APPLICATION AND RESEARCH OF HYDROPOWER STATION OPERATION SCHEDULING CHART BASED ON PARALLEL NORMAL CLOUD MUTATION SHUFFLED FROG LEAPING ALGORITHM

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ABSTRACT

When the conventional method is used to draw the Hydropower Station Operation Scheduling Chart, the selected typical hydrochronology is limited because of the limited number of hydrological year series. In this paper, the Parallel Normal Cloud Mutation Shuffled Frog Leaping Algorithm(PNCM-SFLA) is applied to the Operation Scheduling Chart of Ankang Hydropower Station. By using its better global optimization ability and faster convergence speed, the Operation Scheduling Chart of Ankang Hydropower Station is drawn based on historical measured data. PNCM-SFLA integrates cloud model algorithm into frog leaping algorithm. At the same time, taking advantage of its easy parallel characteristics, parallel computing based on. NET4 parallel extended library in multi-core environment has better global optimization ability and faster convergence speed. Through the application research of practical production project, it is proved that the PNCM-SFLA can overcome some shortcomings of the conventional drawing method and improve the operation efficiency of hydropower stations while ensuring the reliability index.

1. INTRODUCTION

With the emergence of system science and intelligent optimization algorithm, some optimization theories and methods are widely used in reservoir optimal operation. For example, large-scale system decomposition or hierarchical optimization theory, dynamic programming method, genetic algorithm, ant colony algorithm and so on[1-2]. However, due to the deviation between the optimal operation plan and the actual operation, from the current application level of the optimal operation of the hydropower station, it is basically not able to use the optimal operation plan to guide the real-time operation of the hydropower station. The conventional generation operation diagram of the reservoir is still the most commonly used tool for the operation and operation of the hydropower station, which is of great significance to guide the long-term operation of the hydropower station reservoir[3]. The conventional method for drawing the power generation dispatching diagram of hydropower station with annual and seasonal regulation performance is: select a number of typical years meeting the design assurance rate requirements from the historical measured runoff data as samples, calculate the water energy of each year according to the guaranteed output from the dead water level at the end of the water supply period to the beginning of the water supply period in reverse order to get the water storage change process of each year's hydropower station operation, and then take the upper and lower packages As the upper and lower basic dispatching lines, and then the upper and lower basic dispatching lines are the boundary conditions, the increase output lines are drawn up, and the decrease output lines are drawn down[4].

Due to the limitation of historical measured data and the uneven distribution of annual water between years, it is difficult for a small number of typical annual samples to reflect the representativeness of the combination of reservoir water and power generation water. Therefore, the conventional generation scheduling diagram drawn by this method has its limitations[5]. Based on this, this paper introduces Parallel Normal Cloud Mutation Shuffled Frog Leaping Algorithm (PNCM-SFLA) to draw the reservoir power generation operation diagram of hydropower station, making full use of all the measured data information, not only the typical hydrological year, but also the calculation of the operation diagram can directly show the benefits of the simulation operation of hydropower station according to the operation diagram under various constraints, so it is very convenient in the drawing process. In order to improve the operation efficiency of the hydropower station, the dispatching chart is optimized.

2. PARALLEL NORMAL CLOUD MUTATION SHUFFLED FROG LEAPING ALGORITHM

Shuffled Frog Leaping Algorithm(SFLA) is a stochastic global optimization method, which is proposed for the simulation about frogs(solution) in wetland(solution space) by Eusuff and Lansey in 2003. As an efficient parallel optimization method, SFLA can realize the search and analysis for the optimal solution of complex space, and is suitable for the solution of complex optimization problems that are nonlinear, non-differentiable, multi-objective. But SFLA is also easy to fall into local optimum, especially all the individual frogs are concentrated in one place later, if in a local optimum, then all the individual frog is easy to fall into the range of constraints, and premature convergence . Based on the analysis on the principle of SFLA, the cloud model algorithm is mix together in SFLA, then a Normal Cloud Mutation SFLA(NCM-SFLA) is formed to makes up the shortage of SFLA, that is easy to fall into local optimum in the late. But for the dramatically search space in large-scale multivariable task, its solving efficiency and quality is difficult to meet the requirements of engineering in serial environment. In recent years, the increasing popularity of multi-core processors for the parallel computing implementation provides the necessary hardware base, while the long-term optimal operation of cascade reservoirs has large amount of calculation, and has a certain degree of parallelism, is conducive to the implementation of the parallel computing technology. Therefore parallel processing technology are combined with the NCM-SFLA, a Parallel Normal Cloud Mutation SFLA(PNCM-SFLA) is proposed to improve its performance by parallel computing in multi-core CPU [8-11].

In the Shuffled frog leaping algorithm(SFLA), each frogis seen for the vector of element or thought, which is the potential solutions of optimization problems, that can exchange ideas with the other frogs, and as well can transfer information, improved other frogs' information[12]。 SFLA has the specific iterative update mechanism. First of all, local search takes place in the population, and then through the mixing process of Population, global population information is exchanged. Combining the global information exchange and internal communication mechanism, which makes the algorithm can partly avoid getting into local extreme point, so as to guide the optimization process towards the global optima in the direction of search.

When the algorithm is implemented, firstly, we randomly generate group formation of F frogs, every frog represents a solution vector $X=(x_1,x_2,...,x_n)$ in the solution space, where n denotes the number of variables. Then according to the fitness of individuals within a group of frogs, they are ranked in descending order, so as to determine the global best individual X_g. Then the frogs are divided into l sub group, each group has the h frogs, meet $F = l \times h$. Specific method is: first frog is selected into first sub group, second frog is selected into second sub group,......, the number l frog is selected into the number l sub groups; the number l+1 frog is selected into first sub group, the l+2 frog is selected into second sub group,......, and so on, until all the frogs complete classification. Then local search take place in each population, namely the worst individual X_w and the best individual X_b of each sub group are firstly ascertained in each iteration; the worst individual X_w of current populationis updated by the update formula (1).

$$\begin{cases} D_i = rand() \cdot (X_b - X_w) & |D_{\min}| \le |D_i| \le |D_{\max}| \\ newX_w = X_w + D_i \end{cases} \tag{1}$$

In the formula: R is a random number in the interval [0,1]; Di is frog leap step, $i=1,2,...,l$; $|D_{\min}|$ is the allowed minimum frog leap step; $|D_{\max}|$ is the allowed maximum frog leap step; $newX_w$ is the updated X_w. After the update strategy (7) is performed, if the fitness of $newX_w$ is superior to the fitness of the worst individual X_w in original group, then $newX_w$ is used instead of X_w. Otherwise, a new individual frog is randomly generated instead of X_w. After local search in all ethnic groups is completed, all the frogs are mixed and sequenced again, then frog group is divided into sub groups, continue to perform local search, so repeatedly until a predetermined condition of algorithm is satisfied[13]。

Based on Parallel Normal Cloud Mutation SFLA(PNCM-SFLA), Mutation operation on the current group's best individual X_b is proceeded by using the basic normal cloud generator, then to update and replace the X_b. In the process, $E_x=X_b$, $E_n=\Omega/c_1$, $He=E_n/c_2$, Ω is the variable search range[8]. In order to ensure the frogs diversity algorithm later, let c_1 be global hybrid iteration number minus the current global the number of iterations, $c_2=10$, random of individual frog generation later in the basic normal cloud generator is enhanced. Then the global optimum individual X_g is determined at the moment, the formula (1) is used to update the worst individual X_w of the current population. Meanwhile NCM-SFLA is iterative calculation inpopulations，corresponding to different populations, using NCM-SFL Anatural parallel is mand optimization model, then a direct parallel in the original seria lNCM-SFLA foundation, PNCM-SFLA is proposed by embedding Parallel Extensions compiler guidance statement in the original code torealize parallel.

3. THE APPLICATION OF PNCM-SFLA IN THE DRAWING OF POWER GENERATION DISPATCHING DIAGRAM OF HYDROPOWER STATION

3.1 The structure of frogs

The PNCM-SFLA algorithm is used to draw the scheduling chart. If the scale of the frog group is F, then any individual frog can be constructed into a scheduling chart. Its position in the space can be a two-dimensional array of $l \times h, l$is the number of scheduling lines in the scheduling chart, h is the length of the scheduling line. The component $x_{it}(i=1,2,\ldots,l;t=1,2,\ldots,h)$ represents the water level at time t of the ith dispatching line. The coding form is as follows:

$$X_i = \begin{vmatrix} x_{11} & x_{12} & \cdots & x_{1h} \\ x_{21} & x_{22} & \cdots & x_{2h} \\ \vdots & \vdots & \ddots & \vdots \\ x_{l1} & x_{l2} & \cdots & x_{lh} \end{vmatrix} \quad (2)$$

3.2 Fitness function

According to the above introduction, the fitness value of the population is the only index to measure its location. Therefore, combined with the solution goal of the reservoir power generation operation, the fitness function can be directly taken as the fitness function, namely:

$$E = \sum_{i=1}^{T} k \cdot q \cdot h \quad (3)$$

Where:E is the generating capacity; k is the output coefficient; q and h respectively references flow and generating head correspond to the period i; T is the total length of calculation period.

When calculating the fitness value of any population, it is to simulate the operation of the reservoir of the hydropower station according to the generation dispatching diagram shown by the each population, make full use of the known historical measured data, take the benefit result of the simulation operation for many years as the fitness value, which can intuitively show the advantages and disadvantages of each population, effectively combine the drawing of the dispatching diagram with the application purpose of the dispatching diagram, so as to ensure the final dispatching diagram practicability.

When considering the output guarantee rate of hydropower station, the guarantee rate can be treated in the form of penalty function.

3.3 Treatment of constraints

Reservoir operation is a typical multi constraint problem, which mainly includes the following constraints:

Water level (storage capacity) constraint:

$$Z\min \le Zi \le Z\max (V\min \le Vi \le V\max) \quad (4)$$

Output constraint:

$$N\min \le Ni \le N\max \quad (5$$

Reservoir discharge constraint:

$$Q\min \le Qi \le Q\max \quad (6)$$

Water balance equation:

$$V_{i+1} = Vi + (q_i - Q_i) * \Delta T \quad (7)$$

Where, $Z\,i$、$V\,i$、$N\,i$、$Q\,i$ and qirespectively correspond to the water level, storage capacity, output, outbound flow and inflow flow of the reservoir in I period; Z min、Z max（V max、V min）are respectively the minimum and maximum water level (storage capacity) limits of the reservoir; N min、N max are respectively the minimum and maximum outflow limit of the reservoir; Q min、Q max are respectively the minimum and maximum outflow limit of the reservoir; ΔT Is the time period length.

Among them, output constraint, reservoir discharge constraint and water balance equation constraint can be controlled directly in the calculation of reservoir operation, while water level (storage capacity) constraint needs to be controlled not only in the calculation of reservoir operation, but also in the construction of population and frog jump step. First of all, each population in the algorithm corresponds to a scheduling chart, and the scheduling line of the scheduling chart is essentially a water level indicator line, so when constructing the initial population, strict boundary constraints should be applied; secondly, each scheduling line on the scheduling chart should be non-intersecting (overlapping) and strictly controlled; thirdly, the initial population meets the above constraints, but in the process of jumping, it is possible to Jump out of the boundary constraints, so it is necessary to control the leaping step size within the maximum and minimum leaping step size.

3.4 Flow chart based on PNCM-SFLA algorithm

The flow of drawing the scheduling chart with PNCM-SFLA algorithm is as follows[8]:

(1) To initialize the frog populations $F=l\times h$, and the algorithm parameter assignment. Then any individual frog can be expressed as $X_i(i=1,2,\cdots,F)$. The formula(3) as the fitness function is used to calculate the fitness value of the current all individual frog(solution), and then individual frogs, which are sorting from good to bad,are divided into each sub-population in turn;

(2) Each sub population is assigned todifferent coresto perform localdepth search of NCM-SFLAalgorithm;

(3) To determine whether thetermination condition.Ifnot satisfied,then allthe individualfrog are mixed again,return to step 2);otherwise,the optimization results are returnedto the main program;

(4) When calculation of allthreadis finished,themaximum of the objective function value is chosen as the result ofthe optimalsolution of the original problem.

4. INSTANCE APPLICATION

After verifying the feasibility and effectiveness of PNCM-SFLA algorithm, this method is applied to the revision and redrawing of the reservoir power generation operation chart of a hydropower station. The hydropower station has annual regulation capacity, mainly for power generation. The normal water level of the reservoir is 330.0m, the dead water level is 305.0m, the flood limit water level is 327.5m, the guaranteed output is 146.2MW, the installed capacity is 852.5MW, the output coefficient is 8.5. The water level capacity curve, downstream water level discharge curve, predicted output generating head curve and 58 year runoff data of the reservoir are known. After calculation and analysis, the PNCM-SFLA algorithm is proposed. The population size is F=360, the number of subpopulations is 36, the number of computer cores is 4, the number of global mixed iterations is 500, and the number of iterations in subpopulations is 10.

According to the conventional method andPNCM-SFLAalgorithm, the annual generation dispatching diagram of the reservoir is drawn, and the specific results are shown as follows.

The typical hydrological years selected by the conventional method are 8, and the results of the operation chart are shown in Figure 1.

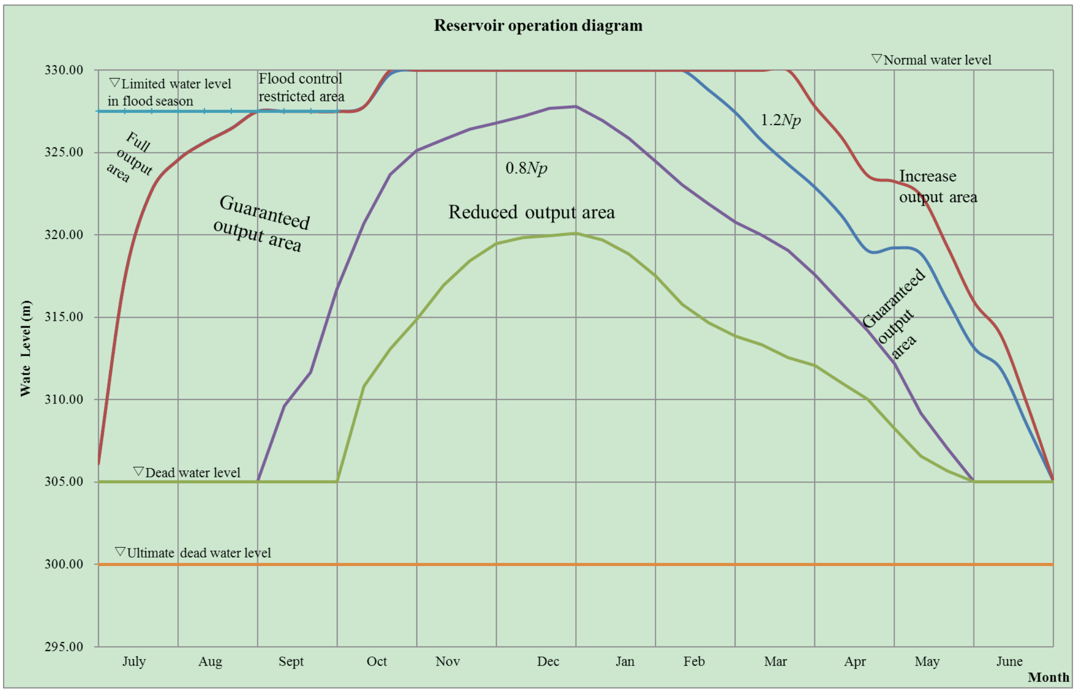

Figure 1 : Operation chart according to conventional methods

According to the dispatching diagram shown in Figure 1, the hydropower station has simulated operation for many years, and the average annual power generation is 2627 million kWh.

The PNCM-SFLA algorithm takes the average annual power generation as the fitness function. For the convenience of comparison, the assurance rate obtained from simulated operation according to Figure 1 is taken as the penalty item, and the scheduling chart is drawn as shown in Figure 2.

The hydropower station has simlated operation for many years according to the dispatching diagram shown in Figure 2, and the annual average generating capacity is 2666 million kWh, which is consistent with the guarantee rate during operation according to the dispatching diagram 1. The generating capacity is increased by 1.4%, and the economic benefit is significant.

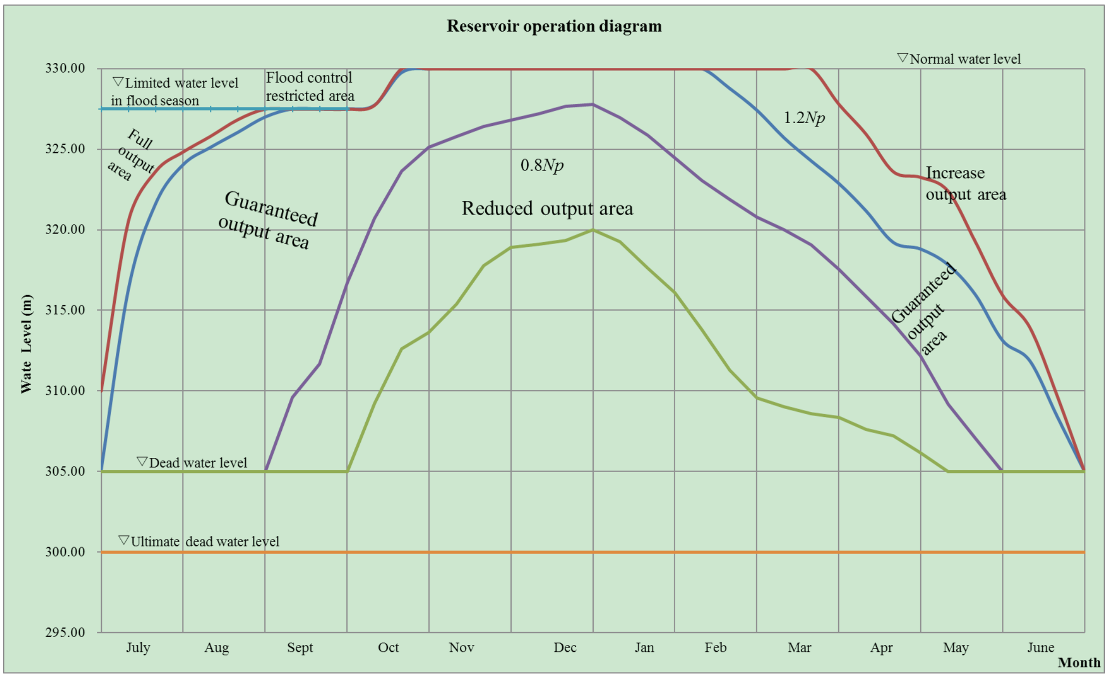

Figure 2 : Operation chart according to PNCM-SFLA algorithm

It can be seen from the comparison between the two figures that the change of the lower basic dispatching line is not big, and the change of the Upper basic dispatching line is large. The dispatching line shown in Figure 2 is significantly lower than that shown in Figure 1 in July to September, and significantly higher than that shown in Figure 1 in April to June. According to the characteristics of simulated operation process and runoff for many years, the rationality of operation chart 2 is analyzed as follows:

The flood season is from July to September, and the reservoir has a large amount of water. Each of the above-mentioned basic operation lines as the boundary condition of the guaranteed output is all feasible, the guaranteed output can be met in these months, so the influence of the reduced degree line on the whole operation result is not significant within this range of change. In the flood season, the basic operation line in the operation chart 1 is higher than that in the operation chart 2, which leads to the increase of the opportunity for hydropower station to operate according to the guaranteed output, and the reservoir is easy to be filled up earlier, resulting in more waste water; in the flood season, the reduction of the basic operation line in the operation chart 2 increases the opportunity for increasing the output in the operation process, and on the premise of ensuring the reservoir to be filled up at the end of the flood season, the waste water is reduced, which is conducive to improving the power generation efficiency.

From April to June in the normal water period, Figure 2 is slightly higher than the basic operation line in Figure 1, which reduces the opportunity to increase the output, makes the hydropower station operate according to the guaranteed output as much as possible, slows down the water level dissipation speed of the reservoir, maintains the reservoir power generation operation at a relatively high water head, and is conducive to improving the power generation efficiency. Therefore, the change of Figure 2 compared with figure 1 is reasonable, which shows the superiority of optimization method in drawing reservoir operation diagram of hydropower station.

The conventional method takes the typical hydrological runoff process which accords with the design assurance rate as the calculation basis, which has its hydrological theoretical basis. However, due to the lack of typical hydrological chronology and relatively conservative regulation rules, it is not conducive to give full play to the operation benefit of the reservoir. PNCM-SFLA algorithm does not consider the theoretical basis of drawing the operation chart, takes the optimization theory as the premise, starts from the practical application purpose of the operation chart, takes the operation benefit of the reservoir as the goal, takes other requirements such as the design assurance rate as the constraint conditions, and directly selects the optimal operation chart based on the results of simulation operation, which can obtain more benefits than the conventional method.

5. CONCLUSION

Parallel Normal Cloud Mutation SFLA (PNCM-SFLA) is a kind of intelligent optimization algorithm, which has global search ability and fast convergence speed, convenient calculation and simple programming. In this paper, the PNCM-SFLA algorithm is introduced into the compilation of the reservoir operation dispatching diagram of the hydropower station. The practical application shows that the PNCM-SFLA algorithm can directly reflect the actual results of the simulated operation of the dispatching diagram, which is conducive to the optimization of the dispatching diagram in the process of drawing, saves the process of selecting and processing the typical hydrological year, and can improve the hydropower station under various constraints. It provides a feasible way for the practicability of the optimization method in the optimal operation of hydropower stations and a new and effective method for drawing the reservoir operation chart.

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