Optimization Research on Surge Chamber of an Energy Dissipation Power Station

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Abstract. With the development of our country’s economy, water conservancy projects such as reservoirs have taken the leading role in the national economic support. The status of water conservancy projects is getting higher and higher, and the country is paying more and more attention to the optimization of water supply, irrigation, and flood control reservoirs. In this paper, the optimization of the large well section of the surge tank is studied in connection with the establishment of the reservoir and the development of hydropower resources. First, the basic equation of the complex surge tank and the calculation equation of the stable section of the surge tank are established, and the calculation model is established through the HYSIM software. For the optimization of the section area of the surge tank, under different working cases, different large well diameters were selected, and the maximum and minimum surge fluctuation amplitude, relative speed deviation, adjustment time, attenuation and convergence speed of the surge tank were carried out. Analysis and optimization. In large fluctuating cases and different large well diameters, the highest and lowest surge of the surge chamber can meet the requirements of structural elevation control. Under small fluctuation Cases and different large well diameters, the water delivery power generation system can meet the stability requirements. The surge decay speed of surge chambers with a diameter of 8m is significantly greater than that of surge chambers of other diameters.

Keywords: surge chamber, large well diameter, surge, working Case.

1. Project Overview
The project is located in Songyang County, Zhejiang Province. The reservoir is a reservoir that focuses on water supply, irrigation, and flood control, combined with the improvement of the water ecological environment, and the comprehensive utilization of power generation. The water supply objects are the people's livelihood and industrial water in the Songgu Basin and the downstream of the reservoir dam site. The water supply population is 201,000 at the 2020 level and 241,000 at the 2030 level; The scope of irrigation involves the farmland in the Songgu Basin and downstream of the reservoir dam site, increasing the irrigation guarantee rate of 166,500 mu of farmland in the Songgu Basin from the current
85% to 90%; The scope of flood protection protection covers the towns downstream of the reservoir dam site, villages on both sides of the bank, and farmland. After the completion of the project, combined with river improvement and embankment construction, the downstream town’s flood control capacity will be increased from once in less than 10 years to once in 20 years, and the flood control capacity of neighboring towns will be increased from once in less than 5 years to once in 20 years. Flood prevention and protection of a population of 30,000 people and 6,500 acres of arable land; Increase the flow of the Xiaogang River Basin during the dry season and improve the water ecological environment of the river; Develop hydropower resources in conjunction with reservoir construction.

2. Mathematical model

2.1. Calculation of the section area of the surge tank Thomas

According to Design Specification for Surge Chamber of Hydropower Station (NB/T 35021-2014), the formula for calculating the stable cross-sectional area of the surge chamber [2] is:

\[ F = K F_{th} \]

\[ F_{th} = \frac{L_f}{2g(\alpha + \frac{1}{2g}(H_0 - h_{w0} - 3h_{wm}))} \]  

In the formula: \( F_{th} \) —— Thomas critical stable section area, \( m^2 \); \( L_f \) —— length of pressure water channel, \( m \); \( f \) —— cross-sectional area of pressure water channel, \( m^2 \); \( H_0 \) —— Minimum static water head for power generation, \( m \); \( \alpha \) —— Head loss coefficient from reservoir to surge tank, \( a = \frac{h_{w0}}{\sqrt{v}} \), \( s^2 / m \); \( v \) —— Pressure diversion channel flow velocity, \( m / s \); \( h_{w0} \) —— Pressure diversion channel head loss, \( m \); \( h_{wm} \) —— head loss of pressure pipe, \( m \); \( K \) — coefficient, generally 1.0~1.1 can be used, this calculation takes \( K = 1.1 \).

2.2. Calculation diagram

The calculation and analysis software used in this paper is the Hysim program self-developed by the East China Institute. According to the pipeline layout of the water delivery system, the established calculation model is shown in Figure 1.

![Figure 1. Schematic diagram of calculation model](image)

3. Optimization of Surge Chamber Section

The size of the large well area of the surge tank has a great influence on the water level fluctuation of the surge tank under large fluctuation Cases and the regulation quality of small fluctuations. This paper analyzes the large-fluctuation Cases and small-fluctuation Cases respectively, and determines the optimized size of the large well.
3.1. Analysis of large fluctuation Cases

In the analysis of large fluctuation Cases, in order to ensure that the highest and lowest surge of the surge chamber meet the requirements of structural control elevation, the highest and lowest surge control Cases of the surge chamber are selected for calculation and research, and two are selected in different working Cases. The analysis is carried out at each operating point. In this study, operating Cases JH1 and JH5 are mainly selected. Select three different large well diameters, 6m, 8m, and 10m respectively for analysis. Surge comparison table 2 for surge chambers of different large well diameters.

| Diameter of large well (m) | Maximum surge in surge chamber (m) (Case JH1) | Minimum surge in surge chamber (m) (Case JH5) |
|----------------------------|-----------------------------------------------|---------------------------------------------|
| 6m                         | 346.55                                        | 272.30                                      |
| 8m                         | 343.37                                        | 277.34                                      |
| 10m                        | 341.47                                        | 280.31                                      |
| Structure control value    | 383.70                                        | 252.00                                      |

Case JH1: The upstream check flood level, the downstream two units are at full tail water level, and the two units run at rated output and suddenly dump all loads[1]. This working Case is the highest surge working Case of the surge tank. In Case JH1, with different large well diameters, the water level of the surge tank also changes with time.

In the whole process, the water level of the surge tank at a diameter of 10m is lower than the water level at a diameter of 6m and 8m, and the convergence rate at 10m is faster than the first two.

Case JH5: the lowest power generation water level in the upstream, the normal tail water level in the downstream, the two units are operating normally at the maximum output, and the two units suddenly throw off all the loads. At the time of the maximum outflow flow, one unit starts to the maximum output. This working Case is the lowest surge Case of the surge tank. In Case JH5, the water level of surge wells with different large well diameters is different.

In the whole process, the water level of the surge tank is lower than the water level of the curve under the large well diameter of 6m and 8m, and the relative convergence speed in the process is faster than the first two curves.
Figure 3. Process line of water level change in surge tank with different large well diameters (Case JH5)

3.2. Analysis of small fluctuations
In order to explore the stability of the small fluctuation transition process of the hydraulic-mechanical system of the Shangdong Wu Power Station under different large well diameters, select control Cases X3 and X6 for calculation and analysis of small fluctuation transition process. The stability of the surge tank water level fluctuation is an important topic in the study of the transition process of small fluctuations [3].

(1) Case X3: the lowest power generation water level in the upstream, the full tail water level of the two downstream units, the two units of the same hydraulic unit both carry the maximum expected load, and the two units suddenly reduce the rated load by 5%.

(2) Case X6: the lowest upstream power generation water level, the tail water level of the two downstream machines is full, Both units of the same hydraulic unit have the maximum expected load, One unit suddenly reduces the rated load by 5%. Select large wells with diameters of 6m, 8m, and 10m for analysis, Calculation table 3 for small fluctuation Cases.

| Calculation Cases   | X3  | X6  |
|---------------------|-----|-----|
| Diameter of large well (m) | 6   | 8   | 10  |
| Adjustment time (s)    | 9.4 | 9.2 | 9.2 |
| Maximum speed Deviation (%) | 3.20 | 3.18 | 3.18 |
| Number of oscillations | 0.5 | 0.5 | 0.5 |
| Attenuation (%)        | 97.21 | 98.40 | 98.95 |
| Over Adjust the Amount (%) | 0   | 0   | 0   |
| Surge tank water level fluctuates | convergence | convergence |

In the two Cases, first select Case X3 for analysis. For three different large well diameters, the relative speed changes of the unit are the same. When the adjustment time is close to 3.5s, the relative speed of the unit suddenly increases, and when the relative speed of the unit reaches 1.032%, The relative speed of the unit begins to drop. When the adjustment time is 12s, the relative speed of the unit drops completely, After 12s, the load has not changed, the relative speed of the unit has completely converged, and the unit has reached a stable state (as shown in Figures 4 and 6). When the diameter of the large well is 6m, 8m, and 10m, the speed change curve of the unit is exactly the same, which is drawn as a curve. The relative speed of the unit under different diameters changes differently. As time changes, the
relative speed of the unit first increases and then decreases, and finally reaches a stable state. When the relative speed of the unit rises, the water level in the surge chamber also rises. In a short period of time, the relative speed of the unit changes to obtain a stable state, However, the fluctuation amplitude of the highest or lowest surge in the surge tank tends to stabilize very slowly.

When the diameter of the large well is 6m, the surge fluctuation amplitude of the surge chamber is the largest, second only to the surge fluctuation amplitude of the surge chamber when the diameter is 8m. When the surge chamber is below 10m, the surge fluctuation amplitude is the smallest. For different large well diameters, the relative speed of the unit changes over time is the same, but the change in the water level of the surge tank or the surge fluctuations in the surge tank are different. When the diameter of the large well is 6m, the surge decay rate is the slowest, the surge surge fluctuation of the corresponding surge chamber is the largest. When the diameter of the large well is 8m, the surge decay speed of the surge chamber is slower, and the surge surge fluctuation of the corresponding surge chamber is relatively large. When the diameter of the large well is 10m, the surge decay rate of the surge chamber is the fastest, and the surge fluctuation of the corresponding surge chamber is the smallest (as shown in Figures 5 and 7). In the two Cases of X3 and X5, the number of oscillations of different diameters is the same, both are 0.5 times.

![Figure 4. Variation curves of different large well diameters and unit speeds (Case X3)](image)

![Figure 5. Different large well diameters, surge tank water level change curve (Case X3)](image)
Comparing the two Cases X3 and X5, the average adjustment time of working Case X3 is faster than that of Case X5. The maximum average speed deviation of Case X3 is greater than the maximum average speed deviation of Case X5. The number of oscillations of different diameters under both Cases is 0.5. The average decay speed of Case X3 is less than the average decay speed of Case X5. In the two Cases, the water level of the surge tank or the maximum and minimum surge fluctuations of the surge chamber will converge. Large well diameters of 6m, 8m, and 10m can meet the small fluctuation stability requirements of the water transmission and power generation system, and the small fluctuation adjustment quality indicators are all better. As the diameter of the large well of the surge tank decreases, the decay speed of the surge tank water level fluctuation becomes slower, when the diameter of the large well is 8m, the surge attenuation speed of the surge chamber is significantly accelerated. Therefore, in order to ensure the stable operation of the unit and have a better adjustment quality, the diameter of the large well is selected as 8m.

4. Conclusion
Through the analysis of different surge chamber diameters:

(1) Large fluctuation Cases, when the diameter of the large well is 6m, 8m, 10m, Both the highest surge and the lowest surge of the surge chamber can meet the requirements of structural elevation control;

(2) Small fluctuation Cases, when the diameter of the large well is 6m, 8m, 10m, Water transmission and power generation systems can meet the requirements of small fluctuation stability; When the
diameter of the large well is 8m, the surge decay rate of the surge chamber is obviously greater than that of the surge chamber when the diameter of the large well is 8m and 10m. Therefore, in order to ensure the stable operation of the unit, it has better adjustment quality. A large well with a diameter of 8.0m can ensure that the water transmission and power generation system can meet the requirements of small fluctuation stability; the optimized surge chamber has a large well diameter of 8.0m.

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