XVIII World Water Congress
International Water Resources Association (IWRA)

Multi-objective Optimal Operation Cascade Reservoirs Considering Ecological Effects

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XVIII WORLD WATER CONGRESS Water for All Harmony between Humans and Nature

第18届 世界水资源大会 水与万物: 人与自然和谐共生

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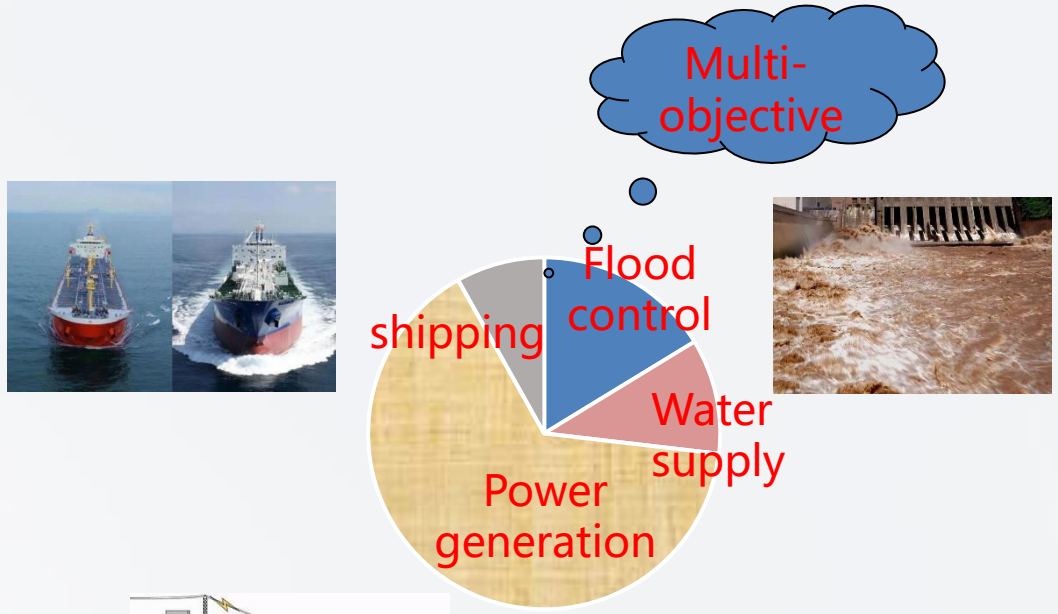
1.Introduction

- Water resources are the natural resources most closely related to human life and production.
- Hydropower resources are clean and pollution-free renewable energy.



Varieties of benefits of the reservoir

- Cascade reservoirs will block the natural hydraulic connection of the river when giving full play to the benefits of power generation, flood control, water supply, shipping and so on.

Uses of water resources (Hydropower stations and reservoirs)

Downstream of the hydrological situation changes result in ecological problems (Drought and fish back block)

1.Introduction

The river become flat

Reservoirs impound water in flood season and replenish water in dry season.

The construction of reservoirs

Hydrological regimes

Ecosystem Stability

Ecological problems

Indicators of hydrological variability

2.Methodology

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Indicators of Hydrological Alteration(IHA)

Table 1. The improved IHA system considering seasonal differences

Classification	Indicators	Prameters	No.
1	The average monthly runoff	The average runoff of every month	1-12
2	The extreme annually runoff	The maximum and minimum runoff of 1,3,7,30,90 day in one year	13-22
		The maximum and minimum runoff of 1,3,7 day in dry season	23-28
		The maximum and minimum runoff of 1,3,7 day in normal season	29-34
		The maximum and minimum runoff of 1,3,7 day in wet season	35-40
		Base flow index, Cutoff days	41-42
3	The time of the extreme annually runoff	The time of the maximum annually runoff	43
		The time of the minimum annually runoff	44
4	High and low runoff frequency and duration	The pulse number of high runoff in one year and their duration time	45-46
		The pulse number of high runoff in dry season and their duration time	47-48
		The pulse number of high runoff in normal season and their duration time	49-50
		The pulse number of high runoff in wet season and their duration time	51-52
		The pulse number of low runoff in one year and their duration time	53-54
		The pulse number of low runoff in dry season and their duration time	55-56
		The pulse number of low runoff in normal season and their duration time	57-58
		The pulse number of low runoff in wet season and their duration time	59-60
5	Runoff change rate and frequency	Average runoff reducing rate, average runoff increasing rate, number of flips in one year	61-63
		Average runoff reducing rate, average runoff increasing rate, number of flips in dry season	64-66
		Average runoff reducing rate, average runoff increasing rate, number of flips in normal season	67-69
		Average runoff reducing rate, average runoff increasing rate, number of flips in wet season	70-72

➢ **Parameter selection**

The information entropy Theory

Pearson correlation coefficient

Principal component analysis (PCA)

Hydrological change rate （Ecological goals）

$$\xi_i(Q) = \frac{\left| z_i' - \overline{z_i} \right|}{\overline{z_i}}$$

$$\xi(Q) = \sum_{i=1}^{m} \omega_i \times \xi_i(Q)$$

3.Results and Discussion

- Analysis of IHA system selected parameters

Table 2. Selected mainly parameters

No.	weight	Selected parameters	Contribution	Corrected Contribution
1	0.334	The maximum and minimum runoff of 90 day in one year	29.34	33.38
2	0.192	Average runoff reducing rate in dry season	16.89	19.21
3	0.130	The minimum runoff of 1 day in normal season	11.43	13.01
4	0.122	average runoff increasing rate in wet season	10.75	12.23
5	0.066	number of flips in wet season	5.76	6.55
6	0.063	The time of the maximum annually runoff	5.53	6.29
7	0.051	Average runoff reducing rate in one year	4.52	5.14
8	0.042	number of flips in one year	3.68	4.19
Sum	1	---	87.91	100

Before eight
87.91%

3.Results and Discussion

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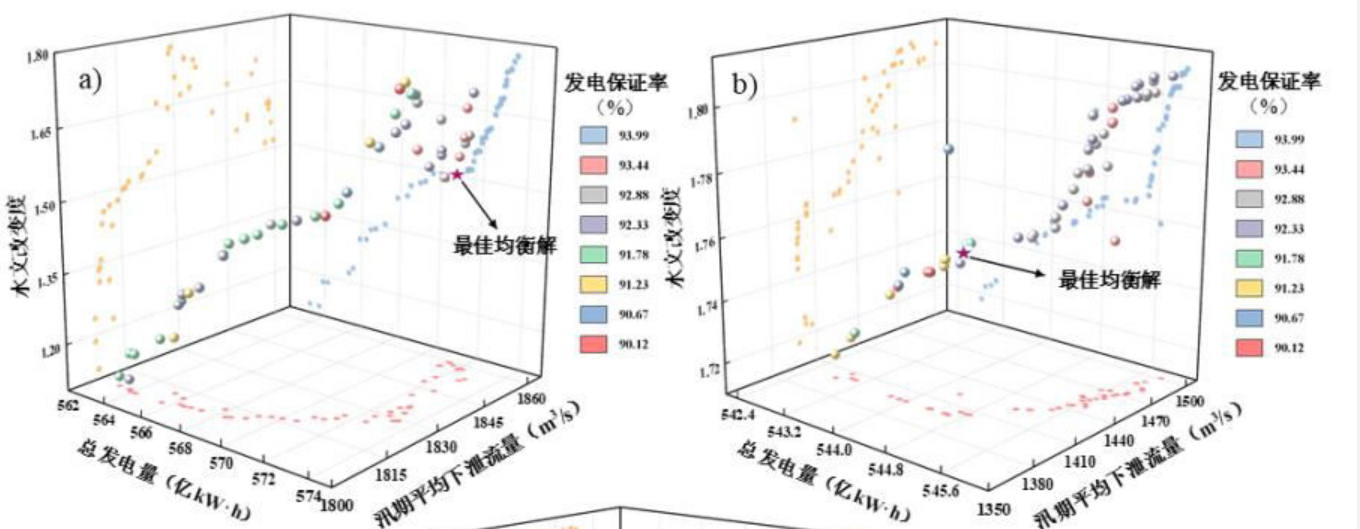
◘ Results of Multi-objective Optimal Operation Cascade Reservoirs



The wet year

The normal year

The dry year

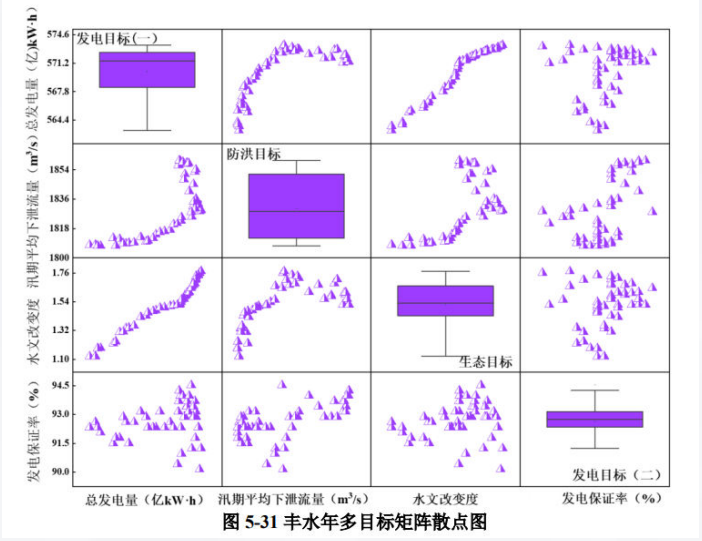


图 5-31 丰水年多目标矩阵散点图

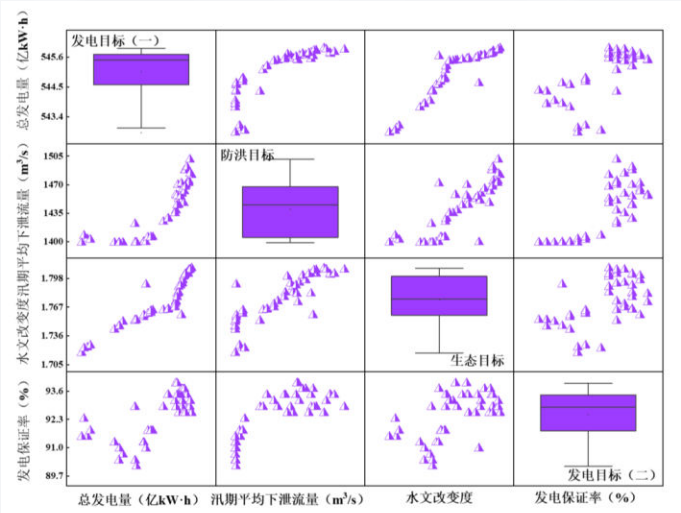


图 5-32 平水年多目标矩阵散点图

4. Conclusions

- Increase some index system of the traditional IHA can reflect the index of the difference of runoff season for quantitative hydrological change degree of ecological goals.
- IHA can better help us to realize the multi-objective optimization scheduling, and produce a variety of benefits.

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Thanks!

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