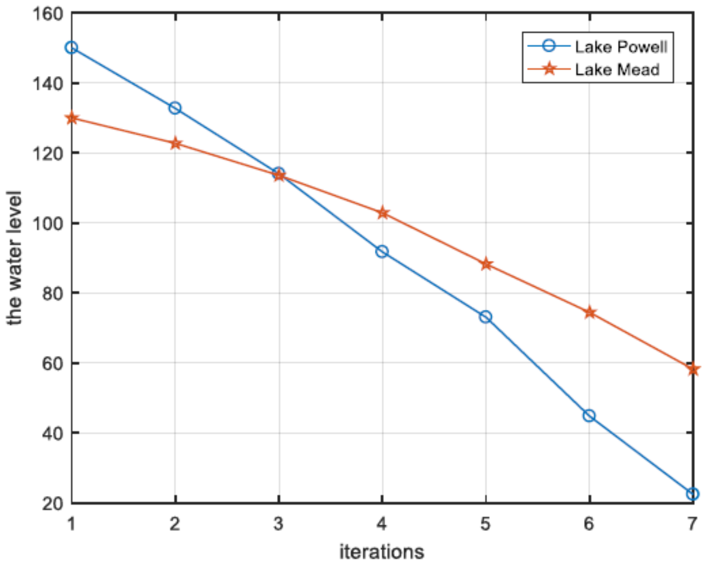

Figure 3: Operation result grap

These are the changes in the water supply at each iteration. Last cycle, will require additional water resources: 2.4428e + 09

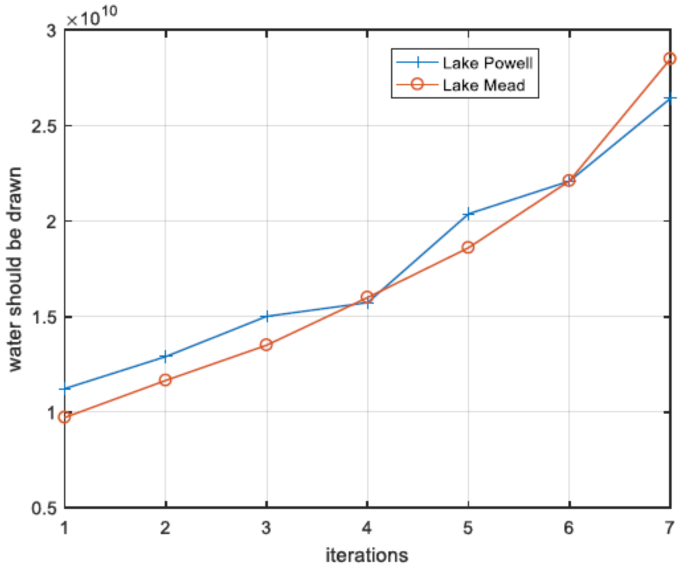

Figure 4: Water supply at each iteration

5. Conclusion

We considered comprehensiveness in the model and established a double dam model. Considering that the operations of Glen Canyon Dam (Lake Powell) and Hoover Dam (Lake Mead) should be closely coordinated and solved by particle swarm algorithm, PSO is an iterative optimization algorithm similar to genetic algorithm. The system is initialized as a set of random solutions, and the optimal value is searched through iteration. Compared with the genetic algorithm, the advantage of PSO is that it is simple and easy to implement, and there are not many parameters that need to be adjusted.

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