Research on the Non-constant Navigable Water Flow Conditions of the River Channel Downstream of the Navigable Facilities of Baise Water Control Project

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Abstract. The exit of Baise ship lift on the Right River is only about 700 m away from Dongsun Hydropower Station. Its dispatching operation, especially the unsteady flow, has a direct impact on the navigable water flow conditions of the approach channel gate area and river channel downstream of the Baise ship lift. According to some characteristics of Baise Junction and Dongsun Junction and the measured topography of Baoai River, a plane two-dimensional numerical model of the research river section is constructed, and the water flow changes in the mouth area under different working conditions are simulated and calculated. The research results show that the safety of navigation in the entrance area can be guaranteed from two aspects: optimizing the operation mode of the Baise and Dongsun cascade hydropower stations, and rationally formulating the downstream ship navigation management mode. Under the operating conditions of the four units of Baise Power Station, it is recommended that the ship wait for 0.5 h after the two units in Dongsun are started, so as to avoid the maximum water level increase period in the first half hour.

Keywords: Baise ship lift · Peak shaving power station · Unsteady flow · Navigation safety

1 Introduction

The exit of Baise ship lift on Youjiang River is only about 700 m away from Dongsun hydropower station. As the reverse regulation reservoir of Baise hydropower station, Dongsun hydropower station only has the function of daily regulation. The dispatching operation of Dongsun hydropower station, especially the unsteady flow, has a significant and direct impact on the navigable water flow conditions at the entrance of the approach channel and the river channel downstream of Baise ship lift.

According to the partial characteristics of Baise hub and Dongsun hub projects and the measured topography of TiAI river channel, the plane two-dimensional numerical model of the research river section is constructed. Combined with the operation

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conditions of Baise power station and Dongsun power station, different simulation conditions are designed, and the water rheology in the entrance area under different working conditions is simulated and calculated. The calculation results of the scheme show that the unsteady discharge process of peak shaving in Baise power station has a significant impact on the navigable flow conditions in the gate area of the downstream Baise ship lift. Due to the weak regulation capacity of Dongsun power station, when four units of Baise power station are full, the maximum water level variation in the entrance area is too large, which affects the navigation safety of ships in the entrance area.

2 Project Overview

The Baise Water Control Project is the second cascade in the Yujiang River planning. It is located in the upper reaches of the Right River, the main stream of the Yujiang River, 22 km away from Baise City. It is a key project of the Right Channel on the southern route, one of the three main channels leading to Yungui in the Right Shipping Plan.

The general layout plan of the navigable buildings of Baise Water Conservancy Project adopts the combination plan of ship lock and ship lift, and the navigation route is arranged in Nalugou on the left bank of Baise Water Conservancy Project. The ship-passing facilities are composed of ship locks, intermediate channels, retaining earth dams, navigable aqueducts, flood-retaining and maintenance locks, and vertical ship lifts. The total length of the line is about 4245 m. The navigable buildings are divided into three relatively independent areas, namely the approach channel upstream of the ship lock, the intermediate channel, and the approach channel downstream of the ship lift. The overall layout of the ship-passing facility project is shown in the figure (Fig. 1).

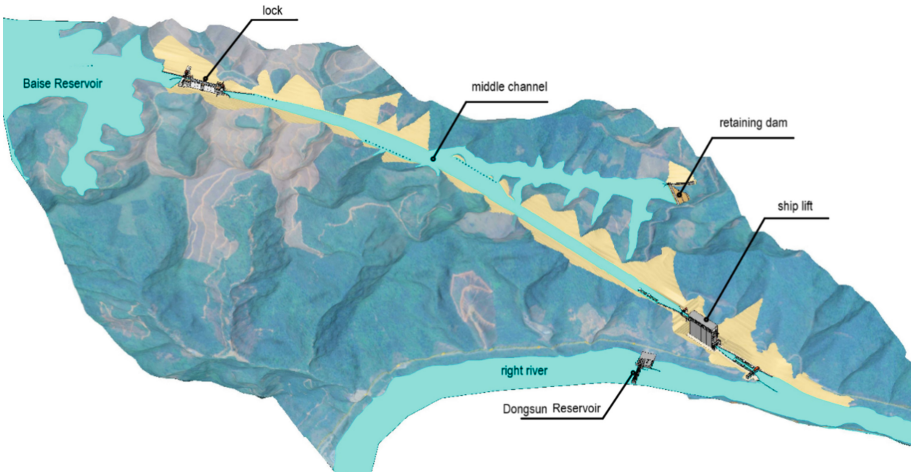

Fig. 1. The general layout of the ship-passing facilities of Baise water control project.

The ship-passing facility project of Guangxi Baise Water Conservancy Project involves three cascade hubs including Baise Water Conservancy Project, Dongsun Hydropower Station and Naji Shipping Hub.

(1) Baise Water Conservancy Project

The main buildings of Baise Water Control Project include dam, power plant, sluice gate and navigation buildings, etc. The normal water level is 228 m, the dead water level is 203 m, and the regulating storage capacity is 2.62 billion m^3. It is an incomplete multi-year regulating reservoir; the installed capacity of the power station is 540 MW, The maximum output is 580 MW; the flood control storage capacity is 1.64 billion m^3, the limited water level during the flood season is 214 m; the daily average minimum discharge is 100 m^3/s.

The Baise Water Control Project is affected by the anti-regulation effect of Dongsun Hydropower Station and Naji Shipping Junction.

(2) Dongsun Hydropower Station

Dongsun Hydropower Station is located 6.5 km downstream of Baise Hydropower Station. It is a water conservancy project mainly based on Baise Reservoir's anti-regulation reservoir for peak regulation, and also has comprehensive utilization benefits such as power generation and water supply. The normal water level is 122.5 m, and the corresponding storage capacity is 6.34 million m^3; the check flood level is 132.68 m, and the corresponding storage capacity is 18.15 million m^3. The available flow is 600 m^3/s, and the installed capacity of the power station is 2×12 MW.

The specific layout from left to right along the axis of the dam is: powerhouse on the right bank, regulating gate, 9 m open overflow dam (practical weir), 5-hole 14m 6.5 m overflow gate dam (overflow weir surface is wide top weir), 9 m open overflow dam (utility weir), thorn wall on the left bank. The net width of the overflow front of the gate dam is 70 m, the elevation of the weir crest is 116.5 m, the net width of the overflow front of the practical weir is 18 m, and the elevation of the weir crest is 122.5 m.

The operating principle of Dongsun Hydropower Station: when the incoming water flow $Q \leq 300$ m^3/s, the daily adjustment operation of the reservoir can be carried out according to whether the upstream Baise Reservoir is peak-regulated; when $300 < Q \leq 600$ m^3/s, the comprehensive utilization of the reservoir needs, the water level of the reservoir is maintained at the normal storage level of 122.5 m; when $600 < Q \leq 1500$ m^3/s, in addition to the turbine overflow of 600 m^3/s, the excess water is discharged from the overflow gate and dam, and the water level on the dam slightly It is 122.5 m higher than the normal water storage level; when $Q > 1500$ m^3/s, the unit stops generating electricity, and the water level of the reservoir basically returns to the state of natural river course.

Dongsun Hydropower Station is about 700 m away from the exit of Baise ship lift, so Dongsun Hydropower Station has a direct impact on the navigable water flow conditions in the approach channel gate area and connecting section downstream of Baise ship lift.

(3) Naji Shipping Hub

The Naji Shipping Hub is located in the downstream of Dongsun Hydropower Station, and its backwater range reaches the exit of Baise Ship Lift. It is a large-scale shipping hub project focusing on shipping, with comprehensive utilization benefits such as power generation, irrigation, flood control, and water supply. The reservoir The normal water level is 115 m, the corresponding storage capacity is 103 million m^3, and the dead water level is 114.4 m. It has daily regulation performance. The Naji Shipping Hub is the anti-regulation reservoir of Baise Reservoir. Its main task is to regulate the peak regulation process of Baise Power Station and ensure the downstream navigation. The flow rate is not less than 140 m^3/s, and at the same time, the channel of the Naji Reservoir area can be channeled to improve the navigation standard of the Right River.

As mentioned above, the exit of Baise ship lift is only about 700 m away from Dongsun Hydropower Station. Dongsun Hydropower Station, as the counter-regulating reservoir of Baise Power Station, only has daily adjustment function. It has a direct impact on the navigable flow conditions of the area and the river. According to the actual situation of the daily variation of the water level downstream of the Dongsun Hydropower Station, the daily variation of the hourly water level is often greater than 1.0 m, and in extreme cases it is greater than 5.0 m, which causes great harm to the safety of downstream navigation. Therefore, it is very necessary to carry out research on the influence of unsteady flow in the downstream channel of the navigation facilities of Baise Hub, and by optimizing the operation and scheduling mode of Dongsun Hydropower Station, so that the characteristics of the unsteady flow in the downstream channel can meet the navigation safety requirements, and it is necessary to minimize the influence of unsteady flow.

Using the two-dimensional mathematical model simulation method, the influence of the unsteady flow in the downstream channel of the navigation facilities of the Baise Hub and the improvement measures are studied. Navigation safety requirements.

3 Numerical Model of Two-Dimensional Flow in the Downstream Channel of the Hub

3.1 Model Construction

According to the characteristics of Baise Junction and Dongsun Junction and the measured topography of the Baoai River, a two-dimensional numerical model of the river reaches is constructed.

(1) Model range

According to the research object, from Baise Junction along the Poai River to the downstream Baise (III) Hydrological Station of Dongsun Hydropower Station. Among them, the section from Baise Junction to Dongsun Power Station is about 6.2 km long, and the length from Dongsun Junction to Baise (III) Hydrological Station is about 17.6 km, see Fig. 2 below.

(2) Model building
This time, taking Dongsun Power Station as the boundary, two-dimensional plane hydraulic models were established for calculation respectively, as shown in Figs. 3 and 4 below.

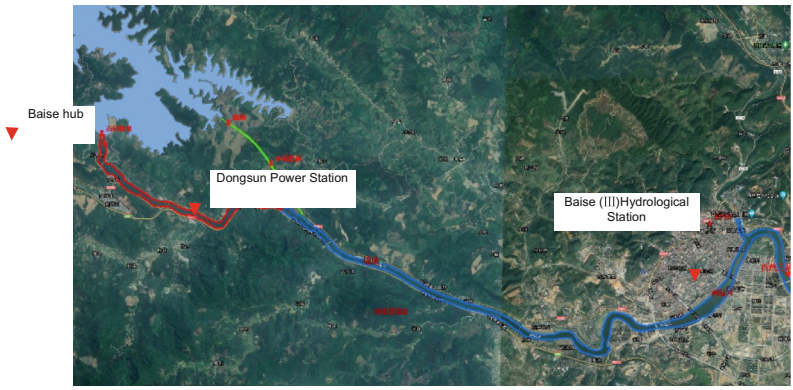

Fig. 2. Model calculation area.

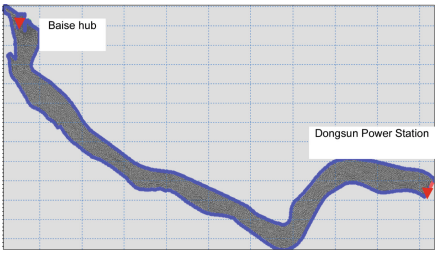

Fig. 3. The 2D model of the dam site of Baise Project-Dongsun project.

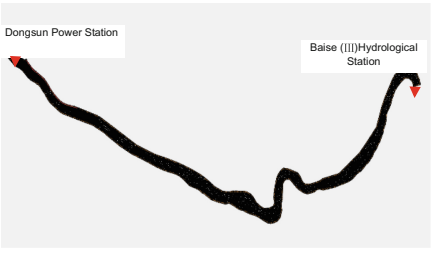

Fig. 4. The 2D model of Dongsun project Dam Site-Baise (III) Hydrological station

(3) Boundary conditions
Upper boundary condition: The model calculates the upper boundary using the corresponding flow process.
Lower boundary conditions: the upstream model, the corresponding design of the power generation flow process of Dongsun Power Station; the downstream model, the water level-flow relationship of the Baise (III) hydrological station (Fig. 5).

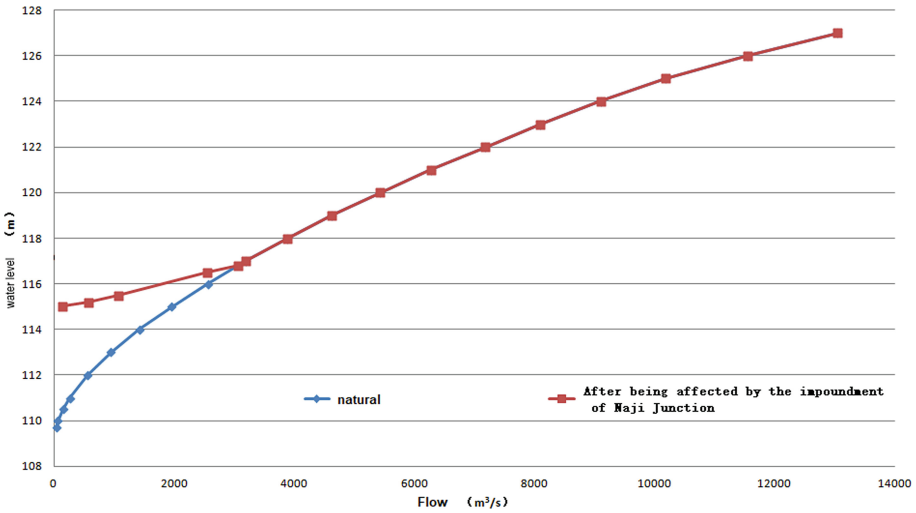

Fig. 5. The relationship between water level and flow at Baise Hydrology (III) Station.

(4) Roughness rate determination

Due to the lack of on-site measured hydrological data, this time, the relationship between the design water level and flow in the mouth area was used to calibrate the parameters of the model. The results show that the average roughness can be in the range of 0.016 to 0.014, and the roughness decreases slightly when the flow rate is large.

3.2 Simulation Conditions

The navigable water flow conditions of Baise ship lift gate area and section channel are affected by the dispatching operation of Baise, Dongsun and Naji hubs. Based on the constructed two-dimensional hydrodynamic simulation model of the study area, the operating characteristics of the three cascade hubs are comprehensively considered, and different simulation conditions are designed. The characteristics of the water level change process in the Entrance area under flow conditions are statistically and analyzed to provide data support for the navigation management of ships downstream of Dongsun Hydropower Station under unsteady flow conditions (Table 1).

Table 1. Simulation conditions.

Working condition	Baise power station			Dongsun power station				Naji junction
	Boot time (min)	Power generation flow (m^3/s)	Boot Number of units	Boot time (min)	Power generation flow (m^3/s)	Before the dam initial water level (m)	Boot Number of units	Before the dam initial water level (m)
1	5	348	2	5	300	122.5	1	114.4
2	5	348	2	5	300	122.5	1	115.0
3	5	348	2	30	300	122.5	1	114.4
4	5	348	2	30	300	122.5	1	115.0
5	10	696	4	10	600	122.5	2	115.0
6	10	696	4	10	600	121.5	2	115.0
7	10	696	4	10	600	122.5	2	114.4
8	10	696	4	10	600	121.5	2	114.4
9	5-60-5	348-348	4	30-60-30	300-300	121.5	2	114.4
10	5-60-5	348-348	4	30-60-30	300-300	121.5	2	115.0
11	5	174	1	5	174	122.5	1	114.4

The operation modes of Baise and Dongsun power stations under various working conditions are described as follows:

(1) Simulation scheme 1. Baise Power Station: Start 2 units within 5 min, reach the rated power generation flow of 348 m^3/s, the water level in front of the dam of Dongsun Power Station at the lower boundary is 122.5 m, and the maximum water level in front of the dam is controlled at 122.8 m. Dongsun Power Station: Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts one unit within 5 min, reaching a rated power generation flow of 300 m^3/s, and the initial water level downstream of the dam site is 114.4 m.
(2) Simulation scheme 2. Baise Power Station: Start 2 units within 5 min, reach the rated power generation flow of 348 m^3/s, the water level in front of the dam of Dongsun Power Station at the lower boundary is 122.5 m, and the maximum water level in front of the dam is controlled at 122.8 m. Dongsun Power Station: Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts one unit within 5 min, reaching a rated power generation flow of 300m^3/s, and the initial water level downstream of the dam site is 115.0 m.
(3) Simulation schem 3. Baise Power Station: Start 2 units within 5 min, reach the rated power generation flow of 348m^3/s, the water level in front of the dam of Dongsun Power Station at the lower boundary is 122.5 m, and the maximum water level in front of the dam is controlled at 122.8 m. Dongsun Power Station: Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts one unit within 30 min, reaching a rated power generation flow of 300m^3/s, and the initial water level downstream of the dam site is 114.4 m.

(4) Simulation scheme 4. Baise Power Station: Start 2 units within 5 min, reach the rated power generation flow of 348m^3/s, the water level in front of the dam of Dongsun Power Station at the lower boundary is 122.5 m, and the maximum water level in front of the dam is controlled at 122.8 m. Dongsun Power Station: In synchronization with the start-up of Baise Power Station, Dongsun Power Station will start one unit within 30 min, with a rated power generation flow of 300 m^3/s and an initial water level of 115.0 m at the lower boundary.
(5) Simulation scheme 5. Baise Power Station: 4 units are started within 10 min, reaching a rated power generation flow of 696 m^3/s, the water level in front of the dam of Dongsun Power Station at the lower boundary is 122.5 m, and the maximum water level in front of the dam is 122.8 m. Dongsun Power Station: Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts 2 units within 10 min, reaching a rated power generation flow of 600 m^3/s, and the initial water level downstream of the dam site is 115.0 m.
(6) Simulation scheme 6. Baise Power Station: 4 units are started within 10 min, reaching a rated power generation flow of 696 m^3/s, the water level in front of the dam of Dongsun Power Station at the lower boundary is 121.5 m, and the maximum water level in front of the dam is 122.8 m. Dongsun Power Station: Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts 2 units within 10 min, reaching a rated power generation flow of 600 m^3/s, and the initial water level downstream of the dam site is 115.0 m.
(7) Simulation scheme 7. Baise Power Station: 4 units are started within 10 min, reaching a rated power generation flow of 696m^3/s, the water level in front of the dam of Dongsun Power Station at the lower boundary is 122.5 m, and the maximum water level in front of the dam is 122.8 m. Dongsun Power Station: Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts 2 units within 10 min, reaching a rated power generation flow of 600 m^3/s, and the initial water level downstream of the dam site is 114.4 m.
(8) Simulation scheme 8. Baise Power Station: 4 units are started within 10 min, reaching a rated power generation flow of 696 m^3/s, the water level in front of the dam of Dongsun Power Station at the lower boundary is 121.5 m, and the maximum water level in front of the dam is 122.8 m. Dongsun Power Station: Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts 2 units within 10 min, reaching a rated power generation flow of 600 m^3/s, and the initial water level downstream of the dam site is 114.4 m.
(9) Simulation scheme 9. Baise Power Station: start 2 units within 5 min, reaching the rated power generation flow of 348 m^3/s; after an interval of 1.0 h, start two units within 5 min, totaling 696 m^3/s; the water level in front of the dam of Dongsun Power Station at the lower boundary is 121.5 m, the maximum water level in front of the dam is 122.8 m. Dongsun Power Station: In synchronization with the start-up of Baise Power Station, Dongsun Power Station starts one unit within 30 min, reaching the rated power generation flow of 300 m^3/s; after an interval of 1.0 h, starts another unit within 30 min, with a total of 600 m^3/s; The initial water level downstream of the dam site is 114.4 m.

(10) Simulation scheme 10. Baise Power Station: Start 2 units within 5 min, reaching the rated power generation flow of 348 m^3/s; after an interval of 1.0 h, start two units within 5 min, totaling 696 m^3/s; the water level in front of the dam of Dongsun Power Station at the lower boundary is 121.5 m, the maximum water level in front of the dam is 122.8 m. Dongsun Power Station: In synchronization with the start-up of Baise Power Station, Dongsun Power Station starts one unit within 30 min, reaching a rated power generation flow of 300 m^3/s; after an interval of 1.0 h, starts another unit within 30 min, reaching a total of 600 m^3/s; dam The initial water level downstream of the site is 115.0 m.
(11) Simulation scheme 11. Baise Power Station: start one unit within 5 min, the rated power generation flow is 174 m^3/s, the water level in front of the dam of Dongsun Power Station in the lower boundary is 122.5 m, and the maximum water level in front of the dam is 122.8 m. Dongsun Power Station: Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts one unit within 5 min, the power generation flow is 174 m^3/s, and the initial water level downstream of the dam site is 114.4 m.

In working conditions 9 and 10, Baise Power Station started 2 units within 5 min, reaching the rated power generation flow of 348 m^3/s; after an interval of 1.0 h, started two units within 5 min, totaling 696 m^3/s. Simultaneously with the start-up of Baise Power Station, Dongsun Power Station starts one unit within 30 min, reaching a rated power generation flow of 300 m^3/s; after an interval of 1.0 h, starts another unit within 30 min, reaching a total of 600 m^3/s.

4 Statistics and Analysis of Water Flow Conditions in 3entrance Area

4.1 Analysis of Water Flow Conditions in the Mouth Area

Table 2 for the statistics of water flow simulation results in the gate area and anchorage under the above 11 working conditions.

Table 2. Each simulated working condition and corresponding simulation result table.

Working condition	Simulation conditions						Simulation results		
	Baise power station		Dongsun power station			Naji hub	Water level in the entrance area		Anchorage water level
	Boot time (min)	Power generation flow (m^3 /s)	Boot time (min)	Power generation flow (m^3 /s)	Before the dam initial water level (m)	Before the dam initial water level (m)	Maximum time-varying amplitude (m /h)	Maximum downhill (‰)	Maximum time-varying amplitude (m/h)
1	5	348	5	300	122.5	114.4	1.12	1.12	0.73
2	5	348	5	300	122.5	115.0	0.88	1.10	0.59
3	5	348	30	300	122.5	114.4	1.08	0.90	0.73
4	5	348	30	300	122.5	115.0	0.83	0.88	0.56
5	10	696	10	600	122.5	115.0	1.70	1.98	1.17
6	10	696	10	600	121.5	115.0	1.70	1.93	1.17
7	10	696	10	600	122.5	114.4	2.07	2.06	1.41
8	10	696	10	600	121.5	114.4	2.07	2.01	1.41
9	5-60-5	348-348	30-60-30	300-300	121.5	114.4	1.08	0.97	0.72
10	5-60-5	348-348	30-60-30	300-300	121.5	115.0	0.83	0.93	0.56
11	5	174	5	174	122.5	114.4	0.67	0.91	0.56

The analysis of water flow conditions in the entrance area is as follows:

(1) The increase of the water level in the downstream port area of the unsteady flow of Dongsun Hydropower Station is affected by the initial downstream water level and the start-up time of the unit. Hourly maximum increase decreases.
(2) If two units of Baise Power Station are fully powered, and one unit of Dongsun Power Station is fully powered, the initial downstream water level is 114.4 m, the dead water level of Naji Power Station. The maximum hourly increase in the Entrance area is 1.12 m; if the initial downstream water level is 115.0 m, the normal water level of the Naji Junction, the maximum hourly increase in the Entrance area is 0.88 m. Under the operating conditions of the cascade power station, it can basically meet the requirements of the navigable water flow conditions in the Entrance area.
When the two units of Baise Power Station are fully powered, the maximum hourly increase in the downstream anchor area is about 0.73 m, and the water level after stabilization is about 115.8 m–115.9 m.
(3) If the four units of Baise Power Station generate electricity normally, limited by the weak storage capacity of Dongsun Reservoir, the maximum hourly increase of water level in the downstream Entrance area will exceed 2.0 m.

The analysis of the results also shows that the water level has the largest increase rate in the first half hour, and within one hour after half an hour, that is, in the period of 0.5 h–1.5 h, even under the most unfavorable working conditions (Condition 7, Dongsun Hydropower Station is not considered. Adjustment and storage, the downstream water level is 114.4 m), the water level increases from 115.92 m to 116.71 m, and the maximum hourly increase is about 0.79 m.

When the four units of Baise Power Station are fully powered, the maximum hourly increase in the downstream anchor area is about 1.41 m (the water level in front of Naji Dam is 114.4 m) or 1.17 m (the water level in front of Naji Dam is 115.0 m), and the water level after stabilization is about 116.7 m–117.1 m.

(4) By properly adjusting the operation settings of the cascade power station, the flow field characteristics in the entrance area can be improved. The adjustment plan is: Baise Power Station starts 2 units within 5 min, and starts 2 units within 5 min after an interval of 60 min. Dongsun Power Station starts one unit within 30 min simultaneously, and starts another unit within 30 min after an interval of 60 min. Under this operation plan, even if the initial water level downstream of Dongsun Hydropower Station is unfavorable at 114.4 m, the maximum hourly increase in the Entrance area is about 1.08 m, which can basically meet the navigation requirements.

Under this plan, the maximum hourly increase of the water level in the anchorage area is about 0.72 m (the water level in front of Naji Dam is 114.4 m) or 0.56 m (the water level in front of Naji Dam is 115.0 m), and the water level after stabilization is about 116.7 m–117.1 m.

In the case of Baise Power Station with only one unit generating power (174 m^3/s), even if the initial downstream water level is 114.4 m, the maximum hourly increase of the water level in the Entrance area is 0.67 m.

When the four units of Baise Hydropower Station are in full power normally, the maximum water surface slope within 600 m of the downstream mouth of Dongsun Hydropower Station is about 2‰. By implementing the operation plan adjustment of Baise and Dongsun power stations (conditions 9 and 10), the maximum water surface slope within 600 m of the Entrance area is reduced to less than 1‰.

The above water level analysis and statistical results can provide strategic support for the safety of ship navigation in the mouth area.

4.2 Ship Operation Plan in the Port Area and Waterway

The unsteady discharge process of Baise Power Station's peak regulation has a significant impact on the navigable water flow conditions in the gate area of the downstream Baise ship lift. Due to the weak regulation capacity of Dongsun Power Station, when the four units of Baise Power Station are fully powered, the maximum water level variation in the Entrance area exceeds 2.0 m/s, which seriously affects the navigation safety of ships in the Entrance area. It is necessary to ensure the safety of navigation in the entrance area from two aspects: optimizing the operation mode of Baise and Dongsun cascade hydropower stations, and the management mode of downstream ship navigation.

For the operation of ships in the gate area and waterway downstream of Dongsun Power Station, it is necessary to make corresponding navigation operation plans based on the actual operating conditions of Baise Power Station and the specific conditions of the downstream initial water level:

(1) If the upstream Baise Power Station generates electricity for one unit, the operation of the ship will not be controlled;
(2) The upstream Baise Power Station generates power for 2 units, and the initial water level downstream of Dongsun Power Station is not lower than 115.0m, then one unit of Dongsun Power Station starts to operate normally, and the navigation of ships in the downstream port area will not be affected.
(3) The upstream Baise Power Station generates power for 2 units, and the initial water level downstream of Dongsun Power Station is 114.4 m, so one unit of Dongsun Power Station is recommended to start operation within 30 min, and the flow field in the downstream port area can meet the navigation requirements.
(4) Baise Power Station is powered by 4 units. It is recommended that the ship sail for 0.5 h after the two units in Dongsun are started, so as to avoid the maximum water level increase period in the first half hour.
(5) If the ship suspension (0.5 h) management plan is not adopted, the operation plan of Baise and Dongsun cascade power stations can be adjusted to meet the navigation requirements of the Entrance area.

5 Conclusions

In this paper, the unsteady navigable water flow conditions of the river channel downstream of the navigable facilities of the Baise Water Control Project are studied, combined with the operating characteristic parameters of the Baise Power Station and Dongsun Power Station, the corresponding simulation conditions are set, and the numerical model is used to simulate and analyze various unsteady flow schemes. The research results show that it is necessary to optimize the operation mode of the Baise and Dongsun cascade hydropower stations, and to rationally formulate the downstream ship navigation management mode to ensure the safety of navigation in the Entrance area: 1) By properly adjusting the operation settings of the cascade hydropower stations, the flow field in the Entrance area can be improved. characteristic. Baise Power Station started 2 units within 5 min, and after 1 h interval, started 2 units within 5 min. Dongsun Power Station starts one unit within 30 min synchronously, and then starts another unit within 30 min after 1 h interval. Under the operation mode of this cascade power station, the non-constant water flow conditions in the downstream gate area and the connecting section can meet the navigation requirements. Require. 2) From the formulation of the ship's operation management mode, under the operating conditions of the four units of Baise Power Station, it is recommended that the ship wait for 0.5h after the start of the two units in Dongsun to sail, so as to avoid the maximum water level increase period of the first half hour.

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