Application Research on Load Allocation of Hydraulic Unit based on Multi-objective Optimized Methods

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***Abstract*--Stratified Genetic algorithm was used in the optimized calculation of Wanjiazhai Hydropower Station, a multi-objective optimized model was established , two sub-populations of independent parallel were used to compute, the calculated values of network model and test values were compared, results showed that the two values are matched, the value of optimized load pressure fluctuation deviates from the average in 3mH2O ,the actual power flow is also less ,it is propitious to improve economic efficiency of the Hydropower station.**

***Index Terms*--Stratified Genetic algorithm, multi-objective optimization, load allocation**

I. EXAMPLE OF POWER STATION

There are six Francis units with capacity of 180MW in Wanjiazhai Hydropower Station, an annual design generation capacity is 2.75 × 109 billion KWh, the largest head is 81.5m and the smallest head is 51.3m, from the upper stream of water for the whole year, it was 15.5 billion Cubic meters in 1999,12.9 billion Cubic meters in 2000 and 11.2 billion Cubic meters in 2001, which is well below the average design runoff of 19.2 billion Cubic meters, Therefore, It is necessary to reduce water consumption, make full use of limited resources and improve hydropower economic benefit to achieve economic operations of hydropower[1].

II. STRATIFIED GENETIC ALGORITHMS

First of all, a problem can generate N × n samples (N ⩾ 2, n ⩾ 2) at random, and then they are divided into N sub-populations, each sub-population contains n samples, for each sub-population, it runs their own independent genetic algorithm, there are large different features between the genetic algorithm N when we set, so we can get more types of fine mode of high-level genetic algorithm in the future, when each sub-population genetic algorithm runs to a certain algebra, the result N will be recorded two-dimensional array R [1 ... N, 1 ... n], the average population fitness value will be recorded array A [1 ... N], the high-level genetic algorithm and the ordinary operation of genetic algorithm are basically same, the produces are selection, crossover and mutation operation[2].

From the above flow chart of stratified genetic algorithm, we know that each of low-level genetic algorithm will get the fine mode at the individual string which based on the specific location after a period of time; with high-level genetic algorithm operation, different individual types of fine mode can be get, thereby they have a more equal chance to compete, this improves genetic algorithm to compare with parallel or distributed genetic algorithm in the previous layer to the exchange of individuals, it does not require human control and specify what should be exchange of individuals[3].

III. THE ESTABLISHMENT OF LOAD MULTI-OBJECTIVE OPTIMIZED MODEL

Network transfer controls the total output, dispatcher notifies the workers to increase or decrease power output in accordance with the system frequency, so the mathematical optimized model uses the model that the total consumption of flow is the smallest, at the same time, considering the influence of hydraulic vibration on the unit, we optimized the load distribution. The overall outlook of optimized model is as follows[4].

When we optimized the load distribution on the unit, the first sub- ΣQi (Pi) (i = 1,2, ... n) should be selected, ΣQi (Pi) (i = 1,2, ... n) is the actual total consumption, the second sub-objective function for ΣQuip (ai) is the value of punished flow according to the tail-water pressure pulsation flow based on the unit in working condition (Pi, H). Adopting the principle of minimum water consumption, we transformed the sub-objective function into punished flow to avoid vibration area, unified objective function is as follows:

$$Q = \omega_1 \sum Q_i(P_i) + \omega_2 \sum Q_{ai}(a_i) \qquad (1)$$

Where, ω 1, ω2 are the two weights of sub-objective function.

Constraint condition: $P_{i\min} \le P_i \le P_{i\max}$

A. The establishment of first sub-objective function

The calculating for the actual consumption flow of the first sub-objective function unit can be run in accordance with characteristic curve of Wanjiazhai unit, so we can read out a series (P, η) values under the head, we can

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make the flow characteristic curve of unit according to calculate a series of (P, Q) values by the following formula under the head[5]:

$$P = 9.81QH\eta \quad (2)$$

$$Q = \frac{P}{9.81H\eta} \quad (3)$$

Where - The unit output; Q - The flow generating unit; H - The head; η - Efficiency of the unit.

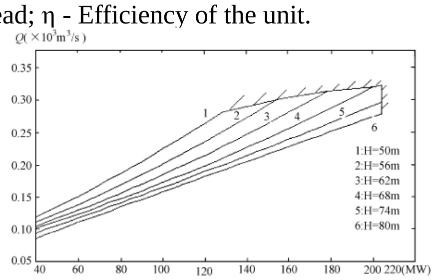

Fig 1 the flow characteristic of the unit

Six-head flow characteristic curves are shown in Figure 1.when the head H = 50m, 56m, 62m, 68m, 74m, and 80m.Observed the flow characteristic curve close to a straight-line shape, we fitted the six-head flow curve with linear function; fitting results are shown in table 1.

Table 1 the fitting coefficients

head	Coefficient of first tem	Constant term
50	1.8207	42.468
56	1.6172	41.098
62	1.477	38.775
68	1.3461	39.47
74	1.2563	36.024
80	1.1647	39.683

In the calculation process, if the current head H is one of the six head Hi (i = 1,2 ... 6),so we calculated according to the above fitting formula, if the current head H between Hi and Hi +1, so we calculated the flow Qi under load Pi according to linear interpolation formula[6].

$$Q = \frac{H - H_i}{H_{i+1} - H_i}(Q_{i+1} - Q_i) \quad (4)$$

The fitting linear equation according to the flow characteristics:

$$Q_i = k_i P + b_i \quad (5)$$

$$Q_{i+1} = k_{i+1} + b_{i+1} \quad (6)$$

The flow calculation formula for

$$Q = \frac{H - H_i}{H_{i+1} - H_i}\left[(k_{i+1} - k_i)P + (b_{i+1} - b_i)\right] \quad (7)$$

B. The establishment of second sub-objective function model

The second sub-objective function for the unit is running to calculate the punishment flow under the condition where (H, P) corresponds to the tail-water pressure pulsation. We used artificial neural network to create the relationship between working condition (H, P) and vibration value α .

Since the RBF[7] network has the structure of adaptive identification and the good characteristics that the output value has nothing to do with the initial right , and in the multi-dimensional surface fitting, free-form surface reconstruction and fault diagnosis of large equipment has a relatively large number of applications, therefore the RBF network was chosen in establishing the relationship between working conditions (H, P) and the vibration value α .The network structure is input layer has two nodes, in which the two neurons are x1 = working head / Max head and x2 = generator output / rated output ,output layer has one node ,after many times compared of network accuracy , the hidden layer neurons are eight, the network's desired output t is the tail-water pressure pulsation dual amplitude / 20.According to the test data of stability, we chose part of the data as the training samples to train and test the network, and establish the corresponding pressure fluctuation value of draft-tube in all running interval through neural network[8].

After network training, the trained network's connection weights W (Cij, b, v) were shown in Table 2

where, CIJ is the central value of excitation function in hidden layer neurons , b is the threshold in hidden layer

Table 2 the connection weights of the net

	C_i	C_j	b	v
1	-25.0678	3.0406	23.0039	0.8727
2	-3.1377	8.5981	0.6554	0.2768
3	-26.6677	0.5988	23.8423	-0.1568
4	25.6878	2.4222	-23.9163	-0.2188
5	7.3163	-8.4242	-1.2804	-1.6495
6	-14.3541	-7.3887	15.7578	-0.2261
7	1.4612	8.7456	-5.0925	-0.535
8	-18.0784	6.4516	8.3195	-0.7901
9	-23.1238	-4.3936	18.118	1.4078
10	-25.9473	2.1043	15.4424	1.0382

neurons, v is connection weights of neuron in output layer neurons and hidden layer. In order to test the accuracy of network training, the network output value of the test samples and the actual test value were drawn in Figure 2 to Figure 5, (the olid line is the test value, and the dashed line is the calculated value of the network).

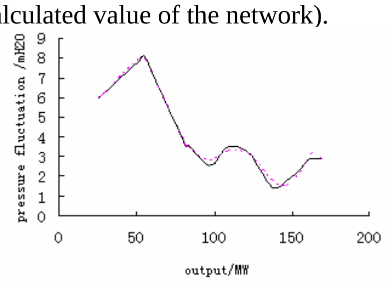

Fig 2 net fitting on H=56.5

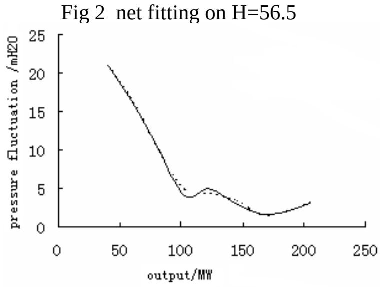

Fig 3 net fitting on H=63

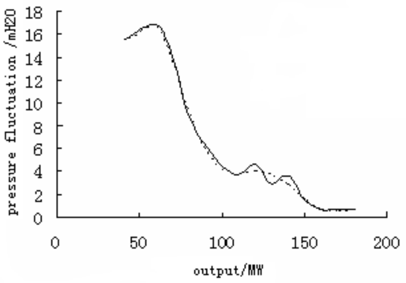

Fig 4 net fitting on H=68

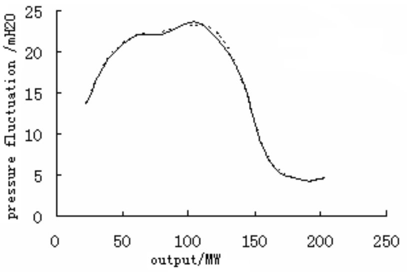

Fig 5 net fitting on H=78.5

Figure 2 to Figure 5 show that the calculated values of the network model was basically consistent with test values, the established network model can reflect the pressure fluctuation characteristics of the draft tube in different conditions, the network model was used to create the curved surface of pressure fluctuation characteristics in operating region, the curved surface is shown in Figure 6

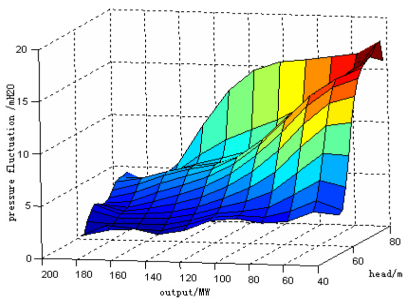

Fig 6 the curved face of the unit pressure fluctuation in operating area

The curved surface was truly reflected pressure pulsation situation of the draft tube.

The trained network has established the relationship between the operating conditions (H, P) and pressure fluctuation value, and established the relationship between vibration value α and established flow Q_{ai} according to the corresponding standards and the degree that the vibration value impacted the unit, one sub-function describes as follows[9]:

$$Q=\begin{cases}0 & a\le 3\\ 2.5a & 3<a\le 5\\ 3.5a & 5<a\le 8\\ 5a & a>8\end{cases} \tag{8}$$

After the establishment of specific expression of the two sub-goals, using the above-mentioned

Theory of stratified genetic algorithm, multi-objective genetic algorithm optimized model was got in load distribution of the units. We used two sub-species to calculate dependently and parallel, but in the actual program, in order to prevent premature sophisticated of the algorithm species and individual requirements, the species should be regenerate after a certain times.

The encoding of chromosome used binary system, according to load value space [0 200], it required to accurate two decimal places, the formula of the binary code length is:

$$2^{m-1} < (b-a)\times 10^{n} \le 2^{m}-1 \tag{9}$$

Where, [a, b] is the space of variable value, n is the n places after the decimal point; m is the length of binary string. When calculated, the length of binary string is 15, the number of initial species is 20, crossover probability pc is 0.4, mutation probability pm is 0.05, since the value of fitness function is positive, and it is better if the fitting value is big in the operation of genetic algorithm, the fitness function expression is as follows:

$$Q = 1200 - \omega_1 \sum_{i=1}^{n} Q_i(P) - \omega_2 \sum_{i=1}^{n} Q_{ai}(a) \tag{10}$$

When calculated, weights of the two sub-goals get equal value; optimized results of load distribution are shown in Table 3

Table 3 the power divider of the units on H=68m

Load	Pressure fluctuation	Consummated flow
210	P_1=105.57 P_2=104.43	361.62
222	P_1=111.06 P_2=110.94	377.77
234	P_1=117.75 P_2=116.25	393.92
368	P_1=183.07 P_2=184.93	574.3
402	P_1=201 P_2=201	620

IV. THE ACTUAL LOAD DISTRIBUTION

When the computer calculate the load, it can give directions to the running unit in order to adjust the output , the principle is that the running units have a smallest changes relative to its own previous state, in order to avoid the conditions that the power grid was fluctuated badly, we supposed that the output of previous state is Pi-1j, (j = 1,2, ... n) and the output of optimized unit is Pij (j = 1,2, ... n),that is[10]:

$$\sum_{j=1}^{n} \left| P_{i-1j} - P_{ij} \right|_{j} \rightarrow \min \tag{11}$$

V. CONCLUSION

This paper is based on the genetic algorithm and uses the model that the consummated flow is smallest to optimize the load distribution in Wanjiazhai power station, after optimizing, the value of pressure fluctuation deviates from the average within 3mH2O, the actual consummated flow is also less.

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